Annex 2: Working Documents

The following working documents were presented to WGHANSA 2021 and are presented in full in Annex 2:

Derhy G., Macías D., Khalil K., Elkalay K., Rincón, M.M. Assessing the impact of external environmental drivers on Atlantic Chub Mackerel (Scomber colias) population dynamics Garrido et al. Anchovy ID

Garrido S., Costa A.M., Nunes C., Pechirra P., Mendes H., Silva R., Milhazes R., Silva A.V., Silva C., Wise L., Silva A. Reproductive characteristics of western component 27.9.a anchovy.

Garrido S., Rodríguez-Ezpeleta N., Ramos F., Rincón M., Feijó D., Moreno A., Castilho R., Díaz N., Da Fonseca R.R., Francisco S.M., Manuzzi A., Silva G., Uriarte A. Population structure of the European anchovy (Engraulis encrasicolus) in ICES Division 9.a.

Ramos F., Córdoba P., Tornero J., Sánchez M.J. and Navarro, R. Acoustic assessment and distribution of the main pelagic fish species in ICES Subdivision 9.a South during the ECOCADIZ-RECLUTAS 2021-10 Spanish survey (October 2021).

Rincón M.M, Ramos F., Tornero J., Garrido S., Elvarsson B., Lentin J. Gadget for anchovy 9.a South: Model description and results to provide catch advice and reference points (WGHANSA-1 2022).

Silva A.A., Wise L., Ramos F., Rincón M.M., Garrido S., Uriarte A. and Mildenberger T. Exploratory assessment of anchovy 27.9.a West using a surplus production model.

Wise L., Silva A. A., Uriarte A. and Garrido S. Life-history parameters of anchovy 9.a western component.

Gadget for anchovy 9a South: Model description and results to provide catch advice and reference points (WGHANSA-1 2022)

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1. Background

The model specifications presented below correspond to those benchmarked in WKPELA 2018. The main difference is that results are presented now for the end of the second quarter of each year instead of be presented at the end of the fourth quarter. This responds to practical modifications in the definition of the assessment year, now it goes from July 1st to June 30th of the next year. Specific model assumptions for this year are presented in section 2.2 and 3, as well as estimated parameters after optimization in Table 2.

2. Model Description

Gadget is an age-length-structured model that integrates different sources of information in order to produce a diagnose of the stock dynamics. It works making forward simulations and minimizing an objective (negative log-likelihood) function that measures the difference between the model and data, the discrepancy is presented as a likelihood score for each time period and model component.

The general Gadget model description and all the options available can be found in Gadget manual (Begley, 2004) and some specific examples can be found in Taylor et al. (2007), Elvarsson et al. (2014) and WKICEMSE assessment for Ling (Elvarsson, 2017). The latest was used as a guide for this document.

The Gadget model implementation consists in three parts, a simulation of biological dynamics of the population (simulation model), a fitting of the model to observed data using a weighted log-likelihood function (observation model) and the optimization of the parameters using different iterative algorithms.

A list of the symbols used and estimated parameters is presented in Table 2 and a graph with the Gadget model structure presented in the last benchmark (WKPELA 2018) is available at Gadget structure graph.

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2.1. Simulation model

The model consists of one stock component of anchovy (*Engraulis encrasicolus*) in the ICES subdivision, 9.a South-Atlantic Iberian waters, Gulf of Cádiz. Gadget works by keeping track of the number of individuals, $N_{a,l,y,t}$, at age $a = 0, \ldots, 3$, at length $l = 3, 3.5, 4, 4.5, \ldots, 22$, at year $y = 1989, \ldots, 2022$, and each year divided into quarters $t = 1, \ldots, 4$.. The last time step of a year involves increasing the age by one year, except for the last age group, which its age remains unchanged and the age group next to is added to it, like a 'plus group' including all ages from the oldest age onwards (Taylor et al., 2007).

Growth

The growth function is a simplified version of the Von Bertalanffy growth equation, defined in Begley (2004) as the LengthVBSimple Growth Function (*lengthvbsimple*). Length increase for each length group of the stock is given by the equation below:

$$\Delta l = (l_\infty - l)(1 - e^{k\Delta t}), \tag{1}$$

where Δt is the length of the timestep, $l_\infty = 19\ cm$ (fixed) is the terminal length and k is the growth rate parameter.

The corresponding increase in weight (in Kg) of the stock is given by:

$$\Delta w = a((l + \Delta l)^b - l^b), \tag{2}$$

with $a = 3.128958e^{-6}$ and $b = 3.277667619$ set as fixed and extracted from all the samples available in third and fourth quarters from 2003 to 2017. The growth functions described above calculate the mean growth for the stock within the model. In a second step the growth is translated into a beta-binomial distribution of actual growths around that mean with parameters β and n. The first is fitted by the model as described in Taylor et al. (2007) and the second represents the number of length classes that an individual is allowed to grow in a quarter and it is fixed and equal to 5.

Initial abundance and recruitment

Stock population in numbers at the starting point of the simulation is defined as:

$$N_{a,l,1,1} = 10000\nu_a q_{a,l}, \quad a = 0, \ldots, 3, l = 3, \ldots, 20$$

Where ν_a is an age factor to be calculated by the model and $q_{a,l}$ is the proportion at lengthgroup l that is determined by a normal density with a specified mean length and standard deviation for each age group. Mean length at age (μ_a) and its standard deviation (σ_a) were extracted from all the data available from 1989 to 2018 including three surveys that are not included in the model: ARSA, ECOCADIZ-RECLUTAS and SAR survey (See table 2). The mean weight at age for this initial population is calculated by multiplying a reference weight corresponding to the length by a relative condition factor assumed as 1. This reference weight at length was calculated using the formula $w = al^b$, with a and b as defined before. In Gadget files this was specified as a normal condition distribution (*Normalcondfile*).

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Similarly to the process of calculate the initial abundance described above, the recruitment specifies how the stock will be renewed. Recruits enter to the age 0 population at quarters 2, 3, 4 (because of the Gadget order of calculations for each time step this is equivalent to have recruitment one quarter later, i.e. in quarters 3,4 and 1 of the next year) of all years, respectively, as follows:

$$N_{0,l,y,t} = p_{l,t} R_{y,t}, \quad t = 2, 3, 4, l = 3, \ldots, 15,$$

where $R_{y,t}$ represents recruitment at year y and quarter t, and $p_{l,t}$ the proportion in lengthgroup l that is recruited at quarter t which is sampled from a normal density with mean (μ) and standard deviation (σ_t) calculated by the model. The mean weight for these recruits is calculated by multiplying the reference weight corresponding to the length by a relative condition factor assumed as 1. Reference weight at age was the same used to calculate the initial population mean weight at age explained above. In Gadget files this was specified also as a normal condition distribution (*Normalcondfile*).

Fleet operations

In the model the fleets act as predators. There are three fleets inside the model: two for surveys (ECOCADIZ acoustic survey and PELAGO acoustic survey) and one for commercial landings including all fleets: Spanish purse-seine, trawlers, Portuguese purse-seine, and others. The main fleet is Spanish purse-seine representing more than a 90 % of all the catches from 2001 to 2016 and more than a 80 % from 1989 to 2000. It is also the only fleet with a lenght distribution available, then we decide to include all commercial reported data in the same fleet which is mostly the Spanish purse-seine.

Surveys fleets are assumed to remove 1 Kg in each of the quarters when the surveys take place while the commercial fleet is assumed to remove the reported number of individuals each quarter. This total amount of biomass (for the surveys) or numbers (for the commercial fleet) landed is then split between the length groups according to the equations 3 and 4 respectively, as follows:

$$C_{l,y,t} = \frac{E_{y,t} S_{l,T} N_{l,y,t} W_l}{\sum_l S_{l,T} N_{l,y,t} W_l}, \tag{3}$$

and

$$C_{l,y,t} = \frac{E_{y,t} S_{l,T} N_{l,y,t}}{\sum_l S_{l,T} N_{l,y,t}}, \tag{4}$$

where $E_{y,t}$ represents biomass landed (in Kg) at year y and quarter t in equation 3 and numbers landed in equation 4, W_l corresponds to weight at length and $S_{l,T}$ represents the suitability function that determines the proportion of prey of length l that the fleet is willing to consume during period $T, T = 1, 2, 3$ where $T = 1$ corresponds to the period 1989-2000, $T = 2$ to 2001-**2021** and $T = 3$ to 1989-**2021**.

For this model the suitability function chosen for the fleet and surveys is specified in Gadget manual as an ExponentialL50 function (*expsuitfuncl50*), and it is defined as follows:

$$S_{l,T} = \frac{1}{1 + e^{\alpha_T (l - l_{50,T})}} \tag{5}$$

where $l_{50,T}$ is the length of the prey with a 50% probability of predation during period T and α_T a parameter related to the shape of the function, both parameters are estimated from the data within the Gadget model. The whole model time period (1989-**2021**) has been splited into two different periods for suitability parameters of the commercial fleet because of changes in size regulation for the fishery around 1995 that become effective around 2001.

2.2. Observation model

Data are assimilated by Gadget using a weighted log-likelihood function. The model uses as likelihood components two biomass survey indices: ECOCADIZ acoustic survey and PELAGO acoustic survey; age - length keys from the commercial fleet (Spanish purse-seine), PELAGO survey and the ECOCADIZ survey; and length distributions for the commercial fleet, PELAGO and ECOCADIZ surveys (see Table 2.2 for a detailed description of the likelihood data used in the model).

Biomass Survey indices

The survey indices are defined as the total biomass of fish caught in a survey. The survey index is compared to the modelled abundance using a log linear regression with slope equal to 1 (*fixedslopeloglinearfit*), as follows:

$$\ell = \sum_t (\log(I_{y,t}) - (\alpha + \log(N_{y,t}))^2 \tag{6}$$

where $I_{y,t}$ is the observed survey index at year y and quarter t and $N_{y,t}$ is the corresponding population biomass calculated within the model. Note that the intercept of the log-linear regression, $\alpha = \log(q)$, with q as the catchability of the fleet (i.e $I_{y,t} = qN_{y,t}$).

Catch distribution

Age-length distributions are compared using l lengthgroup at age a and time-step y, t for both, commercial and survey fleets with a sum of squares likelihood function (*sumofsquares*):

$$\ell = \sum_y \sum_t \sum_l (P_{a,l,y,t} - \pi_{a,l,y,t})^2 \tag{7}$$

where $P_{a,l,t,y}$ is the proportion of the data sample for that time/age/length combination, while $\pi_{a,l,t,y}$ is the proportion of the model sample for the same combination, as follows:

$$P_{a,l,t,y} = \frac{O_{a,l,y,t}}{\sum_a \sum_l O_{a,l,y,t}} \tag{8}$$

and

$$\pi_{a,l,t,y} = \frac{N_{a,l,y,t}}{\sum_a \sum_l N_{a,l,y,t}}, \tag{9}$$

where $O_{a,l,y,t}$ corresponds to observed data.

When only length or age distribution is available. It is compared using equation 7 described above but considering all ages or all lengths, respectively.

Understocking

If the total consumption of fish by all the predators (fleets in this case) amounts to more than the biomass of prey available, then the model runs into ”understocking”. In this case, the consumption by the predators is adjusted so that no more than 95% of the available prey biomass is consumed, and a penalty, given by the equation 10 below, is applied to the likelihood score obtained from the simulation (Stefansson 2005, sec 4.1.)

$$\ell = \sum_t U_t^2 \tag{10}$$

where U_t is the understocking that has occurred in the model for that timestep.

Penalties

The BoundLikelihood likelihood component is used to give a penalty weight to parameters that have moved beyond the bounds in the optimisation process. This component does specify the penalty that is to be applied when these bounds are exceeded.

$$\ell_i = \begin{cases} lw_i(val_i - lb_i)^2 & \text{if } val_i < lb_i \\ uw_i(val_i - ub_i)^2 & \text{if } val_i > ub_i \\ 0 & otherwise \end{cases}$$

Where $lw_i = 10000$ and $uw_i = 10000$ are the weights applied when the parameter exceeds the lower and upper bounds, respectively, val_i is the value of the parameter and, lb_i and ub_i are the lower and upper bounds defined for the parameter.

2.3. Order of calculations

The order of calculations is as follows:

1. **Printing**: model output at the beginning of the time-step
2. **Consumption**: by the fleets
3. **Natural mortality**
4. **Growth**
5. **Recruitment**: new individuals enter to the population
6. **Likelihood comparison**: Comparison of estimated and observed data, a likelihood score is calculated

7. **Printing**: model output at the end of the time-step
8. **Ageing**: if this is the end of year the age is increased

Because of this order of calculations the time step of indexes, age-length keys and length distributions of the surveys are defined in Gadget a quarter before.

2.4. Implementation, weighting procedure

Input data (Likelihood files) were prepared for Gadget format using the *mfdb* R package (Lentin, 2014), running and weighting procedures were implemented in R with the gadget.iterative function from *Rgadget* package. This function follows the approach presented in Taylor et al. (2007) and in the appendix of Elvarsson et al. (2014) based on the iterative reweighting scheme of Stefánsson (1998) and Stefansson (2003), which is summarized as follows:

Let $\mathbf{w_r}$ be a vector of length L with the weights of the likelihood components (excluding understocking and penalties) for the run r, and $SS_{i,r}, i = 1, \dots, L$, the likelihood score of component i after run r. First, a Gadget optimization run is performed to get a likelihood score ($SS_{i,1}$) for each likelihood component assuming that all components have a weight equal to one, i.e., $\mathbf{w_1} = (1, 1, \dots, 1)$. Then, a separated optimization run for each of the components (L optimization runs) is performed using the following weight vectors:

$$\mathbf{w_{i+1}} = (1/SS_{1,1}, \dots, (1/SS_{i,1}) * 10000, 1/SS_{i+1,1}, \dots, 1/SS_{L,1}), i = 1, \dots, L.$$

Resulting likelihood scores $SS_{i,i+1}$ are then used to calculate the residual variance, $\hat{\sigma}_i^2 = SS_{i,i+1}/df^*$ for each component, that is used to define the final weight vector as

$$\mathbf{w} = (1/\hat{\sigma}_1^2, \dots, 1/\hat{\sigma}_L^2).$$

Where degrees of freedom df^* are approximated by the number of non-zero data points in the observed data for each component. Finally, the total objective function is the sum of all likelihoods components multiplied by their respective weights according to the vector $\mathbf{w}$.

In order to assign weights to the individual likelihood components (See table 2.2) in the procedure described above, all the survey indices were grouped together.

2.5. Initial parameters and optimization

Initial parameter values with their boundaries and settings for the optimising algorithms can be found in initial values for parameters file and optimization file. The optimization algorithms converged in individual and weighted runs.

3. Remarkable Model Assumptions (in bold the terms associated to the more recent assumptions)

- Due to lack of information of length distributions and Age-length keys for commercial catches in the first and second quarter of 2020, for **2021** and **2022** assessment the length distribution of those quarters in year

2020 was approximated using the joint distribution of 2018 and 2019. For the Age-length key the one for the PELAGO 2020 survey was used.

- Due to technical problems there are no data available for ECOCADIZ survey in 2021.
- The model was implemented quarterly from 1989 to the second quarter of **2022**.
- All commercial fleets where grouped into only one from 1989 to **2022** second quarter: The Spanish purse-seine. The Spanish purse-seine which represents more than a 90 % of all the catches from 2001 to 2016 and more than a 80 % from 1989 to 2000. It is also the only fleet with a lenght distribution available. For the first two quarters of year **2022**, provisional catches estimations of Spanish (until May 18th) purse-seine fleet were used and catches for June were estimated as the **39%** of January to May catches based on historical records from 2009 to **2021**. There were not any catches for Portuguese purse-seine in these two quarters.
- It was decided to include also discards (available from 2014 onwards) in WGHANSA-1-2020. This decision was taken because they were already accounted for some years in the previous assessments to 2020 but we did not notice about that. Since then we include discards in catches data.
- The parameters for weight-length relationship equation ($w = al^b$,) were assumed fixed and defined as $a = 3.128958e^{-6}$ and $b = 3.277667619$. Those values were calculated from all the samples available in third and fourth quarters from 2003 to 2017.
- Natural mortality at age was also considered fixed with $M_0 = 2.21$ and $M_1, M_2, M_3 = 1.3$,.
- There was a minimum landing size restriction from 1995, that were only effective until 2001. As a consequence it was neccesary to define different suitability parameters for two different periods. One from 1989 to 2000, and the other from 2001 to **2021**.
- Age 0 individuals were removed for **all** the data input corresponding to ECOCADIZ survey. It was noticed that age 0 was not removed from the length distribution in the assessments prior to 2021.
- It was noticed that the length distribution for year 2020 in ECOCADIZ survey was not included in the model used for 2021 assessment. We include that missing information in the model described in this document.
- Recruits enter to the age 0 population at quarters 2, 3 and 4 (because of the Gadget order of calculations for each time step this is equivalent to have recruitment one quarter later, i.e. in quarters 3,4 and 1 of the next year) of all years except the last year, because at the end of June there are no recruits (zero age individuals). Then, biomass and abundance estimates at the end of the second quarter need to be corrected removing age 0 individuals.

4. Natural mortality selection

Natural mortality selection is justified by the following arguments:

- Natural mortality was preferred to be selected from classical indirect formulations based on life history parameters. For it we used the R package *FSA* to obtain empirical estimates of natural mortality.
- For the estimation of the natural mortality rate, the Von Bertalanffy growth parameters and the maximum age that the species can live were used. Growth parameters of the Von Bertalanffy function were taken from Bellido et al. (2000) ($l_\infty = 18.95, k = 0.89, t_0 = -0.02$), and for the maximum observed age, we explored a range from age 3 to 5, but finally age 4 was considered adequate. A total of 13 estimators were produced using the R package *FSA* and the a value of $M = 1.3$ was undertaken (midway between the median and the mean of the available estimates for Agemax=4).
- Currently is generally accepted that Natural mortality may decrease with age, as far as it presumed to be particularly greater at the juvenile phase. It was agreed to adopt for the adult ages of anchovy (ages 1 to 4) the constant natural mortality estimated before (1.3), but for the juveniles (age 0) a greater one in proportion to the ratio of natural mortality at ages 0 and 1 (M_0/M_1) resulting from the application of the Gislason et al. (2010) method for modelling natural mortality as a function of the growth parameters. For it we used four vectors of length-at-age: derived from the Von Bertalanffy growth function in Bellido et al. (2000) for ages 1-5, from the ECOCADIZ-RECLUTAS survey for ages 0-3, the average of the length-at-age in the catches from 1987 to 2016 and the average of the length-at-age in the catches from 2007 to 2016. There was no major basis to select one or the other, we directly choosed the pattern shown by the ECOCADIZ-RECLUTAS data just because it seemed to be smoothest one (particularly for age 1 onwards as presumed here). The ratio M_0/M_1 is 2.722670/ 1.595922 = 1.7. Therefore $M_0 = 1.3 * 1.7 = 2.21$.
- In summary for anchovy 9a South, the adopted natural mortality by ages are $M_0 = 2.21, M_1 = 1.3$ and $M_2^+ = 1.3$ (similar at any older age).

5. Fit to data

A summary of likelihood scores is presented in Figure 1 while a comparison of estimated versus observed data is summarized in the following Figures:

Length distributions

- Figure 2: Length distribution of the commercial fleet.
- Figure 3: Length distribution of the ECOCADIZ acoustic survey.
- Figure 4: Length distribution of the PELAGO acoustic survey.
- Figure 5: Summary of residuals for length distributions.

Age distributions

- Figure 6: Age distribution of the commercial fleet.
- Figure 7: Age distribution of the ECOCADIZ acoustic survey.
- Figure 8: Age distribution of the PELAGO acoustic survey.
- Figure 9: Summary of residuals for age distributions.

Biomass survey indices fit

- Figure 10: Summary of biomass survey indices fit.

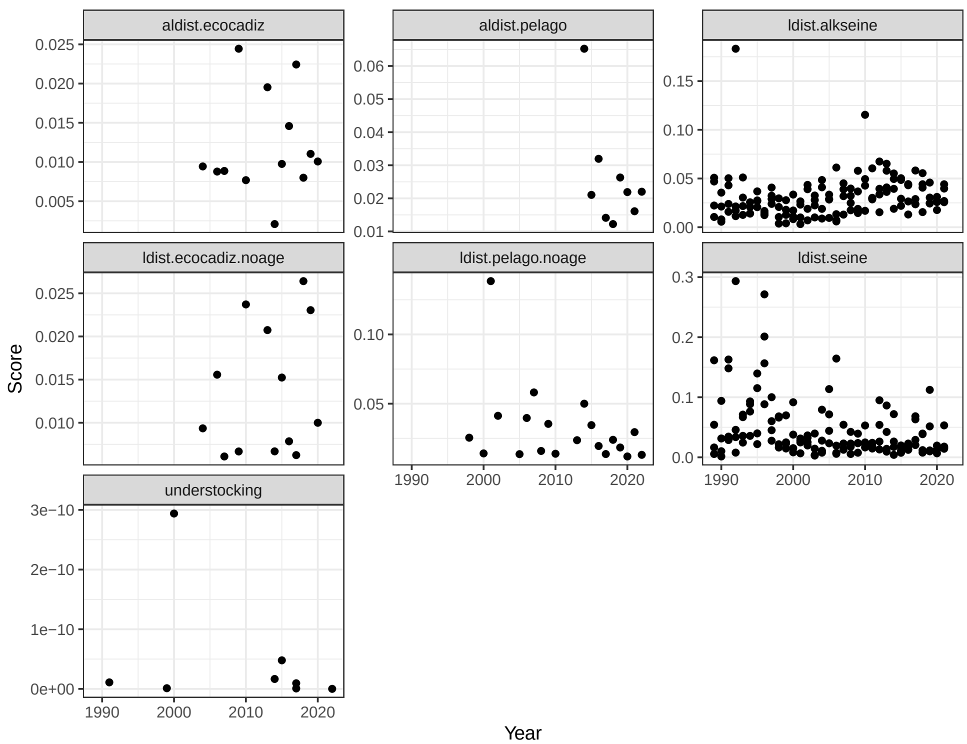

Figure 1: Likelihood scores for age-length key of ECOCADIZ survey, PELAGO survey and commercial landings (Upper panel) and length distribution of ECOCADIZ survey, PELAGO survey and landings. Dots represent the score for each quarter.

Index	
a	Age, $a = 0,\ldots,3$
l	Length, $l = 3{,}3.5{,}4{,}4.5,\ldots,22$
y	Years, $y = 1989,\ldots,2022$
t	Quartely timestep, $t = 1,\ldots,4$
T	$T = 1$ for period 1989-2000, $T = 2$ for period 2001-2021
Parameters	
Fixed	
a	Parameter of weight-length relationship $w = al^b$, $a = 3.128958 \times 10^{-6}$
b	Parameter of weight-length relationship $w = al^b$, $b = 3.277667619$
μ_a	Initial population mean length at age $\mu_0 = 9.99, \mu_1 = 12.1, \mu_2 = 15.2, \mu_3 = 16.1$
σ_a	Initial population standard deviation for length at age $\sigma_0 = 0.836, \sigma_1 = 0.5, \sigma_2 = 1, \sigma_3 = 1.2$
M_a	Natural mortality, $M_0 = 2.21, M_1 = 1.3, M_2 = 1.3, M_3 = 1.3$
n	Maximum number of length classes that an individual is supposed to grow $n = 5$
Estimated	
l_∞	Asympthotic length, l_∞=28.4296
k	Annual growth rate, $k = 0.0772549$
β	Beta-binomial parameter, $\beta = 5000$
ν_a	Age factor, $\nu_0 = 120000, \nu_1 = 116000,$ $\nu_2 = 0.0607, \nu_3 = 9.2e-07$
μ	Recruitment mean length, $\mu = 10.313$
σ_t	Recruitment length standard deviation by quarter, $\sigma_2 = 2.60238$, $\sigma_3 = 2.59163$, $\sigma_4 = 1.79378$
$l_{50,T}$	Length with a 50% probability of predation during period T, $l_{50,1}^{seine} = 12.6$, $l_{50,2}^{seine} = 10.8$, $l_{50,3}^{ECO} = 13$, $l_{50,3}^{PEL} = 14.3$
α_T	Shape of function, $\alpha_1^{seine} = 0.193$, $\alpha_2^{seine} = 0.764$, $\alpha_3^{ECO} = 1.31$, $\alpha_3^{PEL} = 0.406$
Observed Data	
$E_{y,t}$	Number or biomass landed at year y and quarter t
W_l	Weight at length
$I_{y,t}$	Observed survey index at year y and quarter t
$P_{a,l,y,t}$	Proportion of the data sample over all ages and lengths for timestep/age/length combination
$O_{a,l,y,t}$	Observed data sample for time/age/length combination
$x_{a,y,t}$	Sample mean weight from the data for the timestep/age combination
Others	
Δl	Length increase
Δw	Weight increase
Δt	Length of timestep
$N_{a,l,y,t}$	Number of individuals of age a, length l in the stock at year and quarter y and t, respectively.
$q_{a,l}$	Proportion in lengthgroup l for each age group
$R_{y,t}$	Recruitment at year y and quarter t
$p_{l,t}$	Proportion in lengthgroup l that is recruited at quarter t
$C_{l,y,t}$	Total amount in biomass landed by surveys and in number caught by commercial fleet (discards 2014-2019)
$S_{l,T}$	Proportion of prey of length l that the fleet/predator is willing to consume during period T
$\pi_{a,l,y,t}$	Proportion of the model sample over all ages and lengths for that timestep/age/length combination
$\mu_{a,y,t}$	Mean length at age for the timestep/age combination
U_t	Understocking for timestep t
lw_i and uw_i	Weights applied when the parameter exceeds the lower or upper bound
lb_i and ub_i	Lower and upper bound defined for the parameter
val_i	Value of the parameter

Table 1: List of Symbols used in model specification and parameter estimates after optimization

Data source	type	Timespan	Likelihood function
Commercial catches	Length distribution	All quarters, 1989-**2021**	See eq. 7
(discards from 2014 onwards)	Age-length key	All quarters, 1989-**2021**	See eq. 7
ECOCADIZ acoustic survey	Biomass survey indexes	Second quarter 2004, 2006	see eq. 6
		third quarter 2007, 2009, 2010, 2013-2020	
	Length distribution	Second quarter 2004, 2006	see eq. 7
		third quarter 2007, 2009, 2010, 2013-2020	
	Age-length key	Second quarter 2004, 2006	see eq. 7
		third quarter 2007, 2009, 2010, 2013-2020	
PELAGO acoustic survey	Biomass survey indexes	First quarter 1999, 2001-2003	see eq. 6
		second quarter 2005-2010 and 2013-2022	
	length distribution	First quarter 1999, 2001-2003	see eq. 7
		second quarter 2005-2010, 2013-2022	
	Age-length key	second quarter 2014-2022	see eq. 7

Table 2: Overview of the likelihood data used in the model. Important remark: Due to lack of information of length distributions and Age-length keys for commercial catches in the first and second quarter of 2020, the length distribution was approximated using the joint distribution of 2018 and 2019 and the Age-length key used was the one for the PELAGO 2020 survey.

Figure 2: Comparison between observed and estimated catches length distribution. Black lines represent estimated data while gray lines represent observed data

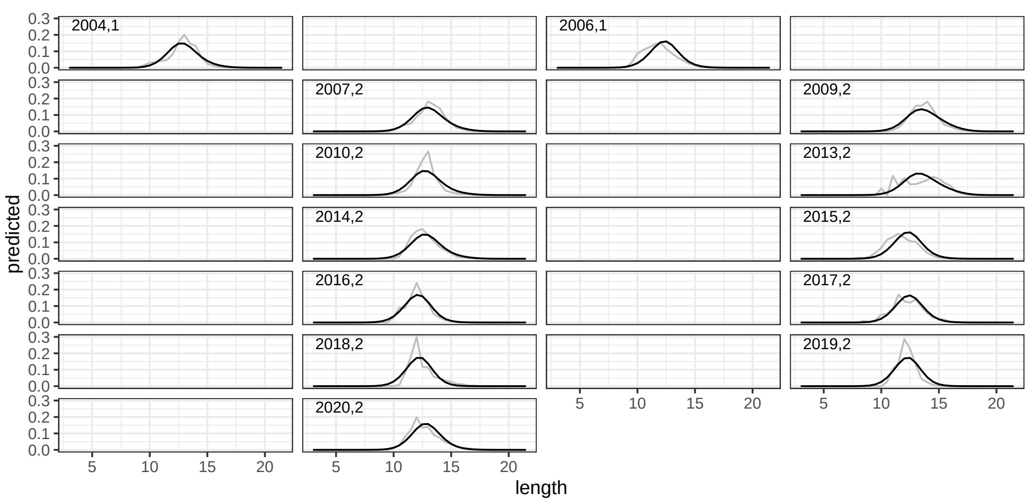

Figure 3: Comparison between observed and estimated catches length distribution for ECOCADIZ survey. Black lines represent estimated data while gray lines represent observed data

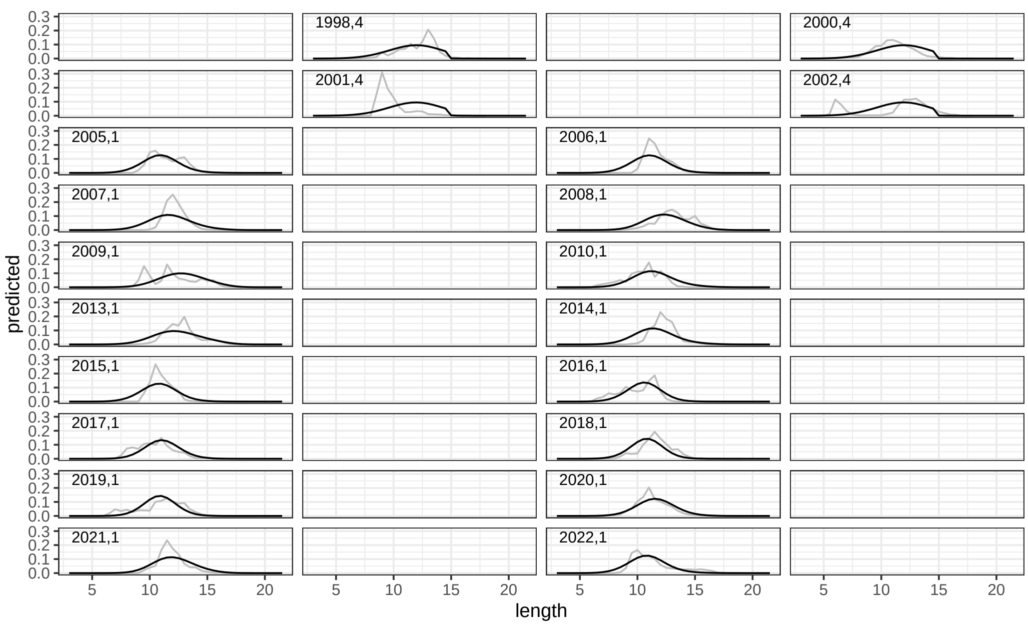

Figure 4: Comparison between observed and estimated catches length distribution for PELAGO survey. Black lines represent estimated data while gray lines represent observed data

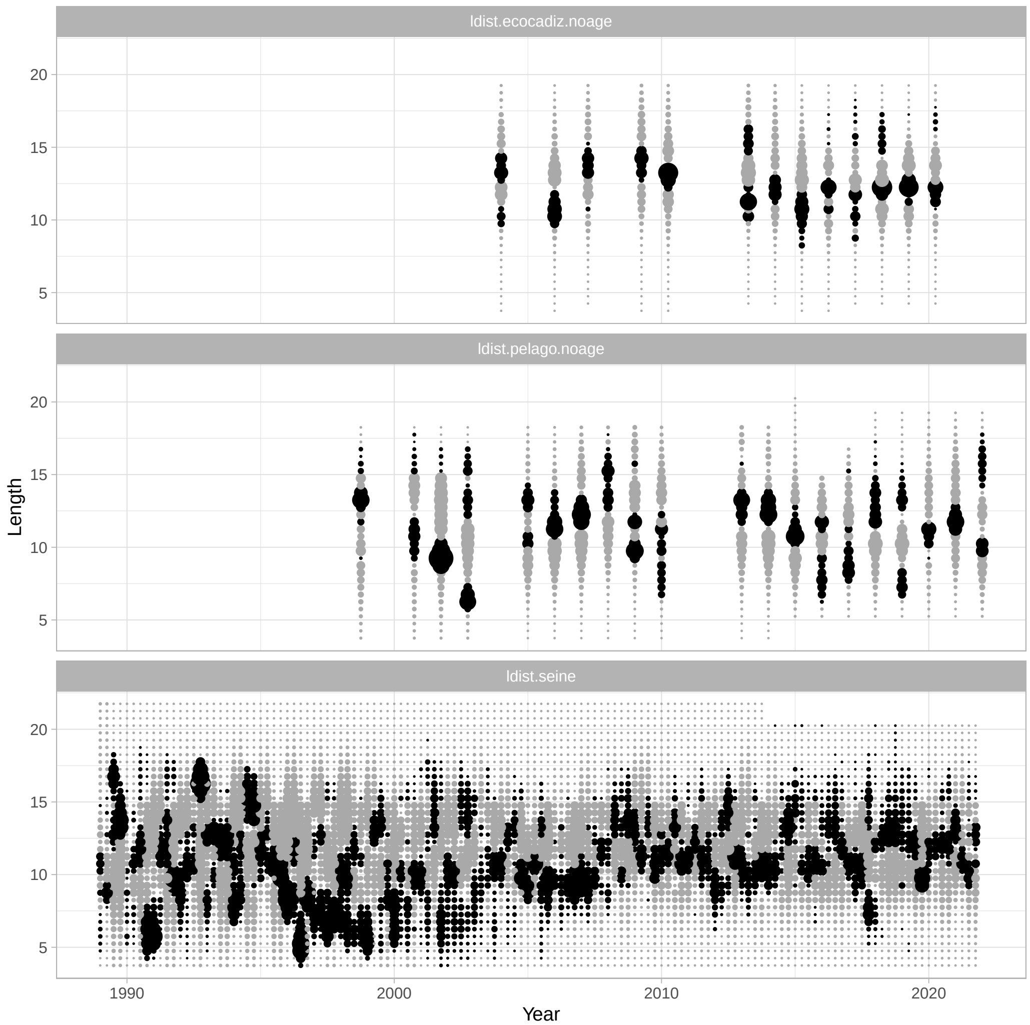

Figure 5: Standardised residual plots for the fitted length distribution from the ECOCADIZ survey, PELAGO survey and commercial landings. Black points denote a model underestimate and gray points an overestimated. The size of the points denote the scale of the standardised residual.

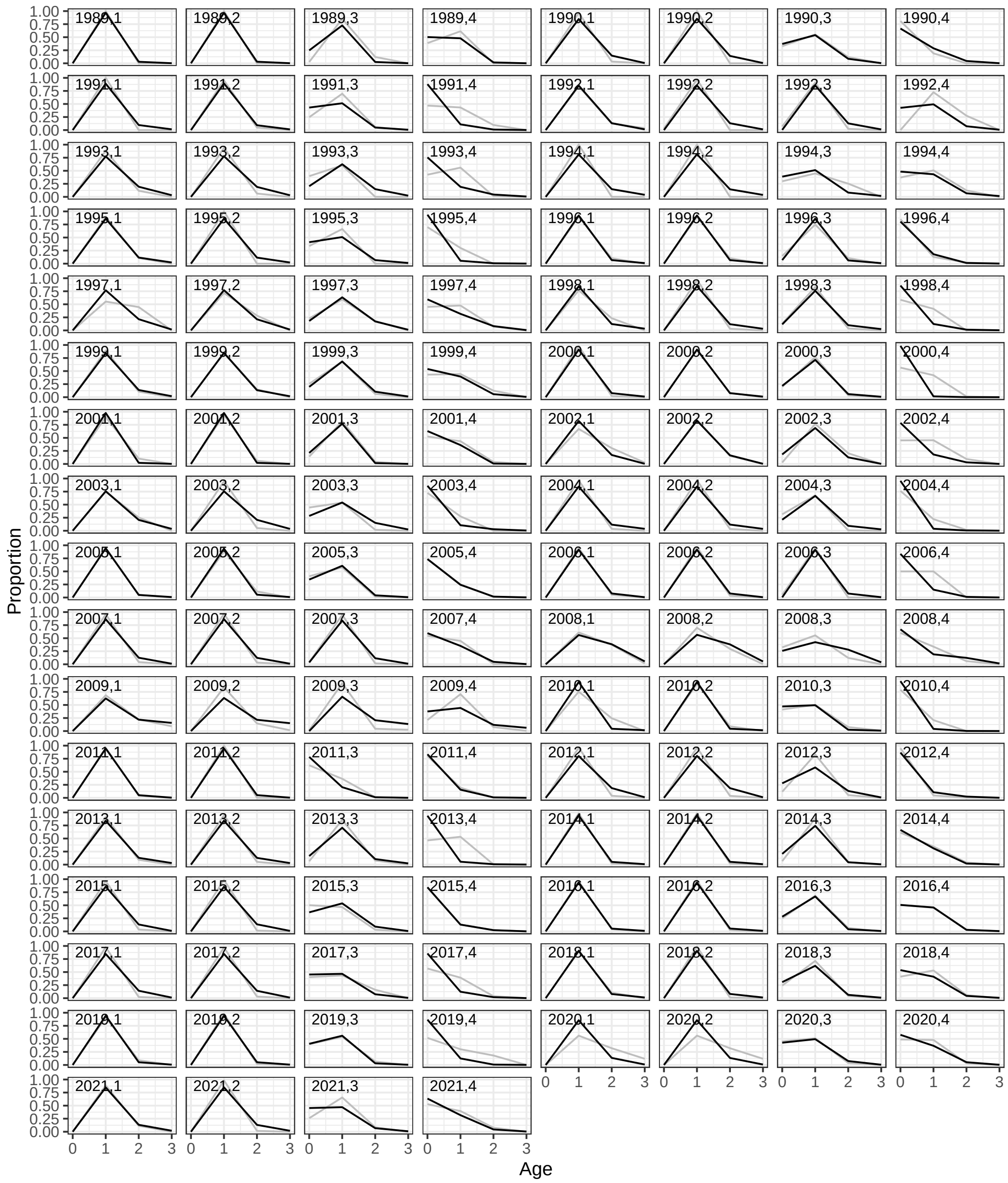

Figure 6: Comparison between observed and estimated catches age distribution. Black lines represent estimated data while gray lines represent observed data.

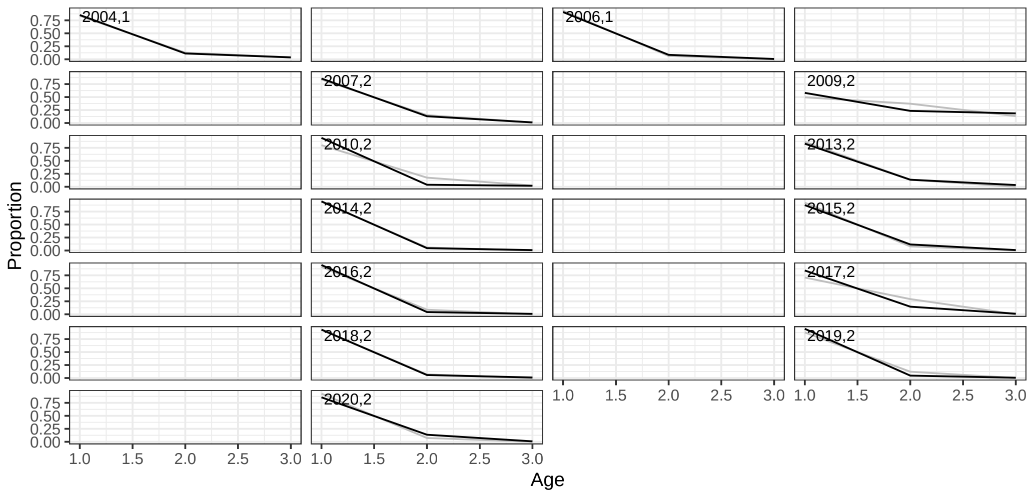

Figure 7: Comparison between observed and estimated ECOCADIZ survey age distribution. Black lines represent estimated data while gray lines represent observed data.

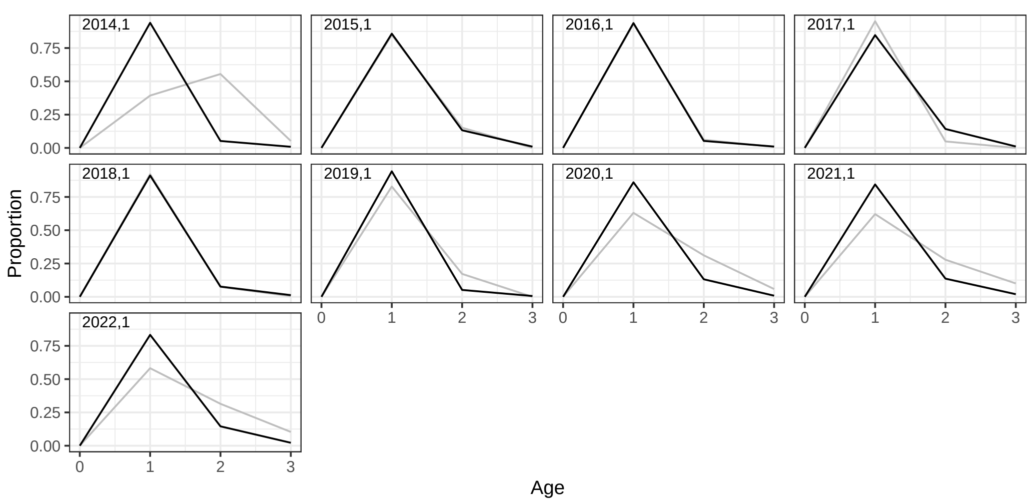

Figure 8: Comparison between observed and estimated PELAGO survey age distribution. Black lines represent estimated data while gray lines represent observed data.

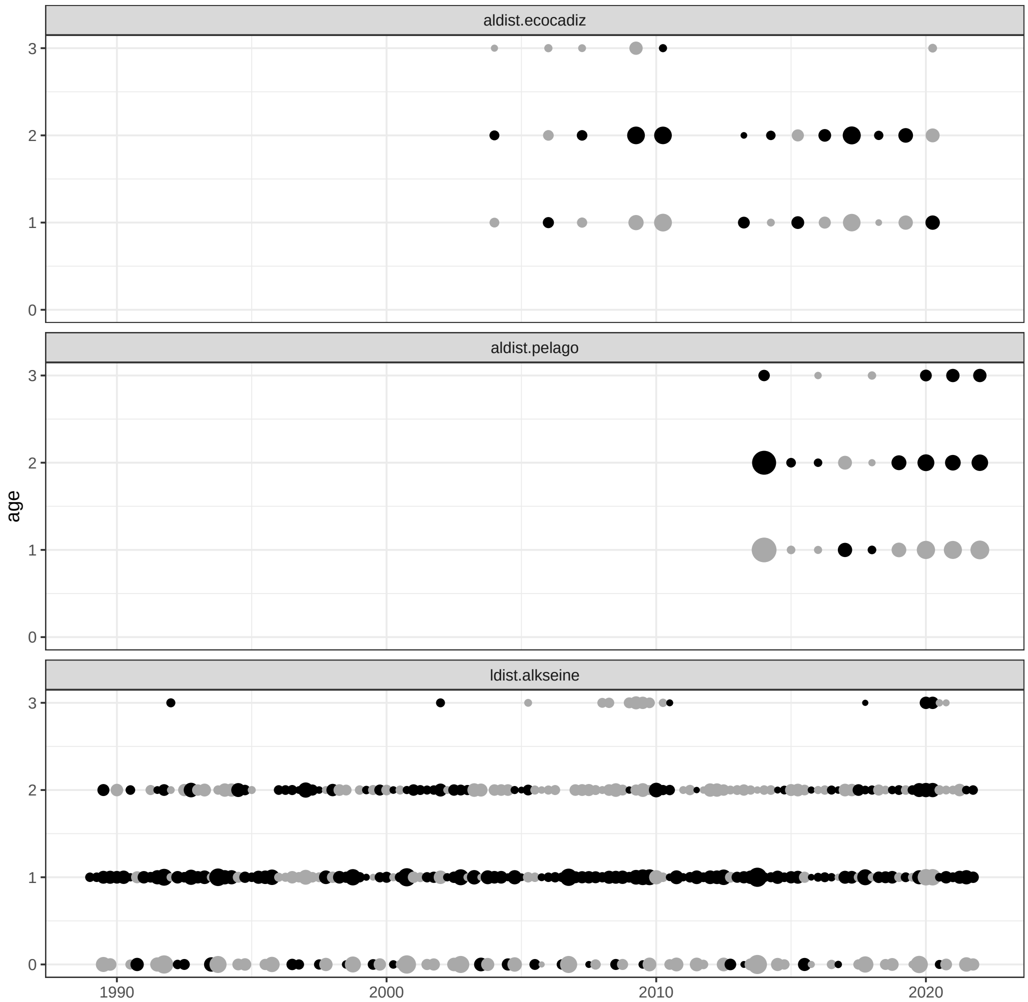

Figure 9: Standardised residual plots for the fitted age distribution from the ECOCADIZ survey, PELAGO survey and commercial fleet. Black points denote a model underestimate and gray points an overestimated. The size of the points denote the scale of the standardised residual.

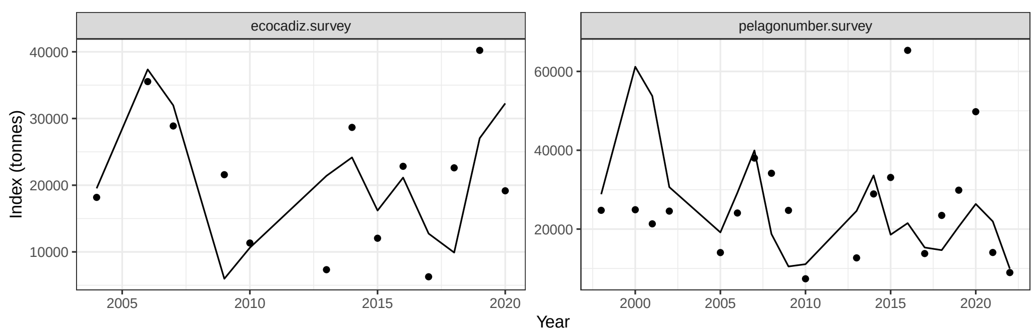

Figure 10: Comparison between observed and estimated survey indices. Black points represent observed data while black line represent estimated data

6. Model estimates

Parameter estimates after optimization are presented in Table 2. Detailed model outputs are available in Results folder on TAF repository, where each file corresponds to the following description:

- sidat: Model fit to the surveyindices
- suitability: Model estimated fleet suitability
- stock.recruitment: Model estimated recruitment
- res.by.year: Results by year
- catchdist.fleets: Data compared with model output for the length and age-length distributions
- stock.full: Modeled abundance and mean weight by year,step, length and stock
- stock.std: Modeled abundance, mean weight, number by age consumed by the fleet, stock and year
- stock.prey: Consumption of the fleet by length, year and step
- fleet.info: Information on catches, harvest rate and harvestable biomass by fleet, year and step
- params: parameter values used for the fit

6.1. Catchability

Figure 11 shows the catchability estimated by the model for the different surveys indices

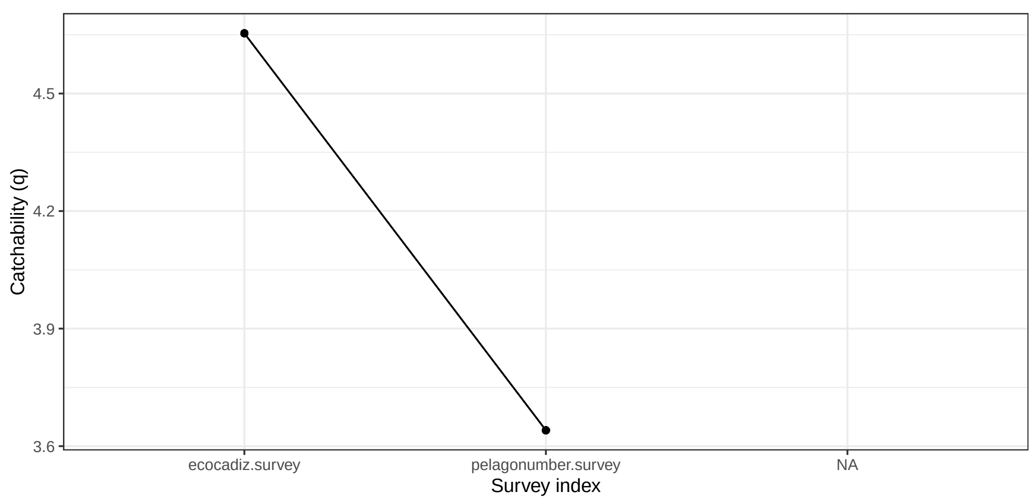

Figure 11: Estimated catchability parameters for the different survey indices

6.2. Estimated age composition

Figure 12 shows the estimated age composition of the population.

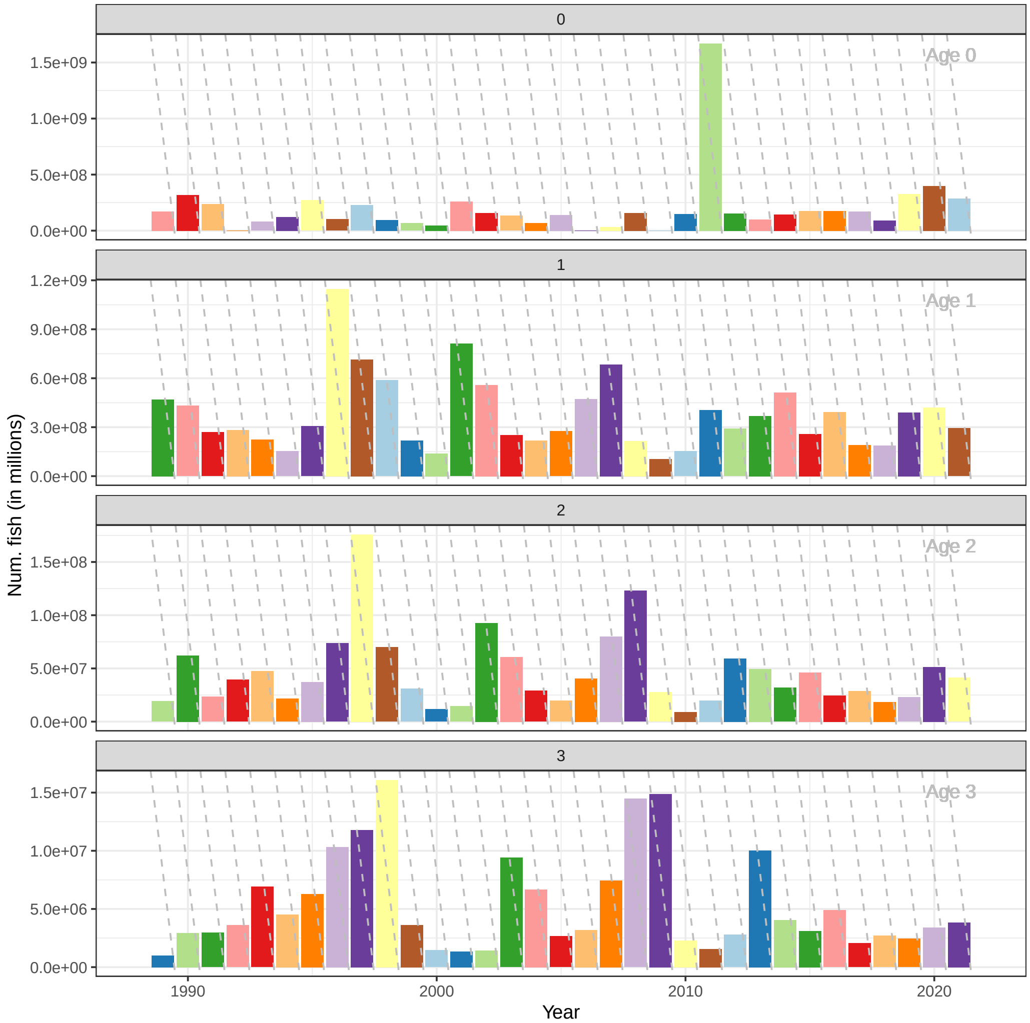

Figure 12: Estimated age composition of the population at the end of the second quarter for each year

6.3. Suitability

Figure 13 shows the fleet suitability functions estimated by the model for the commercial fleet and different surveys

6.4. Abundance, recruitment and Fishing mortality

Figure 14 presents model annual estimates for biomass, abundance (removing age 0 individuals to be accurate with the time of the assessment, see section 3 above for a detailed explanation), recruitment, fishing mortality and catches **at the end of the second quarter of each year**. Figure 15 shows annual estimates for biomass of individuals of age 1+ at the end of the second quarter of each year. Due to some inconsistencies in the maturity ogives not noticed during WKPELA 2018, we assume that all individuals with age 1 or higher (B_1+), are mature i.e. these abundance estimates result equivalent to spawning stock biomass estimates.

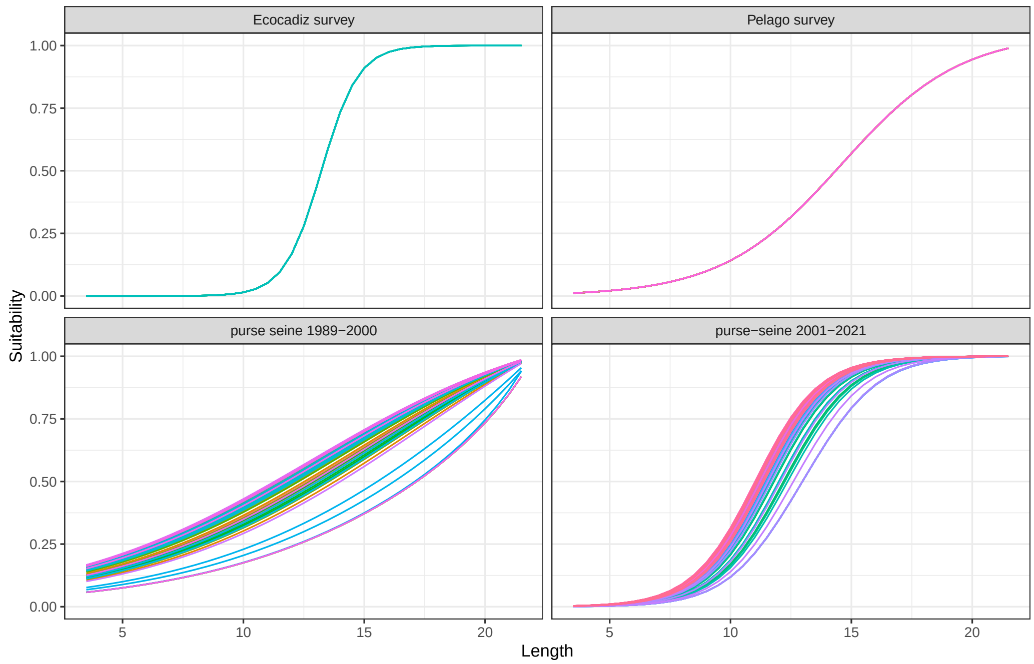

Figure 13: Estimated fleet suitability functions for the commercial fleet and different surveys.

6.5. Comparison with last year estimated time series and sensitivity analysis regarding missing information on the model used corresponding to the length distribution of ECOCADIZ survey in year 2020

A comparison with last year estimated time series, and also with those estimated by a model implementation with length distribution for ECOCADIZ survey in 2020 (that was missing in the last year model) is presented in Figure 16. The pink line represents last year estimated time series, the green line, the estimated by the same model but including the ECOCADIZ length distribution in 2020 and the blue line, the estimated by the model used this year (the one described in this document). It was observed that the estimated biomass for some of the last years is smaller when including the length distribution missing (green line) but population trend remains very similar. It is also important to remark that the number of iterations for the optimization process in the first model was 2000000, while in the others was just 1000000.

7. Reference points

The methodology applied was the same decided in WKPELA 2018 (page 286 of WKPELA 2018 report (ICES, 2018)) following ICES guidelines for calculation of reference points for category 1 and 2 stocks and the report of the workshop to review the ICES advisory framework for short lived species ICES WKMSYREF5 2017 (ICES, 2017).

According to the above ICES guidelines and the S-R plot characteristics (Figure 17), this stock component can be classified as a “stock type 5” (i.e. stocks showing no evidence of impaired recruitment or with no clear relation between stock and recruitment (no apparent $S-R$ signal)). According to this classification, B_{lim} estimation is

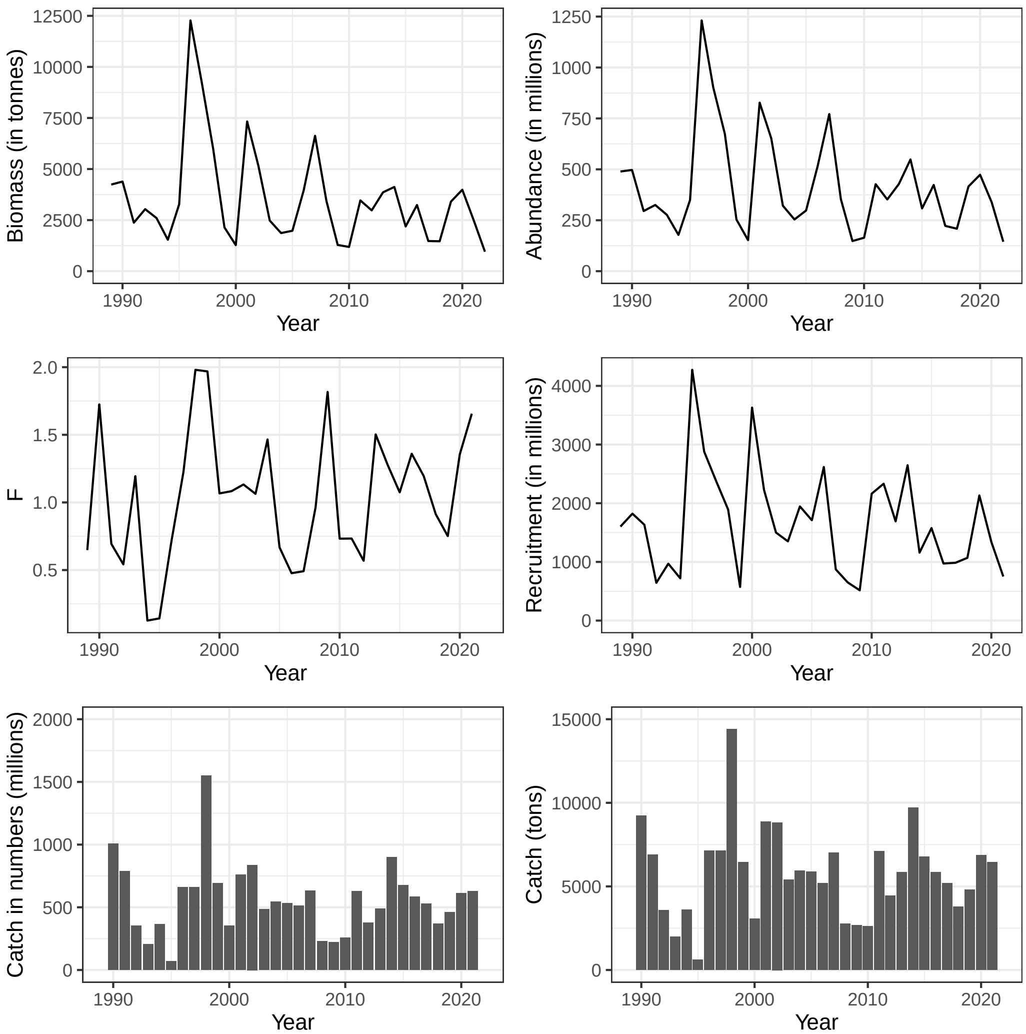

Figure 14: Annual catches time series (in numbers and biomass) compared with annual model estimates for abundance of individuals with more than one year of age(in numbers and biomass) recruitment and fishing mortality. Measures were summarized at the end of June each year, assuming that a year starts in July and ends in June of the next year. Recruitment was calculated including all the recruits of the previous year according to calendar year

possible according to the standard method and it is assumed to be equal to $Bloss$ ($B_{lim} = B_{loss}$). For **2022** the value of B_{loss} for the 9a South anchovy corresponds to the estimated SSB in **2010** (1186.34 t), hence B_{lim} is set at 1186.34 t and the relative B_{lim} (divided by the mean value of B_1+) results equal to 0.325. Note that due to some inconsistencies in the maturity ogives used in WKPELA2018, age 1+ individuals (B_1+) are assumed as mature i.e. B_1+ class is equivalent to Stock Spawning Biomass (SSB) (see subsection 6.4 above).

ICES recommends to calculate B_{pa} as follows:

$$B_{pa} = e^{(1.645\sigma)} B_{lim},$$

where σ is the estimated standard deviation of $ln(SSB)$ in the last year of the assessment, accounting for the uncertainty in SSB for the terminal year. If σ is unknown and for short living species, as it is in our

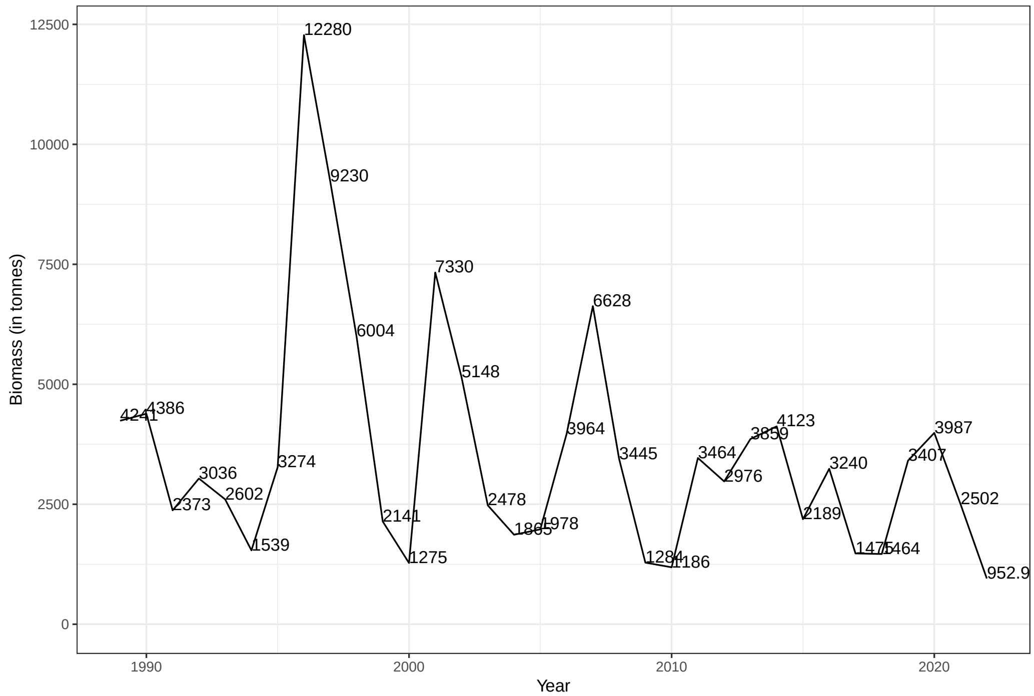

Figure 15: Estimated biomass time series at the end of quarter two (Age 0 removed to be consistent with recruitment at the end of the second quarter of the year). Note that under the assumption that all individuals in $B1+$ class are mature, this biomass is equivalent to SSB

case, it can be assumed that $\sigma = 0.30$ (see page 34 of ICES WKMSYREF5 2017 report (ICES, 2017)), then $B_{pa} = e^{(1.645\sigma)} B_{lim} = 1.64 B_{lim}$. According to this B_{pa} is set at 1945.5976 t.

8. Catch advice for July 2022 to June 2023

The ratio between the last year biomass estimate and the mean of the two previous years is:

$$\frac{B_y}{\overline{B_{y-1} + B_{y-2}}} = \frac{953}{(3987 + 2502)/2} = 0.2937$$

for B representing the estimated abundance by the model as shown in Figure 15. According to the report of WKLIFEVX (ICES,2021), if this ratio is above 1.8, the advice would be equal to the latest advice mutiplied by 1.8, if not, the latest advice would be multiplied by this ratio. In case the estimated abundance is below a biomass trigger, which in this case is B_{lim}, it is also multiplied by a biomass safe guard as follows:

$$C_{y+1} = \hat{C}_y * \min\left(1.8, \frac{B_y}{(B_{y-1} + B_{y-2})/2}\right) * \frac{B_y}{B_{lim}}$$

where $\hat{C}_y$ is the value of adviced catches in the previous year. Then the adviced catches (in tonnes) for the next year (July 2022 to June 2023) would be:

$$C_{y+1} = 7181 * 0.294 * 0.803 = 1694.$$

This procedure modification has been implemented since this year and it is not specified in the Stock annex.

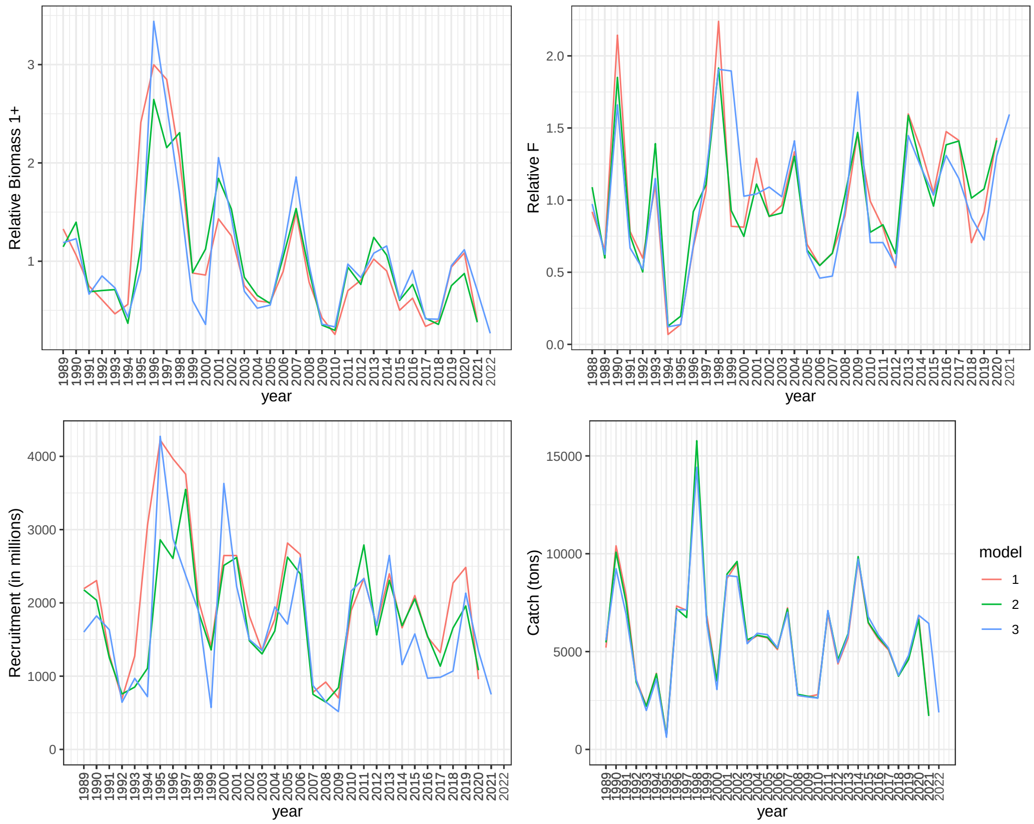

Figure 16: Comparison of estimates from different model implementations.1. Model used last year (pink), 2. Model used last year but including the ECOCADIZ length distribution in 2020 (green), 3. Model described in this document which is the reference for the advice provided in 2022 (blue): Annual model estimates for relative abundance of individuals with more than one year of age, relative fishing mortality, recruitment and catches (in numbers). Measures were summarized at the end of June each year, assuming that a year starts in July and ends in June of the next year. It is also important to remark that the number of iterations for the optimization process in the first model was 2000000, while in the others was just 1000000.

9. Acknowledgements

We thank Jamie Lentin from Shuttlethread for the automatization of data input, Bjarki Elvarsson for having an open repository with very useful Gadget data processing routines and his valuable help, and to the members of WGHANSA group for their guidance and support.

We gratefully thank CESGA (Galician Supercomputing Center) for computational time at the FTII Supercomputer and technical assistance.

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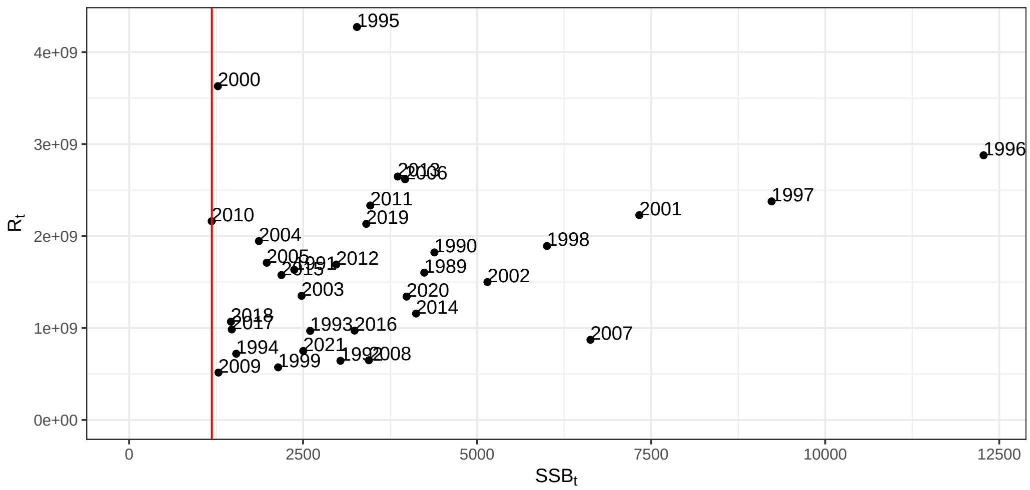

Figure 17: Estimated Stock Spawning biomass (SSB_t) vs. Recruitment (R_t), SSB_t corresponds to the Stock Spawning Biomass at the end of quarter 2 of year t, while R_t corresponds to the sum of the recruitment at the beginning of quarters 3,4 and 1 of years t and $t + 1$, respectively.

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Assessing the impact of external environmental drivers on Atlantic Chub Mackerel (*Scomber colias*) population dynamics

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Abstract:

Small pelagic fish populations are characterized by considerable inter-annual and inter-decadal fluctuation dynamics forced by fishing pressure and environmental factors. Nevertheless, knowledge of this environmental forcing remains very limited. The Northwestern African waters from Morocco to Mauritania are known as one of the most productive ecosystems in the world due to the upwelling, resulting in a significant abundance and variation of the catches of small pelagic species. Their population dynamics are strongly modulated by different environmental covariates. Therefore, the assessment of stock status considering the impact of environmental conditions on the population dynamics is a key issue for fisheries management. In the case of the Moroccan Atlantic coast, the chub mackerel represents one of the most important small pelagic fishery resources. To assess population abundance, it is necessary to use Data-Limited Methods (DLM) considering the limited biological data availability for this species in this region and also poor understanding of the effects of environmental forcing on stock size and distribution. The objective of this study is to evaluate the correlation between different environmental factors and population trend estimated by a DLM approach for stock assessment. To achieve this aim, the Surplus Production model in Continuous Time (SPiCT) is implemented to analyze the population fluctuations of the chub mackerel stock based on surveys and landing data. The estimated relative biomass trend is used to explore the influence of external environmental drivers on stock dynamics, which is considered in a second step of this study. The correlation analysis results show a significant correlation with salinity, net primary production, oxygen, nitrate and chlorophyll concentrations that are also consistent with spatio-temporal variations of the chub mackerel. The years with high biomass (above 75% of the mean) are linked to the very high physical variability of the upwelling, accompanied by specific variations of other environmental parameters that are also tested. Based on these results, the SPiCT model in which environmental covariates are modeled as random variability can be developed by integrating these relationships. The development of this model can help managers to improve stock assessment results to achieve a sustainable management and exploitation of the stock considering all external factors.

Working document presented to the:

ICES Working Group on Horse mackerel, anchovy and sardine (WGHANSA 2022). 23-27 May 2022.

POPULATION STRUCTURE OF THE EUROPEAN ANCHOVY (*ENGRAULIS ENCRASICOLUS*) IN ICES DIVISION 9A

By

SUSANA GARRIDO, NAIARA RODRÍGUEZ-EZPELETA, FERNANDO RAMOS, MARGARITA RINCÓN, DIANA FEIJÓ, ANA MORENO, RITA CASTILHO, NATALIA DÍAZ, RUTE R. DA FONSECA, SARA M. FRANCISCO, ALICE MANUZZI, GONÇALO SILVA, ANDRÉS URIARTE

ABSTRACT

The present WD summarizes the state-of-the art and presents new information on the stock structure of anchovy in the Division 27.9.a (Atlantic Iberian waters). This stock of 9a started to be assessed after its first benchmark in February 2018 (WKPELA 2018, ICES, 2018a). According to the information provided by WGHANSA, WKPELA 2018 supported considering two different stock components due to different fisheries and populations dynamics: The Western component – in ICES Sub-divisions 9a.N, 9aCN and 9aCS, and the Southern component – in ICES Sub-divisions 9a.S, for which advice is given separately. During the benchmark, it was advised to gather more information regarding the population structure of anchovy Iberian populations, namely genetic information, to decide if the two components should be managed as independent stocks. Anchovy spatial distribution in Division 9a provided by surveys shows a persistent discontinuity between the western and southern components of the stock for several life stages (eggs, juveniles and adults) and during different seasons of the year. Landings also show this discontinuity, with most Portuguese landings (>90%) occurring in Subdivision 9a CN. Moreover, no correlation of anchovy catches was found between the Western and Southern components, further suggesting independent dynamics, and refuting the hypothesis of western population(s) arising from the southern component. A review of studies conducted in Portuguese estuaries show the persistent occurrence of recruits in numerous estuaries, mainly in the Subdivision 9a CN, which, agreeing with the concentration of eggs in this subdivision, points to the presence of a self-sustained population in this area. Morphometric and genetic studies seem to indicate a differentiation of the western and Cantabrian populations, as well as a separation with those from the Gulf of Cadiz, but additional analyses are needed as these conclusions might be affected by the presence of two ecotypes (marine and coastal), which are often not considered in these studies. The information presented in this WD leads the WGHANSA to consider the anchovy populations inhabiting the southern and western Iberian regions and their exploited populations as spatially separated with independent dynamics (via their recruitment pulses) and therefore, should be considered separate stocks for management.

1. INTRODUCTION

The European anchovy, *Engraulis encrasicolus*, is a small pelagic coastal marine fish distributed from the North Sea to Southeast Africa, including the entire Mediterranean basin. This species supports an important fisheries and economic activities for the countries bordering the Iberian Peninsula and Mediterranean Sea (Uriarte *et al*., 1996; Lleonart and Maynou, 2002). Due to its market value, production, and wide distribution in several East Atlantic and Mediterranean countries, anchovy is a major shared resource in the region. For management purposes, the European anchovy was separated in two distinct stock units, one distributed in the Bay of Biscay (Subarea 8) and the other distributed in ICES Division 9a (Portuguese coast and Spanish waters of the Gulf of Cadiz). Further north this species is not assessed. However, these stock limits were essentially based on administrative considerations.

A review on the sub-stock structure of the European anchovy in the Bay of Biscay and Iberian-Atlantic waters was provided by Ramos (2015) to the ICES Stock Identification Methods Working Group (SIMWG) in 2015. The evidence presented in that document suggested the existence of a stable population in the Gulf of Cadiz that seems to be relatively independent of the remaining populations in Division 9a. At that time, the ICES SIMWG (ICES, 2015a) considered that there was evidence to support a self-sustained population of anchovy located in the Gulf of Cadiz (ICES Subdivision 9a South, 9aS), but there was a lack of information regarding the origin of European anchovy in ICES Subdivisions 9a North (9aN), 9a Central-North (9aCN) and 9a Central-South (9aCS) (Fig. 1). At the time the stock was benchmarked (WKPELA 2018), an updated review of anchovy stock structure was provided (Garrido et al. 2018), including new information of the potential connectivity of anchovy population of the 9a West subdivisions with the South Iberian population. Data on spatial distribution of surveys and landings identified a discontinuity of anchovy distribution in the southwestern Iberia, separating the western and southern populations. Different dynamics of western and southern populations were identified. A summary of studies on genetics and morphometry was presented, pointing to a differentiation of western and southern anchovy populations. These evidences led WKPELA to support the proposal of considering two different components of the stock (western and southern components) for which the advice should be given separately, but the evidence was not consensually considered sufficient to modify the current stock structure. New studies on genetics and otolith microchemistry, aimed at elucidating the identity and structure of anchovy populations in the western component were still in progress. WKPELA suggested to present both, the available evidences and the resulting new evidence from these undergoing studies to the ICES Stock Identification Methods Working Group for future consideration. Still, evidence shown at that time led to the decision of considering the anchovy populations inhabiting the southern and western Iberian regions as separate stock components for management purposes.

In the present WD we i) compile and summarize the information presented previously on the stock structure of anchovy, ii) update the analysis of the historical dynamics of landings and surveys, iii) describe new evidence that point to independent dynamics of western and southern Iberian anchovy populations.

2. SPATIAL DISTRIBUTION OF ANCHOVY IN DIVISION 27.9.A

The distribution of anchovy in Division 9.a (Fig. 1) was investigated by using all the available information of the scientific cruises carried out regularly in the area, and covering several life-stages (eggs, juveniles and adults) and seasons of the year (spring, summer, fall). In what follows, the historical data of the distribution of the species will be shown for the indices derived from those cruises and those covering most of the division 9.a (PELAGO, PT-DEPM, Portuguese Trawl Surveys).

Figure 1. ICES Statistical Divisions and Subdivisions in Southern Europe. Western component of anchovy stock distributes in the area identified in blue as 9.a. West (comprising Sub-divisions 9aN, 9aCN, 9aCS). Southern component of anchovy stock distributes in the area identified in blue as 9.a. South (comprising sub-divisions 27.9.a.S (Portugal) and 27.9.a.S (Spain)).

2.1. HISTORIC DYNAMICS OF SURVEY DATA

2.1.1. SPRING ACOUSTIC SURVEYS

There are 3 spring acoustic surveys that cover the Atlantic Iberian waters: PELGAS in the Bay of Biscay, PELACUS in western Galician waters and the Cantabrian Sea, and PELAGO, covering the area from western Portugal and the Gulf of Cadiz (Fig. 2). According to the estimates provided by the spring acoustic surveys carried out in the Atlantic Iberian waters from 2013 to 2021, adult anchovy core distribution areas in springtime are, 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 the north western Portuguese coast, North of Cape Mondego (~40°N).

There is a gap in the distribution of adult anchovy in the western side of the Cantabrian Sea and in the southwestern Portuguese coast.

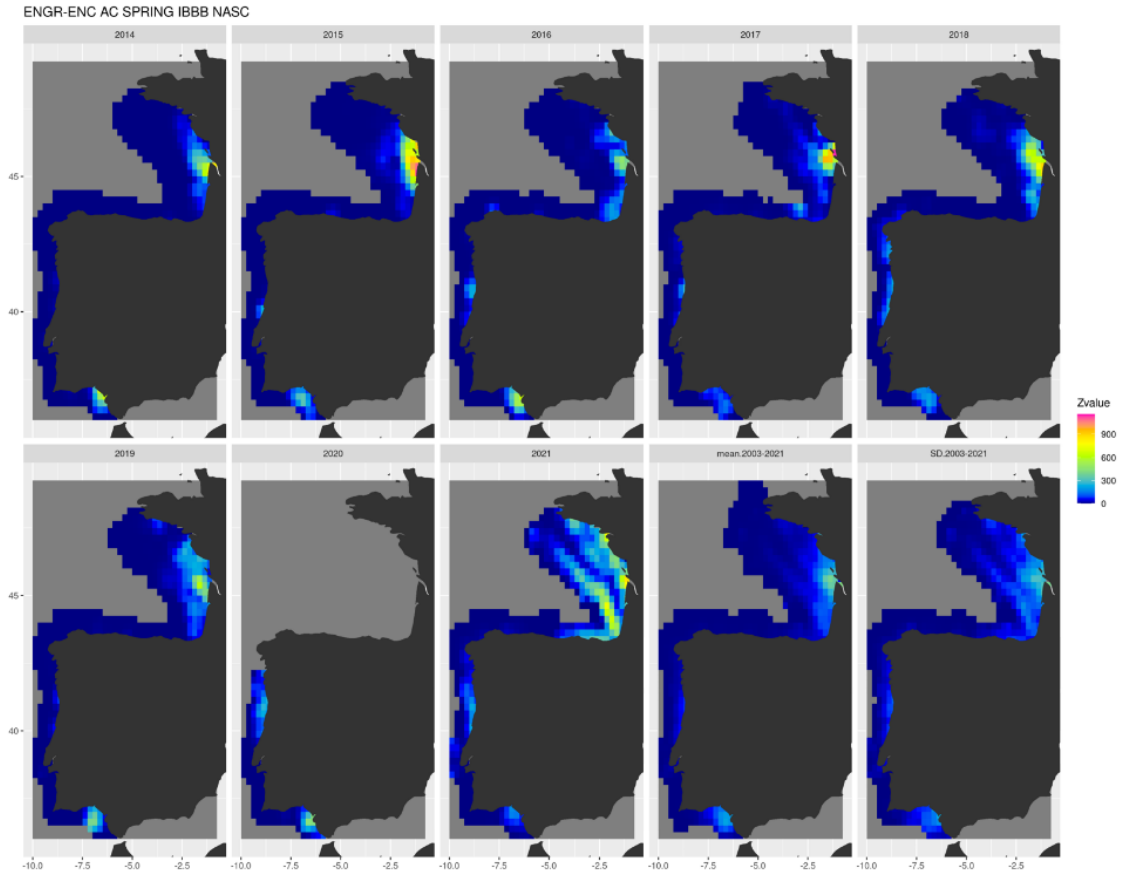

Figure 2 Mean acoustic density (NASC, m².NM-²) of anchovy in surveys PELGAS, PELACUS and PELAGO 2014 to 2021. Last two maps: mean and standard deviation from 2003 to 2021. Source: ICES WGACEGG 2021 Report.

Anchovy egg distribution estimated during the spring acoustic surveys from 2018 to 2021 is similar to that of the adults, being higher in the Bay of Biscay, followed by the Gulf of Cadiz and the north western coast of Portugal (Fig. 3). However, it should be noted that peak spawning for anchovies in Division 9a generally occurs two months after these surveys.

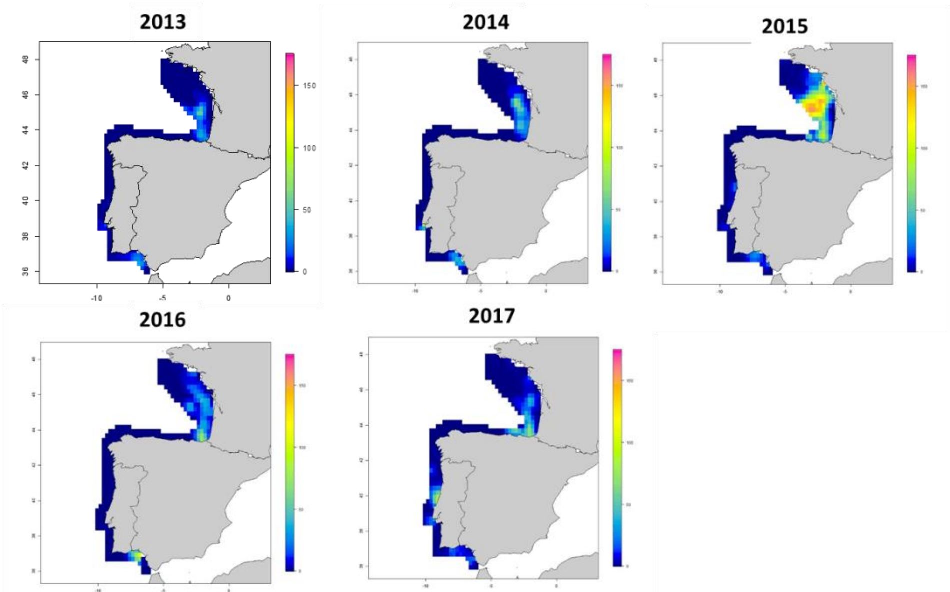

Figure 3. Anchovy egg density (eggs m^{-3}) distribution derived from CUFES sampling during the spring acoustic surveys, PELGAS (Ifremer), PELACUS (IEO) and PELAGO (IPMA) for the period 2013-2017. Source: ICES WGACEGG 2017 Report.

2.1.1.1. PELAGO SURVEY SERIES

The PELAGO survey covers most of 9a Division, from sub-areas 9aCN to the Gulf of Cadiz, only excluding the 9aN Sub-division, that accounts, on average, 5.4 ± 6.24% of anchovy abundance in Division 9a and 3.3 ± 4.91% of anchovy in the western component (data from 2007 to 2021). Acoustic surveying is undertaken along 71 transects perpendicular to the coast, covering the whole platform, and separated approximately 6 (south) or 8 nm (west). Fishing hauls are carried out for species ground-truthing and fish size composition. Zooplankton samples are collected underway every 3 nm, with the CUFES system (water pumped from 3m from the surface, system fitted with a 335 µm mesh size net), concurrently to the acoustic surveying along the trajectory of the acoustic transects. As described above, detailed observation of the PELAGO results (Fig. 4) allows the identification of two main centres of anchovy distribution, in Cadiz and in the north western Portuguese coast.

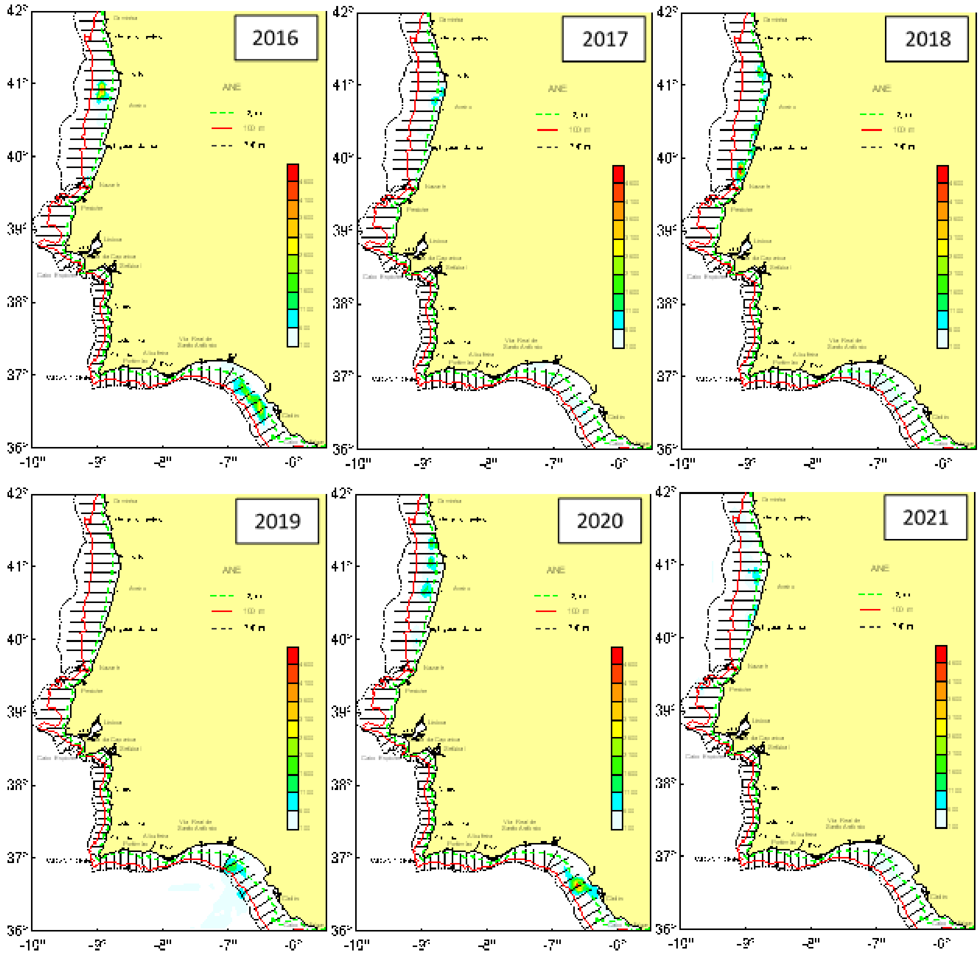

Figure 4 – Acoustic density (NASC, m².nm-²) of anchovy in PELAGO survey series from 2016 to 2021.

Egg distribution assessed in the PELAGO survey (conducted near or at the beginning of anchovy spawning season) shows a recurrent concentration of eggs in the Gulf of Cadiz and in the area from Cape Carvoeiro to Cape Espichel (North-western Portugal) (Fig 5). Occasionally, some eggs are detected off River Mira (south of Cape Sines) in the southwestern coast. The major egg densities in the western Iberia occur more often in the central region off Ria de Aveiro – River Mondego area. The anchovy egg distribution is highly variable between years. During years of high abundance, the southern coast appears almost entirely occupied, with observations from the inner Cadiz Bay to Cape S. Vincente, while during low abundance periods the distribution is retracted to the Spanish waters. Likewise, in the west coast during years of higher abundances anchovy eggs may be observed in a larger area occupying the northwestern and the north part of the southwestern Portuguese coast (e.g. in 2017) while during low density periods may only be observed in the core areas. It is worth noting that the spawning period for anchovy in the area covered by the PELAGO survey is from May to July. Unplanned delays that occurred in the 2016 and 2017 surveys have contributed to the higher anchovy egg abundances observed since the survey was conducted. In fact, 2017 was the year with the record high anchovy egg abundances during the PELAGO survey series and the following year (2018) the second highest peak on anchovy abundance was registered. The highest egg densities were observed on the northwest coast and in good agreement with the detection of anchovy, where high fish abundances were also registered during the previous spring.

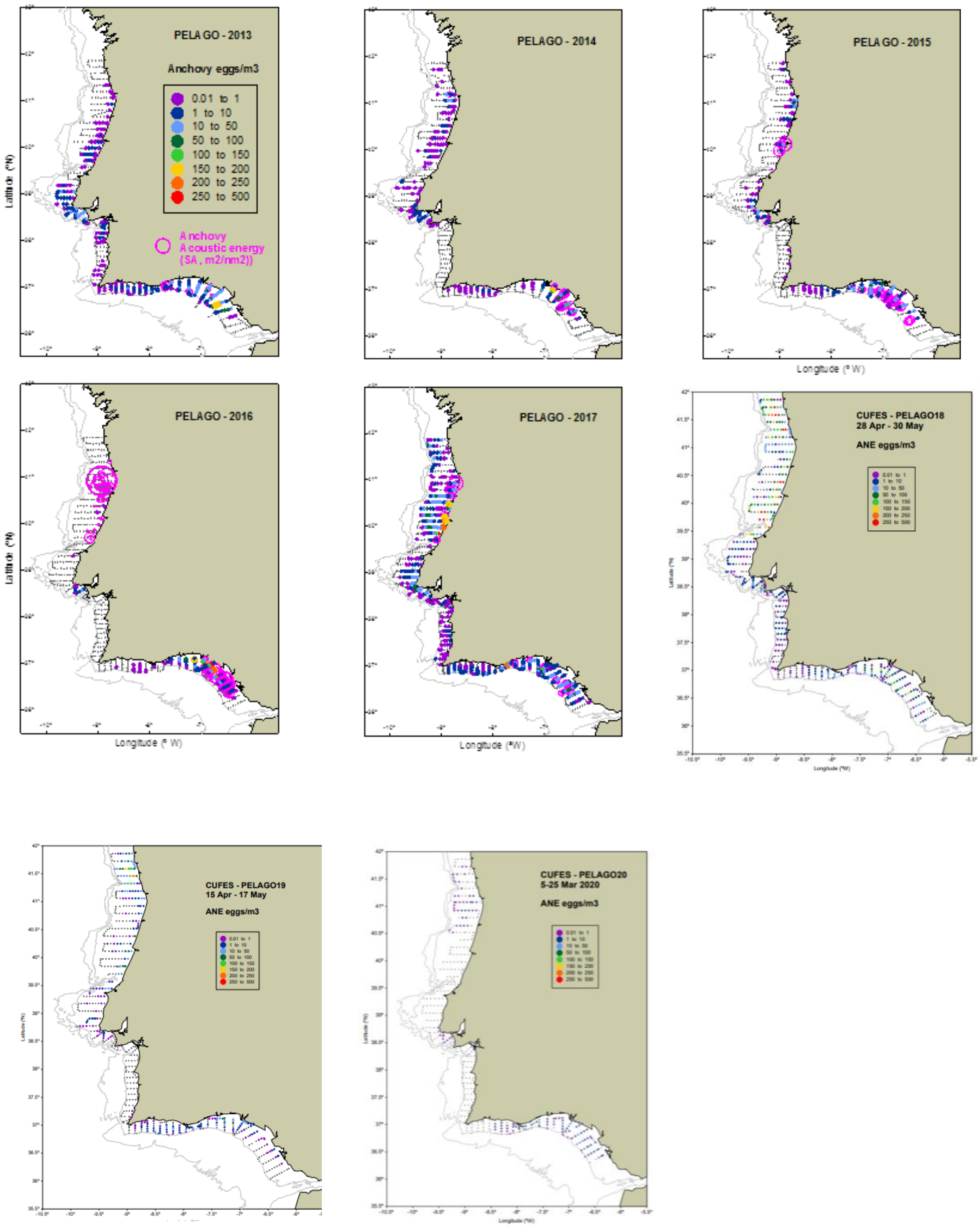

Figure 5 - Anchovy egg density (eggsm-³), from CUFES sampling, and acoustic energy (SA m^2/nm^2) distributions, during the acoustic surveys of the PELAGO series (IPMA) for the period 2013-2020. Egg distributions are represented by density classes according to the colour scale depicted. Acoustic energy of adult anchovy is shown in pink circles with areas proportional to SA in maps from 2013-2017. Source: ICES WGACEGG.

The PELAGO survey series has data of anchovy abundance and distribution since 1998. In the beginning of the survey series, the majority of anchovy in the 9a Division was in the southern component, mainly in the Spanish waters. From 2011 onwards, no clear trend was found in anchovy abundance in the southern component, but a sharp increase was observed in western Iberia, with peak abundances registered in 2021 followed by 2018 (Figure 6).

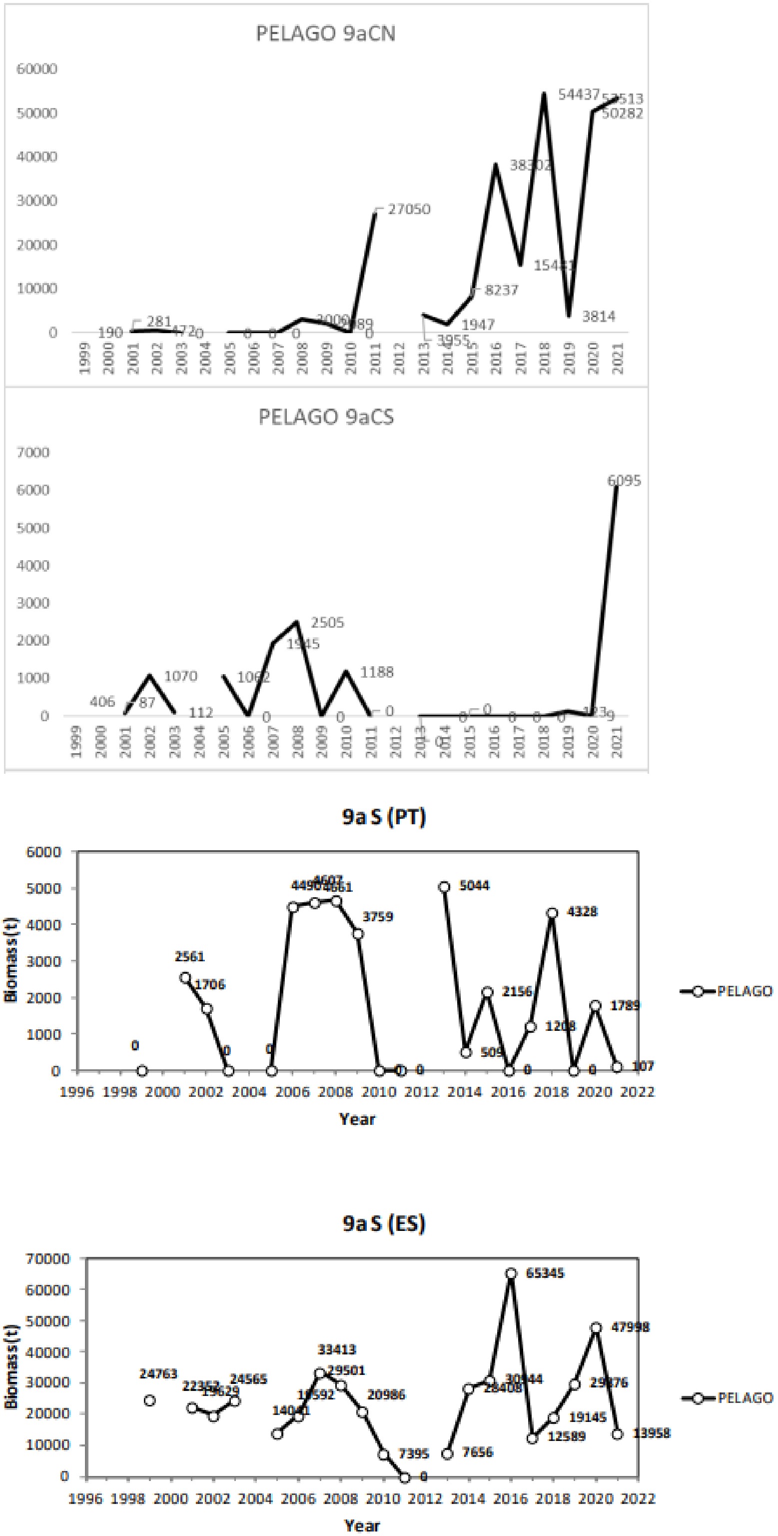

Figure 6 - Anchovy in Division 9.a. Western and Southern components. Subdivisions 9.a Central-North to 9.a South. PELAGO survey series (spring Portuguese acoustic survey in Subdivisions 9.a Central-North to 9.a South). Historical series of regional acoustic estimates of anchovy biomass (t). Note the different scale of the y-axis.

Focusing on the western Iberia, in the beginning of the PELAGO survey series, when anchovy abundance was very low in in the western Portuguese coast (Fig. 7), the species was largely found in the northern part of the southwestern Iberia – 9aCS (or OCS in Figure 7) - (mostly near Lisbon). Since 2011, when the abundance of anchovy started to sharply increase until present levels, anchovy was absent from the southwestern area during 10 surveys, from 2011 to 2018, and its biomass was very low in the remaining 3 surveys, carried out in 2019, 2020 and 2021, being 3, 0.02 and 10% of the total biomass in the western Portuguese coast, respectively.

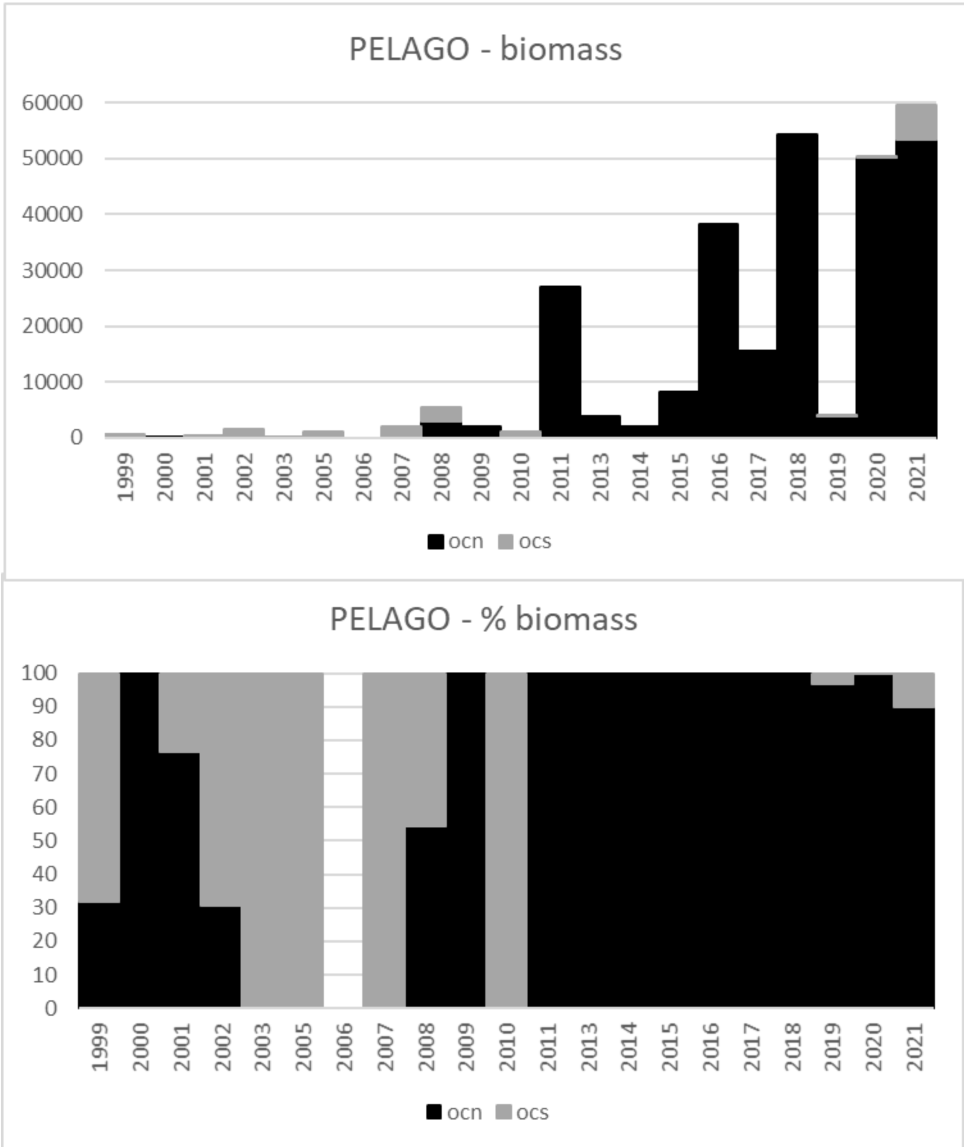

Figure 7 - Anchovy in Division 9.a. Western component. Subdivisions 9.a Central-North to 9.a Central-South. PELAGO survey series. Historical series of regional acoustic estimates of anchovy biomass (t).

2.1.2. AUTUMN ACOUSTIC SURVEYS

According to the estimates provided by the autumn acoustic surveys from 2018 to 2021 targeting sardine and anchovy recruitment (CSHAS, PELTIC, JUVENA, IBERAS and ECOCADIZ-RECLUTAS surveys, Fig. 8), the core distribution areas of adult anchovies are similar to those detected in the spring-time. Anchovy biomass is concentrated, by decreasing order of importance: along the coastal areas of the Bay of Biscay, followed by the Gulf of Cadiz and the north western Portuguese coast. Again, there are gaps in the distribution anchovy the western side of the Cantabrian Sea and in the southwestern Portuguese coast.

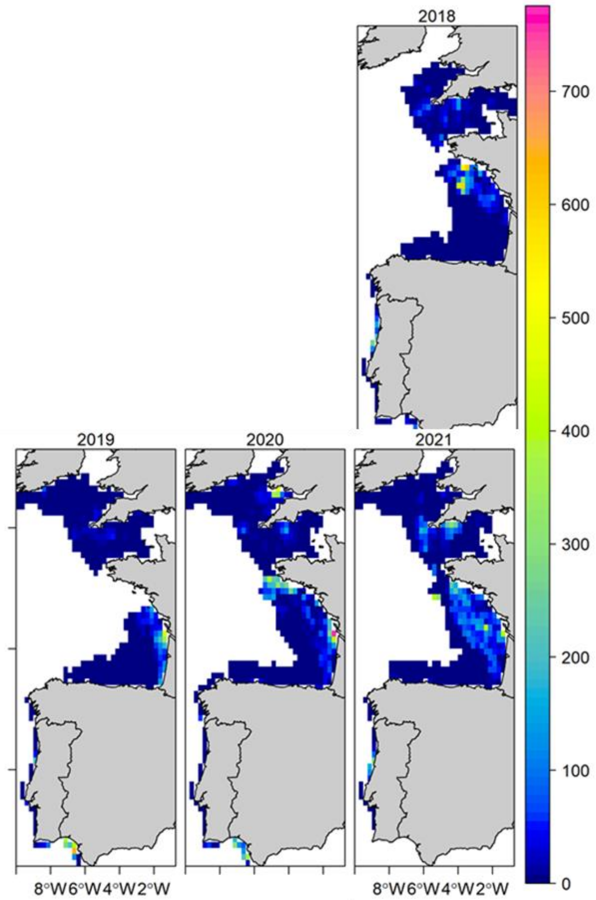

Figure 8. Adult anchovy mean acoustic density (NASC, $m^2.nm^{-2}$) maps derived from the CSHAS, PELTIC, JUVENA, IBERAS and ECOCADIZ-R surveys, 0.25° map cells. No data yet available for the last survey series when information for the current WD was compiled. Source: ICES WGACEGG.

2.1.2.1 IBERAS SURVEYS

Until 2017, an acoustic survey series carried out during autumn to estimate sardine and anchovy recruitment strength was limited to the north western Portuguese coast (JUVESAR survey series). From 2018 onwards, the surveyed area was extended to the whole Iberian western coast, including Sub-divisions 9aN, 9aCN and 9aCS (IBERAS survey series).

During the IBERAS survey series, anchovy was found to be particularly high in the 9aCN area during peak abundance years (2018 and 2021), accounting for >99.9% of total anchovy abundance and 70% in a low abundance year (2019), while showed low abundance during 2020 when most anchovy was found in the 9aN area (94%). For the remaining years, abundance in the 9a.N area was residual. In the 9a.CS subdivision, anchovy abundance was very low (<0.2% of western abundance) in 2018, 2020 and 2021 and was 29% in the low abundance year (2019) when it occurred in the northern part of the southwestern Iberian coast, near Lisbon (Fig. 9 and 10).

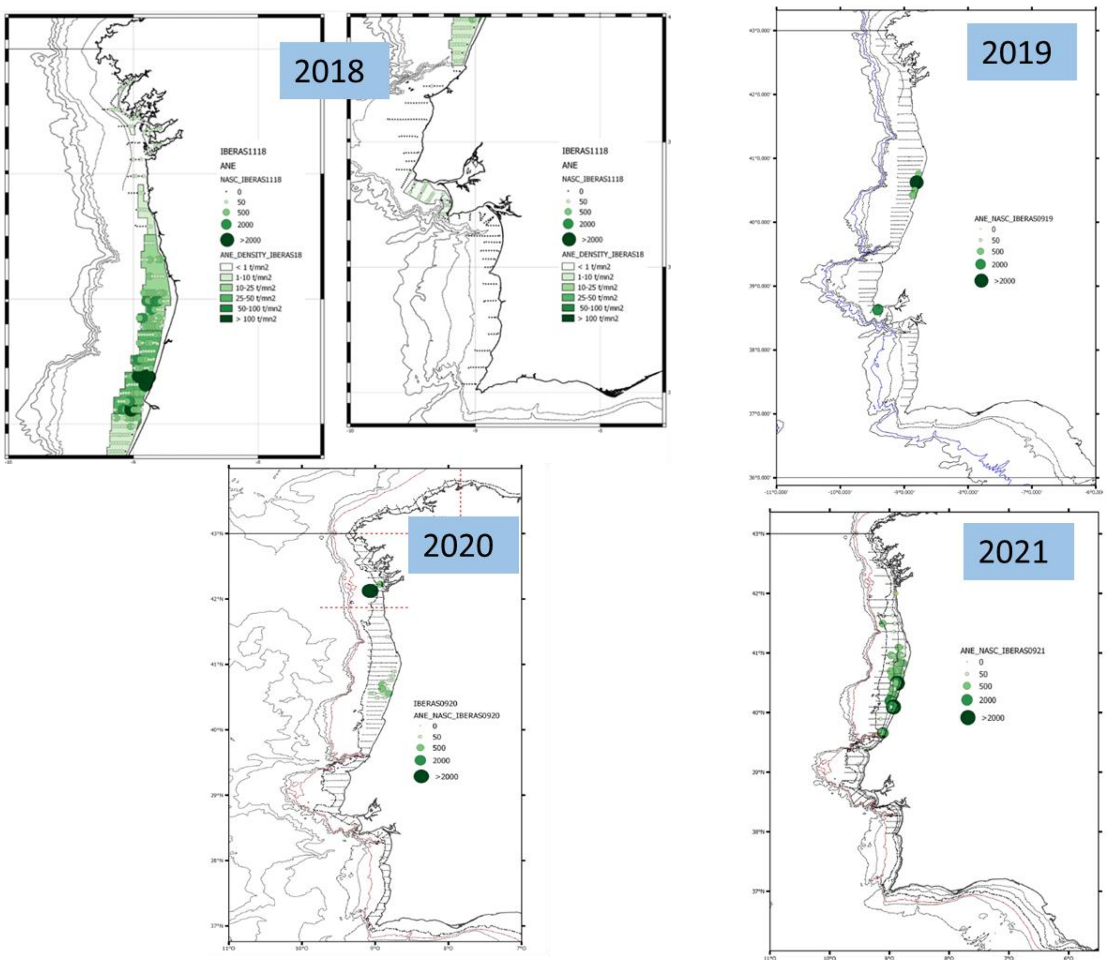

Figure 9 - Map of anchovy in the IBERAS survey series from 2018 to 2021 (allocated NASC at 38 kHz).

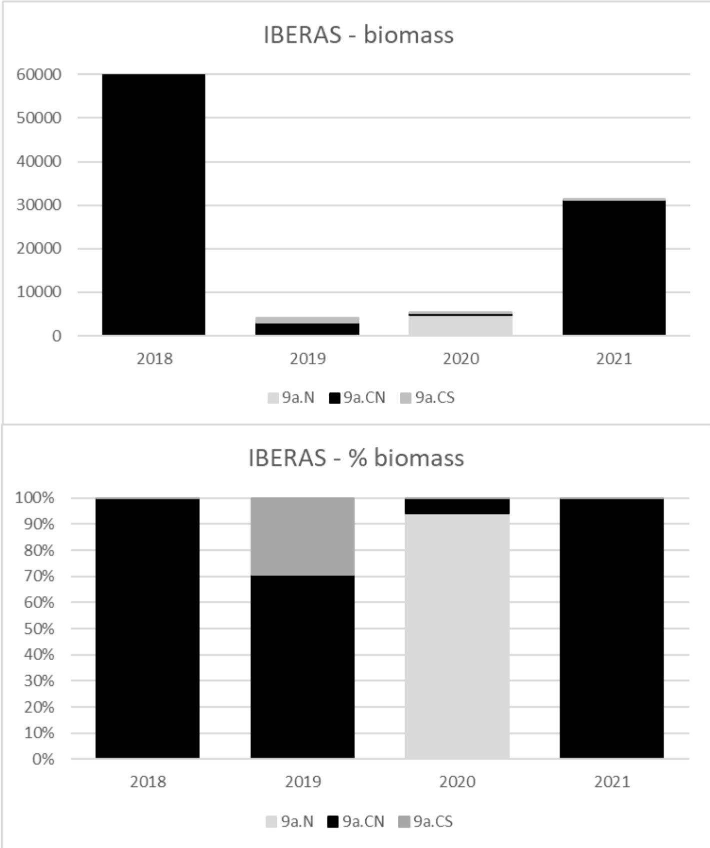

Figure 10 – Biomass of anchovy in the IBERAS survey series from 2018 to 2021, by sub-division (subdivisions 9.a North, 9.a Central-North and 9.a Central-South, total biomass in the upper panel and proportion in the lower panel).

2.1.3. TRAWL SURVEY SERIES – PORTUGUESE CONTINENTAL COAST

Data on the occurrence of anchovy in the time series of demersal trawl surveys since 1990 until 2017 was analysed to investigate the distribution of the species in seasons different from that analysed in the spring acoustic survey series. The surveys follow a fixed grid of 97 sampling stations, spread throughout the shelf between 36 and 710 m. The time series of data (1990–2017) collected by 43 surveys conducted in the fall (26 surveys), summer (10 surveys), spring and winter (5 and 1 survey, respectively). The fishing gear used is a bottom trawl (type Norwegian Campell Trawl 1800/96 NCT) with a 20 mm codend mesh size. The target duration of each tow was 60 min and further details on the methodology of the surveys can be found in Cardador et al. (1997).

Most of fish caught in the Portuguese demersal trawl surveys are distributed in the subdivision 9aCN, particularly near Aveiro - Figueira da Foz and in the southern coast (Algarve) (Fig. 11 and 12). The occurrence of anchovy in subdivision 9aCS is almost limited to the area around Lisbon, which has a similar trend to that found in the spring acoustic survey series. A persistent gap in distribution in southwestern Iberian waters is evident during all years, including the recent ones when anchovy abundance reached peak values (Fig. 12).

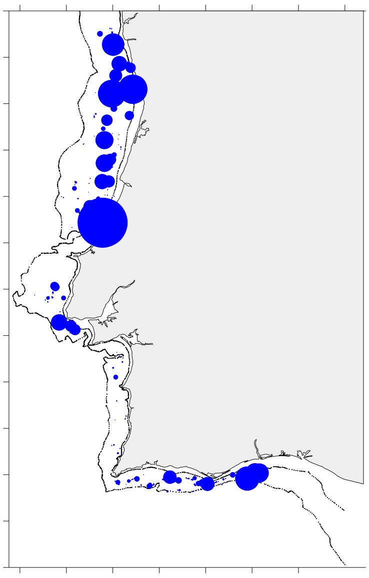

Figure 11. Distribution of the anchovy in demersal research trawl surveys conducted in the Portuguese continental margin since 1990 until 2017 during summer and autumn months. Symbol is proportional to the square root of the catch rate (number of fish caught per hour). Source: IPMA data.

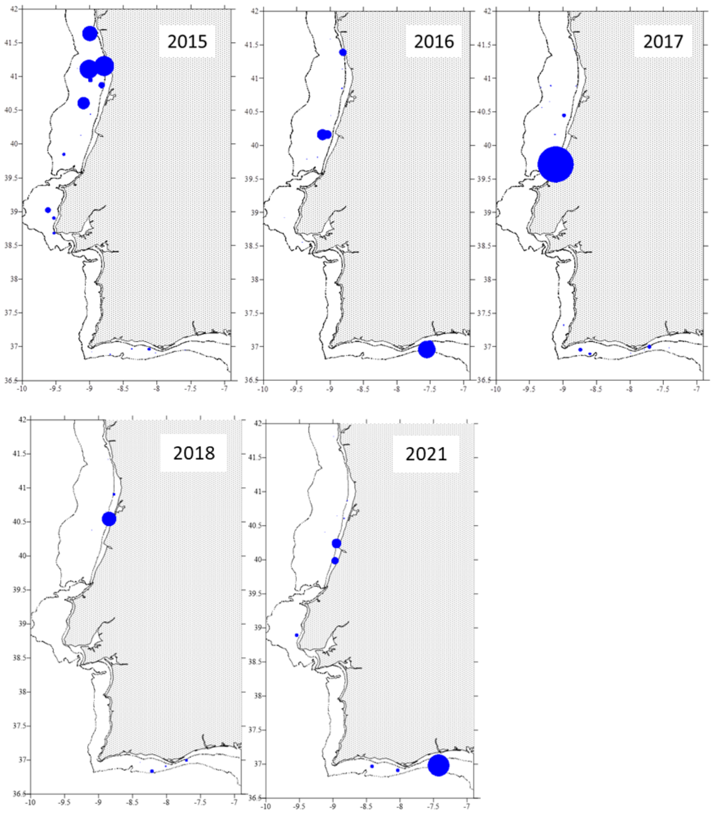

Figure 12. Distribution of the anchovy in demersal research trawl surveys conducted in the Portuguese west and south coasts in 2015 to 2021 autumn surveys. No survey was carried out in 2019 and 2020. Symbol is proportional to the square root of the catch rate (number of fish caught per hour). Source: IPMA data.

3. HISTORIC DYNAMICS OF STOCK BIOMASS SIZE INDICATORS

The distribution of anchovy biomass between the western and southern components of the 9a stock, as shown from the PELACUS and PELAGO spring acoustic survey series (Fig. 13) shows that, in the beginning of the time series (2007 to 2015), most anchovy biomass was recorded in the southern Iberia (>70%), with the exception of 2011 when anchovy increased in the west and comprised 34% of anchovy biomass in the 9a Division. Since 2016, the biomass in the western component has increased sharply and a similar biomass estimate was registered for the two components during 2016, 2017 and 2020 but significantly higher in the west in 2018 and 2021, the peak biomass years for the western component, representing > 70% of anchovy biomass in the 9a Division.

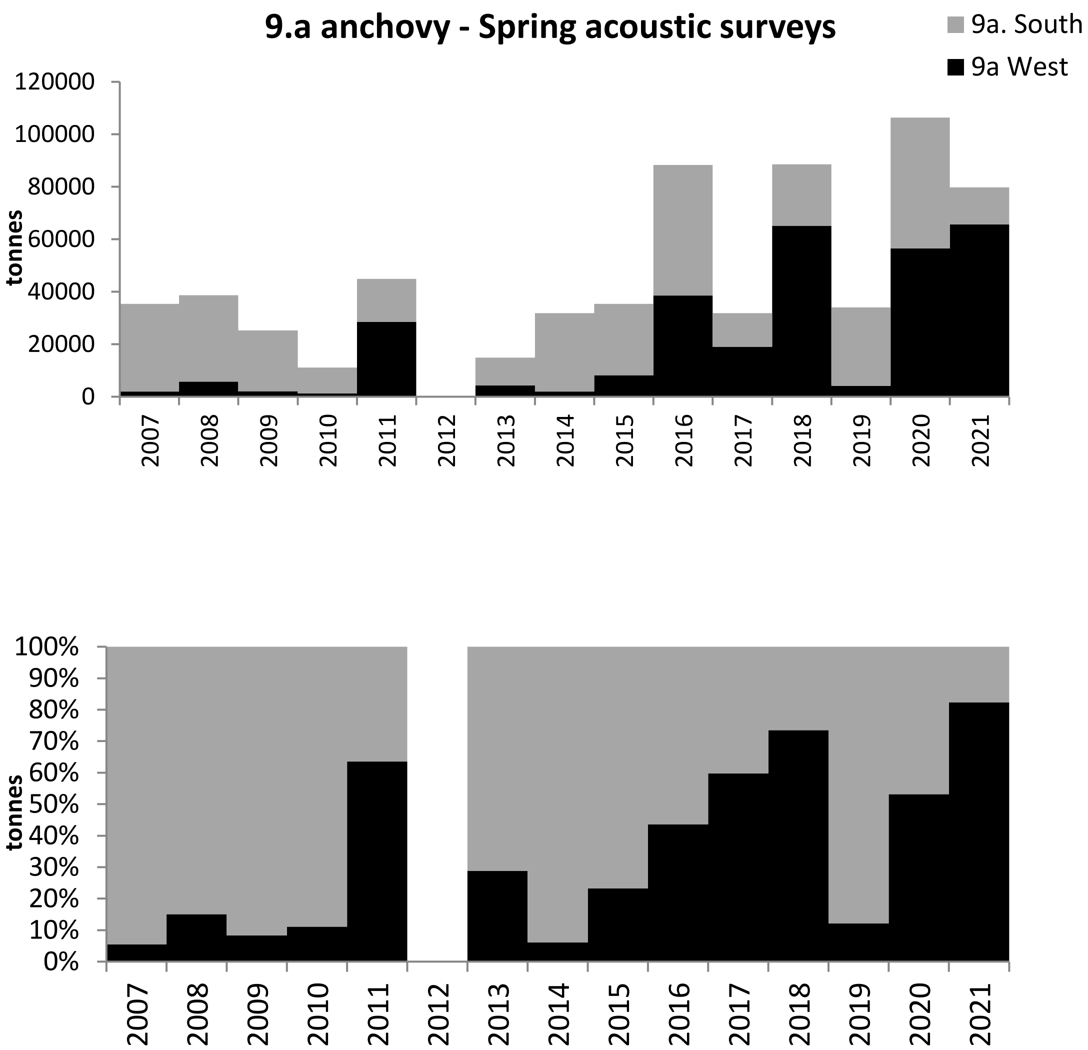

Figure 13. Distribution of anchovy biomass between the western and southern components of the 9a stock. Upper graphs represent total biomass (tons) and lower panel represents proportion between the two components.

Within the western Iberia, most anchovy is concentrated in the 9a-Central North, followed by the 9a. North while anchovy is absent or has residual abundance in the 9a Central South during most years. In the Southern Iberia, most anchovy is located in the 9a South Cadiz area, and anchovy in the 9a South Algarve has a residual abundance (Fig. 14).

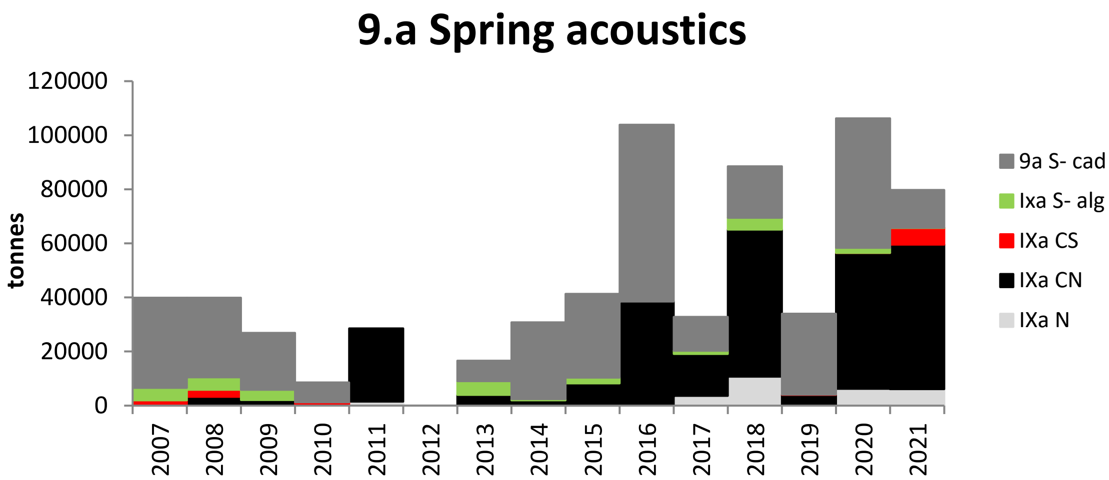

Figure 14. Biomass estimates for all the 9a sub-divisions estimated in the spring acoustic surveys PELACUS (Subdivision 9a N) and PELAGO (Subdivisions 9a CN, 9a CS 9a S alg, 9a S cad).

4. OTHER INDEPENDENT DATA OF ANCHOVY DISTRIBUTION: PORTUGUESE ESTUARIES

According to different works with seasonal sampling in the Portuguese estuaries were conducted during different years: small anchovy (<10 cm) is frequently detected in estuaries, namely in estuaries of rivers Lima, Douro, Mondego, Tejo, Sado, Mira, Arade and Guadiana (Figure 15) (França et al. 2011, Ramos et al. 2006, Pombo et al. 2002, Nyitrai et al. 2012, Marques et al. 2006, Ribeiro et al. 1996, Marques 2003, Cardoso et al. 2011, Chicharo et al. 2006, Chicharo et al. 2012), only 1 study did not detect the species, in River Minho estuary (Mota et al. 2014).

Figure 15 – Location of Portuguese estuaries.

Frequency of occurrence of anchovy during several years in the Aveiro estuary (several studies throughout the 1900' until 2000) showed a persistence of the species in the estuary (Nyitrai et al. 2012) as reproduced in Table 1.

Table 1 – Occurrence of several species including anchovy in the Portuguese estuary of Ria de Aveiro, summarized in Nyitrai et al. (2012).

TABLE II. Fish species, grouped by families, that have occurred in the Ria de Aveiro.

Family	Species	1912	1915	1981	1988	1997	1999	2000
Ammodytidae	*Ammodytes tobianus*	×	×	×	×		×	
Ammodytidae	*Gymnammodytes cicerelus*							
Ammodytidae	*Hyperophus lanceolatus*	×		×	×		×	
Anguillidae	*Anguilla anguilla*	×	×	×	×	×	×	×
Atherinidae	*Atherina boyeri*				×	×	×	×
Atherinidae	*Atherina presbyter*	×	×	×	×	×	×	×
Balistidae	*Balistes carolinensis*						×	
Belonidae	*Belone belone*	×	×	×	×	×		
Blennidae	*Lipophrys pholis*	×	×					
Blennidae	*Parablennius gattorugine*	×	×	×	×		×	×
Blennidae	*Parablennius sanguinolentus*	×			×		×	
Callionymidae	*Callionymus lyra*		×	×	×	×	×	×
Carangidae	*Trachurus trachurus*	×		×		×	×	×
Centrarchidae	*Micropterus salmoides*			×				
Clupeidae	*Alosa alosa*	×	×			×	×	×
Clupeidae	*Alosa fallax*	×	×	×	×	×	×	×
Clupeidae	*Sardina pilchardus*	×	×	×	×	×	×	×
Clupeidae	*Sprattus sprattus*	×	×	×				
Cobitidae	*Cobitis taenia*			×	×			
Congridae	*Conger conger*	×	×	×			×	
Cottidae	*Taurulus bubalis*	×			×			
Cyprinidae	*Barbus bocagei*		×	×				
Cyprinidae	*Carassius auratus*	×						
Cyprinidae	*Carassius carassius*	×	×	×	×	×		×
Cyprinidae	*Rutilus macrolepidotus*	×	×	×				
Engraulidae	*Engraulis encrasicholus*		×	×	×	×	×	×
Gadidae	*Ciliata mustela*	×	×	×	×		×	×
Gadidae	*Gaidropsarus mediterraneus*	×	×		×			

A comparative study of many of these estuaries revealed very high abundance in the Sado estuary from May to July 2006 (França et al. 2011).

5. HISTORIC DYNAMICS OF LANDINGS

Anchovy in Division 9a is mostly harvested by purse-seine fleets (generally 99% of total catches). For the period with complete data for the whole Division (from 1989 to present), landings have ranged from 1,984 t (1993) to 13,775 t (2018) (Fig. 15). Landings have been dominated by those done in the Gulf of Cadiz (Subdivision 9a South – Cadiz) for most time series, representing >80% of catches during most years. In contrast, in the western Iberia, anchovy was only harvested during years of high abundance. As of 2016, the majority of catches were taken in the western Iberia, of which >90% concentrated in the 9a Central North Subdivision (Fig. 16).

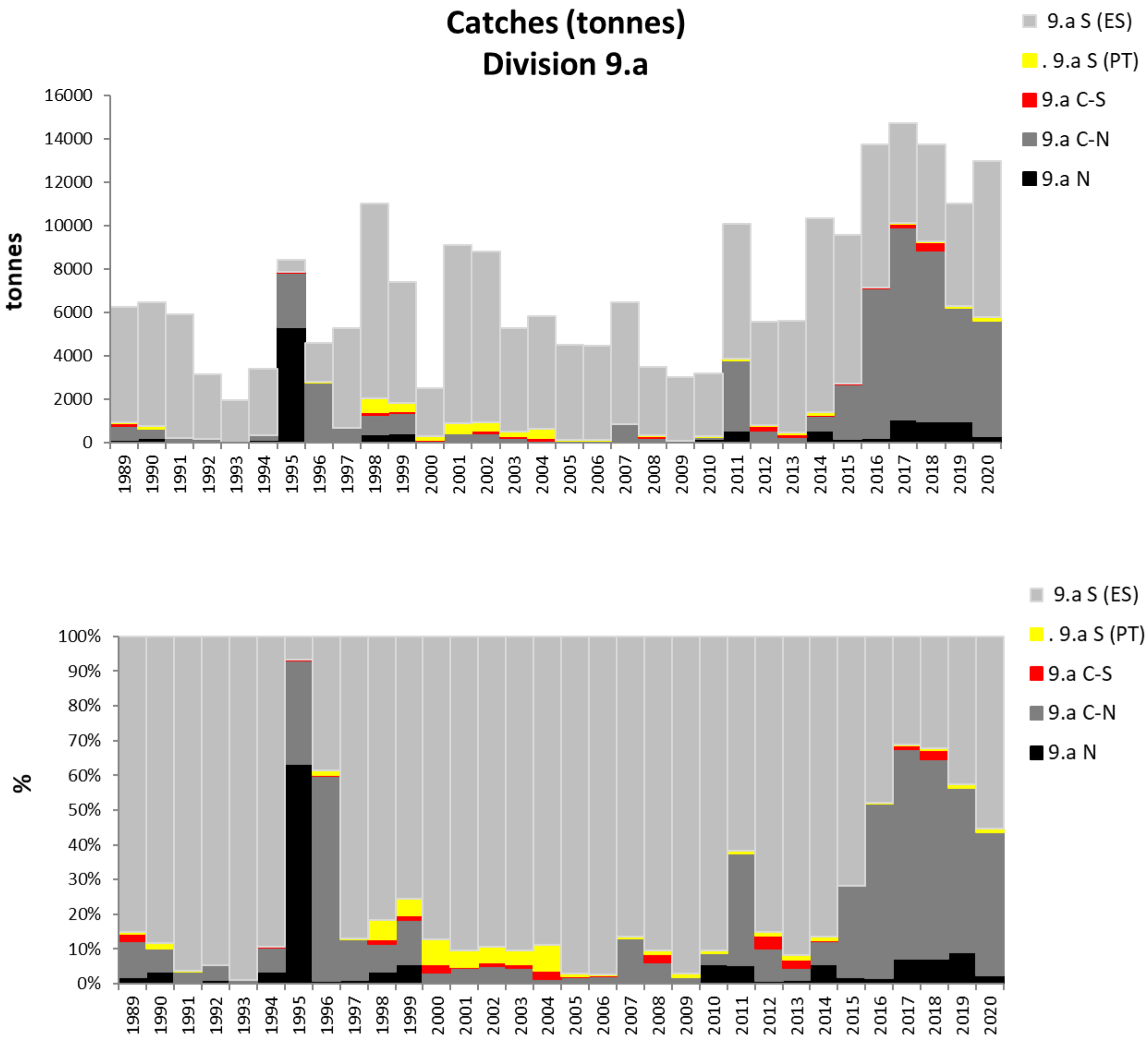

Figure 16. Time series of anchovy landings in Division 9a (1989-2020) in ICES Subdivisions 9a North, Central-North and Central-South (western component) and Subdivisions 9a South-Alg and 9a South-Cad (Southern Component).

The annual contribution observed in each fishing zone in the Portuguese landing of anchovy from 2003 to 2020 shows an increasing trend in northwestern and southwestern Iberia, which is not as clear in southern Portugal. In the first three years of the time series most catches occurred in the south while in recent years, the large majority of catches occurs in northwestern Portugal (Fig. 17 and 18).

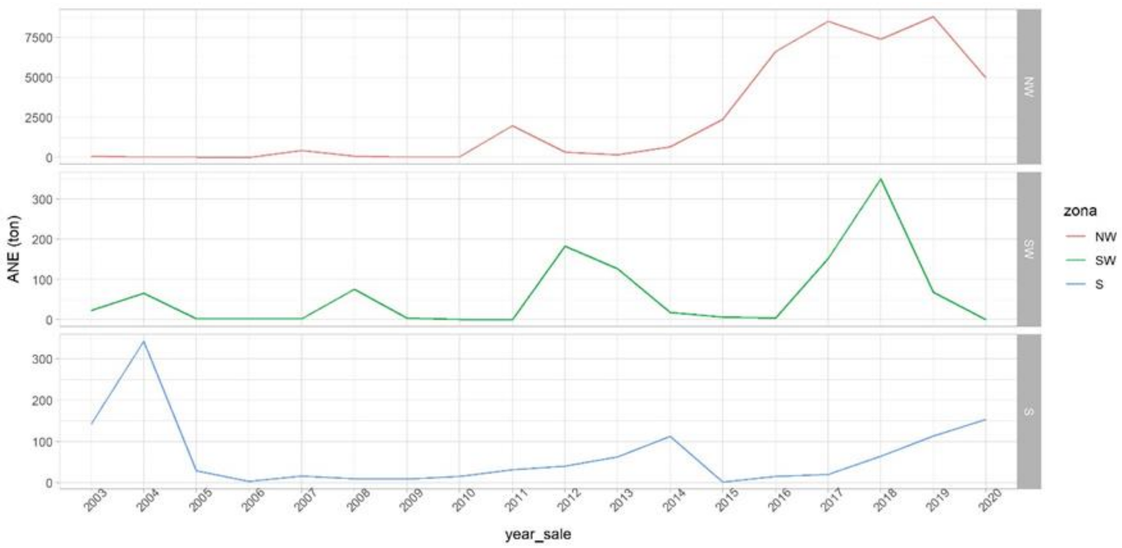

Figura 17 - Time series of anchovy landings carried out by the purse seine fleet in Portugal by zone (Northwest, Southwest and South Portugal) from 2003 to 2020.

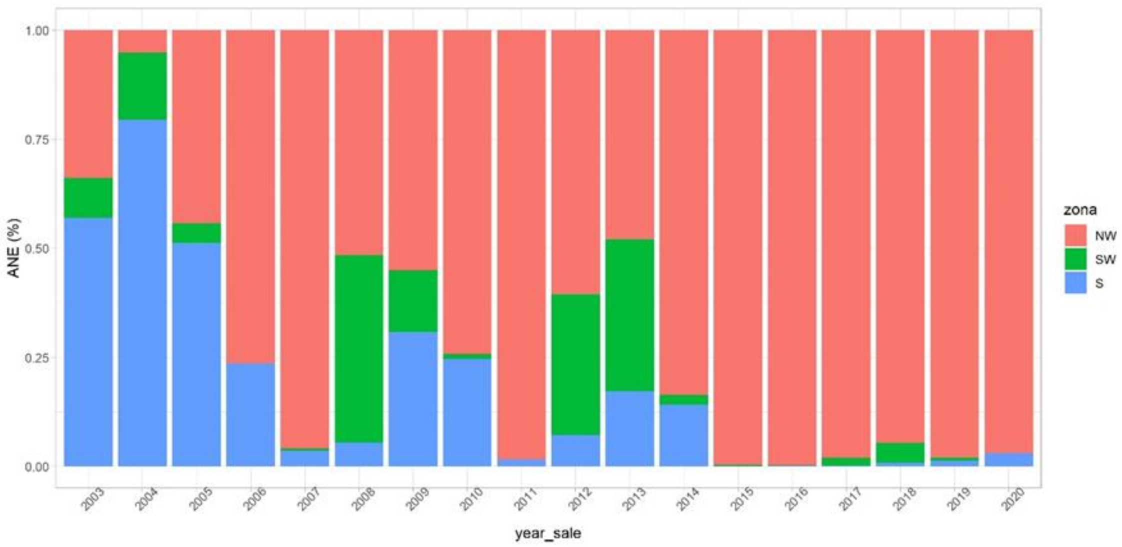

Figure 18 - Annual proportion of anchovy landings in Portuguese ports carried out by the purse seine fleet in each zone (Northwest - NW, Southwest - SW and South – S Portugal), in the period from 2003 to 2020.

The distribution of catches by main fishing ports in Portugal reveals that the great majority of catches concentrate in the northern part of the northwestern Iberia (north of 9aCN area), followed by the area around Lisbon (port of Sesimbra) with catches 1 order of magnitude lower, catches while those in southwestern south Iberia and significantly lower (Fig. 19).

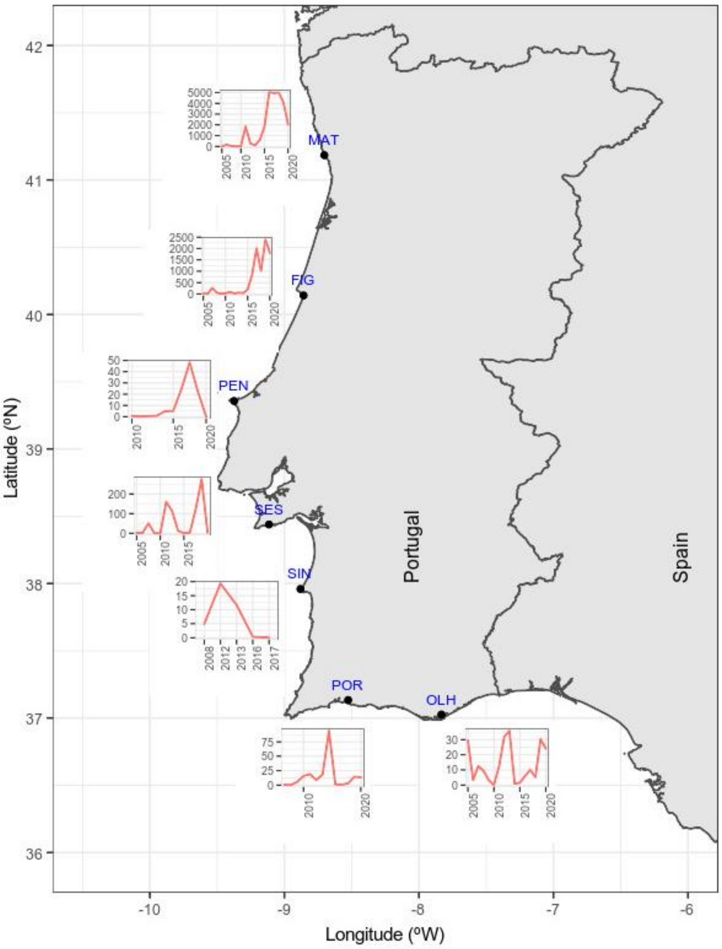

Figure 19 – Distribution of catches (tons) in the main fishing ports (Matosinhos - MAT, Figueira da Foz – FIG, Peniche – PEN, Sesimbra – SES, Sines – SIN, Portimão – POR, Olhão – OLH) of Portugal from 2005 to 2020.

Correlation analysis of the historical series of catches per Subdivision, previously analysed by Ramos et al. (2001) and Garrido et al. (2018), comparing the western and southern components of the stock were updated until present days. Annual landings per Subdivision (period 1989-2021) were analysed with the Spearman correlation test showing no significant correlation between the landings for the two components (Spearman correlation=0.33, p=0.06). An alternative correlation analysis was done to test whether the fluctuations of catches along the Division were the result of a potential northward migration (theoretically from Gulf of Cadiz to northern areas). In this second approach, correlations were estimated by comparing catches in the year y from the southern area (Algarve and Gulf of Cadiz) with the ones landed in the year y+1 in the western area (9a-N+9-CN+9-CS). No significant correlation (Spearman correlation=0.7, p=0.07) was found accounting for with this one-year lag, which would be consistent with a northward migration between areas. On the other hand, the correlation between landings and anchovy abundance in the western coast was found to be highly significant (Spearman correlation=0.71, p=0.008).

6. POPULATION DIFFERENCES IN ANCHOVY LIFE HISTORY TRAITS IN DIVISION 9A.

6.1 BIOLOGICAL DATA

Mean length and weight of anchovy in spring acoustic surveys was generally lower in the Gulf of Cadiz (Fig. 18) when compared to the other Subdivisions, followed by the 9aCN Subdivision, which may indicate the presence of two different recruitment areas for this species; whereas the mean length in the Algarve (9a-S Alg) and in Galician waters (9aN) were generally higher. Mean length data for the 9aCS Subdivision are only available for five years, when mean length was comparable to that of the 9a CN Subdivision. Similarly, anchovy weight at age was lower in the 9a S Cadiz Subdivision, while similar values were found in the other areas (Fig. 20).

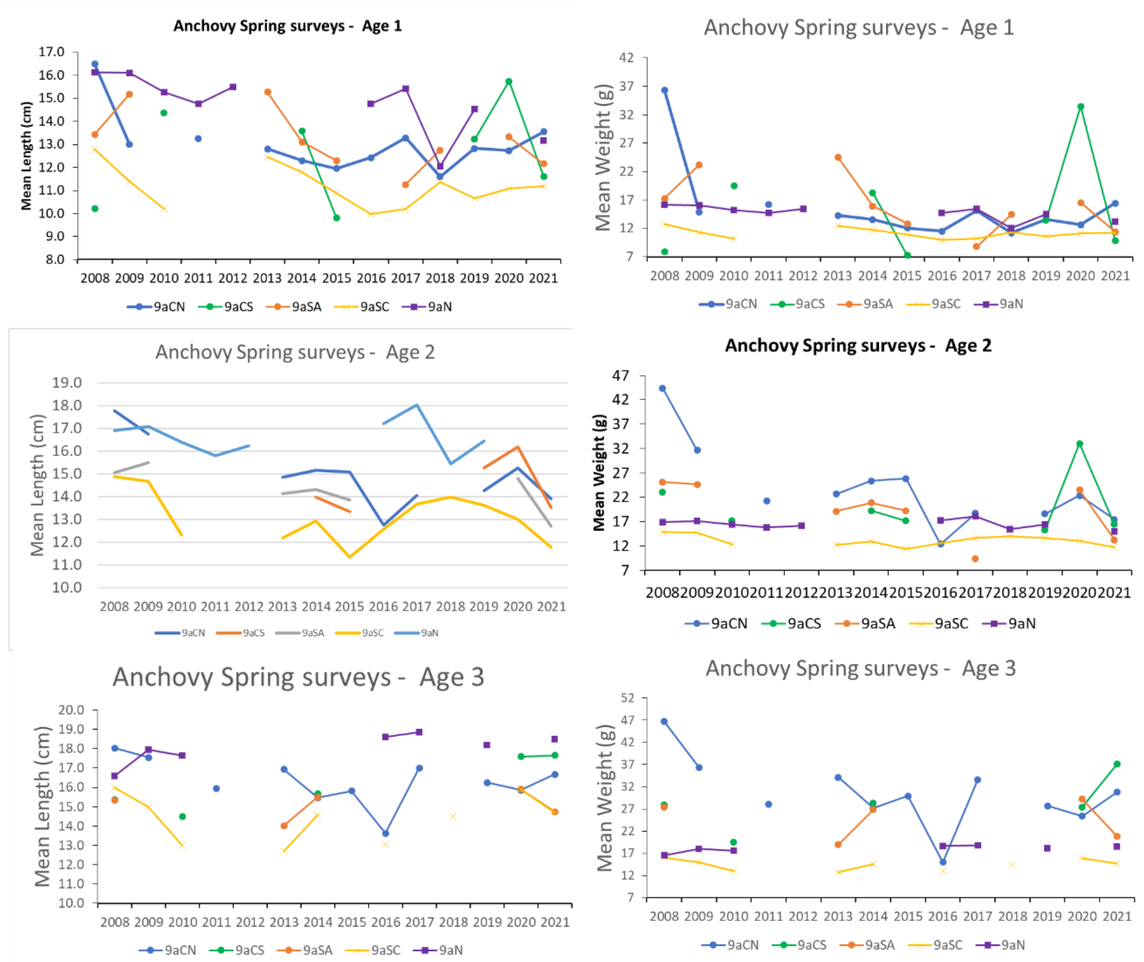

Figure 20. Anchovy mean length (left panels) and mean weight (right panels) estimated for fish captured during the spring acoustic surveys (PELACUS and PELAGO) for each area of ICES Division 9a.

Continuous information on mean length and mean weight at age in catches from the Portuguese fishery (9a.C.N) started to be available in 2017 whereas time series for areas 9a.N and 9a.S-Cadiz are longer. Comparing the period when there is information for Portuguese and Spanish fisheries, it can be seen that, similarly to spring acoustic surveys, mean length and weight at age in the catches are smaller in the 9a South Cadiz area while data from 9a North and Central North are similar (Fig. 19). Due to the residual catches, there is no length and age data for the 9a Central South and 9a South Algarve areas.

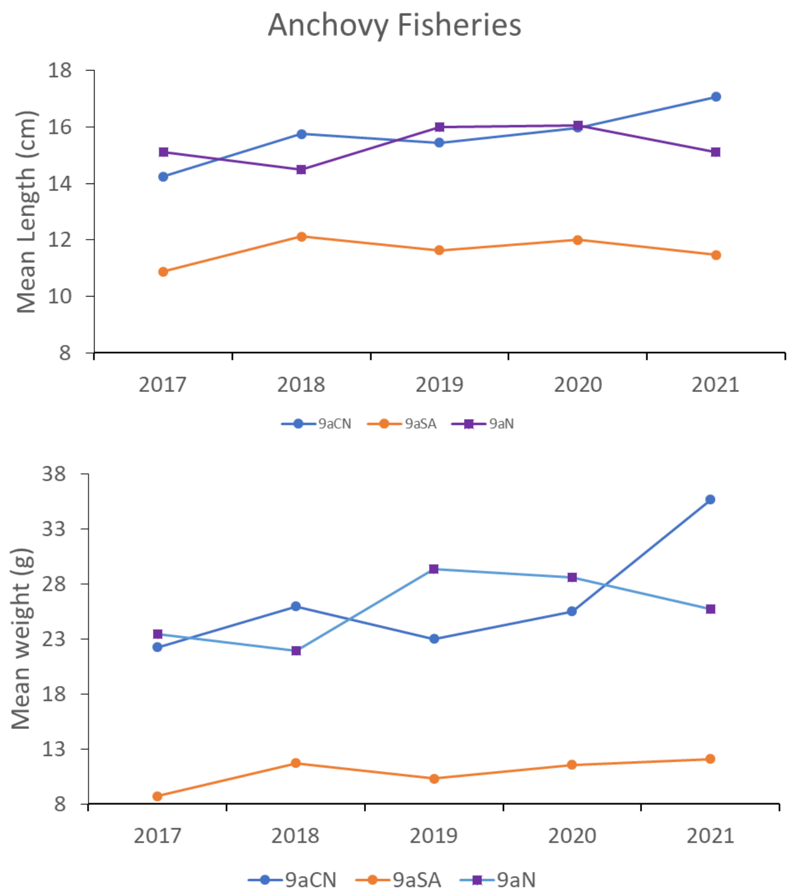

Figure 20. Anchovy mean length (upper panel) and weight (lower panel) in catches from the Spanish fishery in subdivisions 9a-N and 9a-S.

Potential connectivity of anchovy populations from the Western and South Iberia was investigated by cohort tracking. No significant correlation was found in the abundance of fish of the same age between the areas. Moreover, no correlation was found between age 1 individuals in the South component with age 2 individuals of the western component in the following year (Fig. 21).

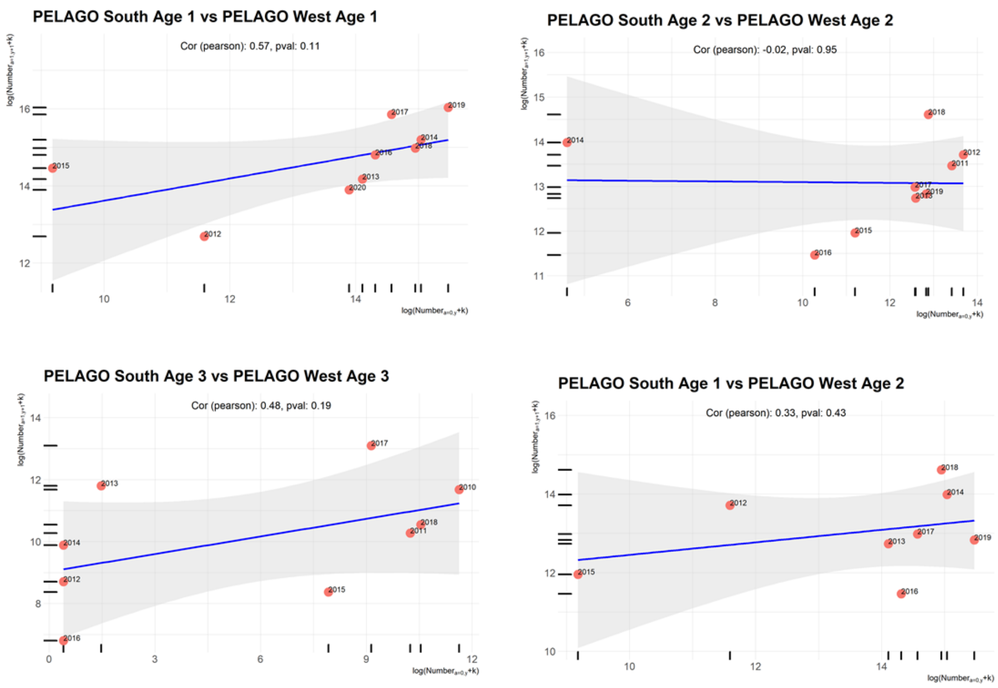

Figure 21. Relationship between the abundance of Age 1, 2 and 3 individuals estimated in the PELAGO survey series and in the West and South Iberian coasts, and with Age 1 in the south and Age 2 in the West Iberian coast. Units for both axes are Log the number of individuals + K, being K half the minimum N observed, method described in ICES, 2004; Payne et al., 2009).

The same type of analysis was carried out on the potential connectivity of anchovy populations in the western Iberia with those of the Bay of Biscay (Subarea 8, different stock). No significant correlation was found in the abundance of fish of the same age between the areas. Moreover, no correlation was found between age 1 individuals in the Bay of Biscay with age 2 individuals of the western Iberia in the following year (Fig. 22).

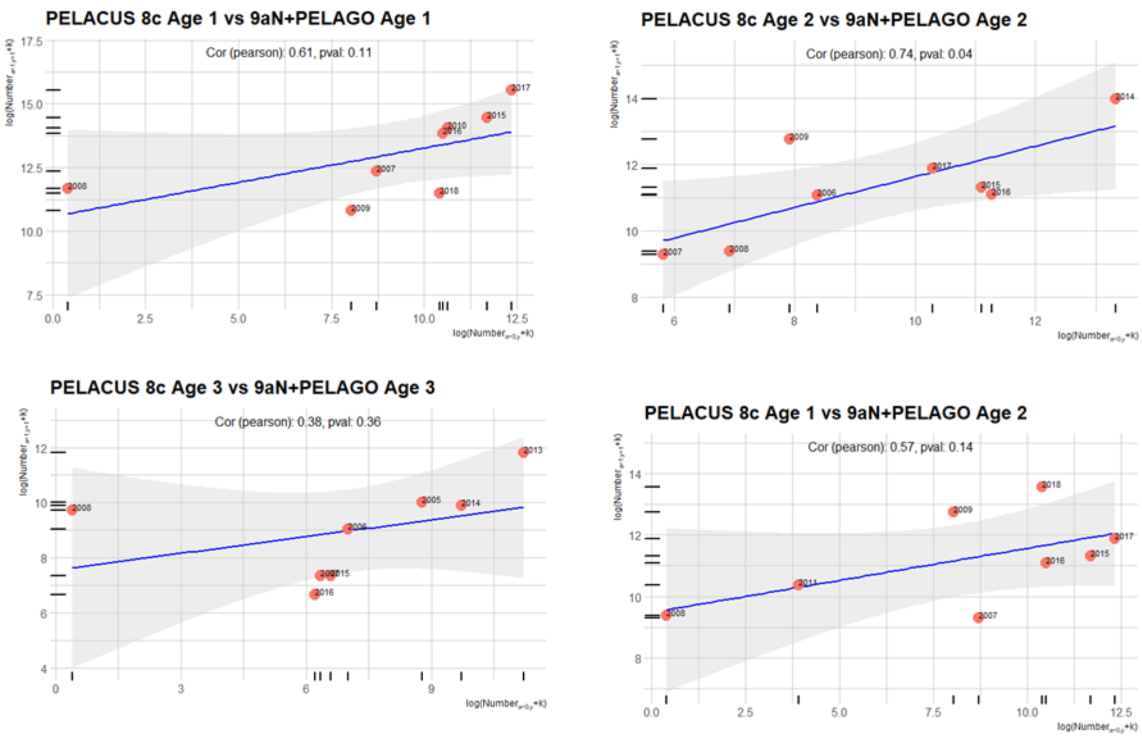

Figure 22. Relationship between the abundance of Age 1, 2 and 3 individuals estimated in the PELAGO+PELACUS survey series and in the Cantabrian Sea (sub-division 8c), and with Age 1 in the Cantabric and Age 2 in the West Iberian coast. Units for both axes are Log the number of individuals + K, being K half the minimum N observed, method described in ICES, 2004; Payne et al., 2009).

6.2 SYNOPSIS OF PUBLISHED WORKS ON POPULATION STRUCTURE

Several studies have been conducted on the population structure of the anchovy in Atlantic waters, namely using morphometrics, otolith shape analysis and genetic analysis.

MORPHOMETRICS

Morphometric differentiation between anchovy populations from north of Division 9a (Sub-division 9a North) and populations from the Bay of Biscay were obtained by Junquera and Pérez-Gándaras (1993), also suggesting the existence of an intermediate population in the Cantabrian area (west of the 8c). Subsequent studies of morphometrics and genetics have failed to sample fish in the western Cantabrian, which is probably related to the low abundance of the species in this area. Morphometric analysis conducted in fish collected during 2000 and 2001 from the Bay of Biscay to the Southern Iberia in the algarve (Caneco et al. 2004) point to a clear separation between anchovies from the Bay of Biscay (ICES Divisions 8b, 8c) and those from Division 9a, as well as a north-south cline along the Portuguese and Gulf of Cadiz area, with fish from the Gulf of Cadiz being mostly different from those in northern 9a area. The group of fish from the Algarve (E) was the one whose separation was less robust, given that the classification by cross-validation attributed most of its fish on western Portuguese coast groups than on itself. Results from this study indicate that fish from the Iberian area (i.e. Division 9a) have larger heads and smaller medium-posterior body dimensions than the ones from Bay of Biscay (Divisions 8b,c).

These differences were more pronounced in the Spanish waters of the Gulf of Cadiz (Subdivision 9a-South, Cadiz). Anchovies from the Spanish waters of the Gulf of Cadiz had the greater head-to-body ratios, having shown the greater divergence from the Biscay populations. The Iberian samples had also greater dorsal fin base lengths.

OTOLITH SHAPE ANALYSES

Bacha (2014) showed that the Alborán Sea anchovy population is distinct from the Northeast Atlantic populations, including neighbouring populations (e.g. Gulf of Cadiz) using otolith shape analyses. Anchovies were analysed from seven locations in the SW Mediterranean Sea and Atlantic Ocean along the northwestern African (Morocco) and Portuguese (Bay of Cadiz) coasts (Bacha et al. 2014). According to this study, three distinct anchovy stocks were identified: the Algero-Provençal Basin, the southern Alborán Sea, and the Atlantic Ocean (Morocco and Gulf of Cadiz). Shape variability of anchovy otoliths was associated with the presence of the Almeria-Oran front (AOF), and the strait of Gibraltar. The Southern Alborán stock was distinct from the Algero-Provençal Basin and from the closest Atlantic stocks (Gulf of Cadiz or Atlantic coast of Morocco).

GENETIC ANALYSIS

The European anchovy exhibits a complex evolutionary history that has produced conflicting results regarding its population structure within the Atlantic Ocean (Table 2). The presence of two ecotypes (hereinafter, oceanic, and coastal) that differ both genetically and morphologically was first documented in the Mediterranean Sea (Borsa, 2004). Additional analyses based on comprehensive datasets in terms of genetic markers and number of samples have confirmed presence of these two ecotypes also in the Atlantic Ocean (LeMoan et al. 2016, Montes et al. 2016). Interestingly, there is more differentiation between ecotypes (oceanic/coastal) than between Atlantic Ocean and Mediterranean Sea locations within the same ecotype (LeMoan et al. 2016; Catanese et al. 2017). Besides, both ecotypes hybridize, although it is not known in which proportions (LeMoan et al. 2016; Montes et al 2016). Additionally, analyses based on mitochondrial DNA have found presence of two lineages with different proportions in each area and which are not related to the oceanic and coastal ecotypes (Magoulas et al. 2006; Borrell et al. 2012, Viñas et al. 2013, Silva et al. 2014a, Silva et al. 2014b). Adding a further layer of complexity, Zarraonaindia et al. (2012) suggested the presence of other two ecotypes (unrelated to the coastal/oceanic ones) associated with narrow or wide oceanic platforms respectively. This complex evolutionary history makes inferences of population connectivity among locations difficult without further studies considering presence of ecotypes and mitochondrial lineages. From the studies available thus far, there seems to be population differentiation between the North Sea+English Channel populations and the Bay of Biscay (Petitgas et al. 2012; Montes et al. 2016, Huret et al. 2020), although some studies suggest otherwise (Zarraonaindia et al. 2012, Silva et al 2014a). Concerning the connection between West Galicia and North of Portugal with the Gulf of Cadiz anchovies, two studies suggest differentiation (Silva et al. 2014a, Zarraonaindia et al. 2012), but results might be biased by the small number of markers used and/or by the different proportions of each ecotype in the samples used.

Thus, population structure studies aiming at understanding European anchovy connectivity should consider the presence of the two ecotypes and consider the different scenarios causing the presence of non-ecotype related mitochondrial lineages. Additionally, it is important to understand the proportion of each ecotype in the scientific surveys used for assessment and in the commercial catches in order to evaluate if assessing population structure within one ecotype (*e.g.* oceanic) would suffice to support assessment. Yet, the fact that both ecotypes hybridize should be considered, as hybrids seem to be less fit or suffer from strong negative selection pressures, which could indicate that they contribute less to spawning stock biomass estimations.

Table 2: Summary of the genetic studies trying to decipher the population structure of European anchovy who include the area of interest for this WD.

Reference	Number of individuals	Locations	Number and type of markers	Results	Sampling
Magulas et al. (2006). MPE 39: 734–746	24	Bay of Biscay, Portuguese coast; Gulf of Cádiz; Canary Islands; Senegal; Alboran Sea; other regions in Med	mitochondrial RFLP	Two co-occurring mitochondrial genetic lineages; BoB about 40-60%; rest of the Atlantic locations, one more dominant	Fishing vessels and fish markets
Zarraonaindia *et al.* (2012). PLOS ONE 7(7): e42201	626	North Sea, English Channel, Bay of Biscay, Coast of Portugal, Gulf of Cádiz, Canary Islands, South Africa, Alboran Sea, other regions in the Med	47 nuclear and mitochondrial SNPs (not clear how they were selected)	Patterns compatible with two ecotypes: one group included samples from the North Sea and English Channel, the Bay of Biscay and the Mediterranean (excluding Alboran Sea); the other group included samples from eastern Atlantic locations from Galicia to south Africa (and Alboran Sea)	Acoustic surveys (BIOMAN, PELGAS, ECOCADIZ, ECOMED, PELACUS)
Petitgas et al (2012). MEPS 444: 1–13	797	Bay of Biscay, English Channel, North Sea	49 nuclear SNPs (extracted from Zarraonaindia et al. 2012)	Differentiation between North Sea/English Channel and Bay of Biscay; conflicting interpretations with respect to Zarraonandia et al. 2012, despite using common samples and same SNPs.	not specified
Borrell et al (2012). IJMS 69: 1357–1371	141	Bay of Biscay, Med	mitochondrial cytb & 16S/14 microsats	Two co-occurring genetic groups; BoB about 50-50% in the French coast and one coastal location in the Cantabrian sea; 75-25% in offshore Cantabrian sea and and 25-75% in Getarian coast	not specified
Viñas et al. (2013). 71: 391–397	563	Bay of Biscay, Cadiz, Med, Canarias	mitochondrial Control Region	Two genetic groups; Bay of Biscay about 50-50%, Cadiz, one more dominant	Mediterranean, fishing vessels; BoB (THALES, AZTI)
Silva et al. (2014). J. Biogeogr. 41: 1171-1182.	312/462	Eastern Atlantic: Norway to Ghana	mitochondrial cytb/9 microsats	2 co-occurring mitochondrial lineages whose frequency vary along the distribution area; 4 nuclear genetic clusters (ecotypes not considered): Norway+English Channel+Bay of Biscay/Portugal north+Malaga/Gulf Cadiz +Canaries+GuineaBissau+Ghana/Tangier+Senegal.	fish markets and scientific surveys (IMR, IFREMER, AZTI, CCMAR, IEO, WRI)

Silva et al. (2014). Proc. R. Soc. B. 2812014109320141093	2776 (455 new)	North Sea, Baltic sea, English Channel, Bay of Biscay, Coast of Portugal, Gulf of Cadiz, Canary Islands, eastern Atlantic African coast to South Africa, Mediterranean Sea	mitochondrial cytb	Two co-occurring genetic groups, one is present all over the distribution area, whereas the other one is absent from the tropics; Temperature and dissolved oxygen are significantly correlated with the latest (particularly from the BoB to the North Sea).	fish markets and scientific surveys (IMR, IFREMER, AZTI, CCMAR, IEO, WRI)
Le Moan *et al.* (2016). Mol. Ecol. 25: 3187–3202	128	Coastal and marine locations from Atlantic and Mediterranean French coast (Bay of Biscay for the Atlantic, Bay of Leon for the Med)	5,638 SNPs (RADseq)	2 ecotype which hybridize. Higher differentiation between ecotypes than between Mediterranean and Atlantic. Lower differentiation between offshore ecotypes than between coastal ecotypes. Gene flow between ecotypes; limited enough to maintain high differentiation between the ecotypes.	ad-hoc for study
Montes *et al.* (2016). Mar. Biol. 163:205	851	Whole distribution: North Sea, Bay of Biscay, NW and S Iberian Peninsula, Mediterranean Sea and Canary Islands	456 SNPs (exons, might not have power to detect fine population structure)	Presence of two ecotypes in the Bay of Biscay. The Bay of Biscay offshore population is closely related to Mediterranean populations and secondarily to northern populations in the Irish, Norwegian and Baltic seas	Scientific Surveys (PELGAS, EVHOE, CAMANOC, CGFS, French IBTS, NOURDEM)
Catanese et al (2017). Sci. Rep. 7: 4180	1008	Bay of Biscay, Cadiz, Med, Canarias	96 SNPs (Catanese et al. 2016; most differentiating pops within Med and btw Atlantic and Med. Sea)	Confirm the presence of two ecotypes. Partial overlap in habitat use for ecotypes in the Med. Most outlier SNPs identified for the Med are shared with the Atlantic. Confirm higher difference between ecotypes than between Med vs Atlantic.	ad-hoc for study
Huret *et al*. (2020). Fish Res. 229: 105619	602	Atlantic French coast, English Channel North Sea and Irish Sea (In total 25 sampling locations, 4 in estuaries)	308 SNPs from Montes et al 2016 select as a trade-off between number of samples and number of SNPs	Two ecotypes. Within the oceanic ecotype, genetic differentiation between the subareas 8abd stock and further north locations, with populations boundary located west of Brittany. Anchovy from the English Channel cluster together with samples form the North Sea, both showing high differentiation from the Bay of Biscay for both ecotypes.	Scientific Surveys Professional vessels for Irish Sea. Samples from Montes et al. 2016.

7. IMPLICATIONS FOR MANAGEMENT

Currently, advice for the west and south components of the 9a stock is given separately, but a single TAC is set for the 9a Division, resulting from the sum of the advices for each component. Given the independent dynamics of the two components, in the short time series when the stock is being assessed (2018-2022), it is frequently observed opposite trends of biomass for the two components in several years, resulting in very different advices (Table 3). The fact that fishing opportunities are set for the whole 9a Division can result in overfishing the component with limited fishing opportunities.

Table 3 - Anchovy in Division 9.a. ICES advice, the agreed TAC, and ICES catches. All weights are in tonnes. Catches from 1 July to 30 June in the following year to match the advised period.

Management year	Catches corresponding to advice		Agreed TAC	ICES catches	
	West component	South component		West component	South component
Jul 2018 – Jun 2019	13308	3760	17068	10093	3815
Jul 2019 – Jun2020	2662	6290	10240	2624	6472
Jul 2020 – Jun 2021	4347	11322	15669	5461	7904
Jul 2021 – Jun 2022	7824	7181	15005	11217*	5839*
Jul 2022 – Jun 2023	14083**	1694**			

* Catch estimates of the first two quarters of 2022 are provisional.
** Preliminary data resulting from WGHANSA May 2022.

8. CONCLUSIONS

Data of the spatial distribution of anchovy in division 9a shows a discontinuity of the western and south components of the stock (around 9aCS), in several life stages (eggs, juveniles and adults) and seasons of the year based on research cruises covering the whole 9a subdivision (spring, fall) or the entire Portuguese waters (summer).

No correlation was found between anchovy catches between the two stock components, suggesting independent dynamics. The hypothesis that the western stock might come from migration from the southern component was not supported by the current data, since there was no correlation between anchovy landings or abundance in the western Iberia with anchovy landings or abundance in the southern Iberia in the following year. On the contrary, anchovy landings in the western coast were significantly related to the abundance of the species in that area, demonstrating the independent dynamics of anchovy fishery from the two components.

The spatial discontinuity and the independent dynamics between the western and southern anchovy populations are likely related to the presence of a self-sustained anchovy population in the western Iberia, independent of the southern component.

Morphometric and genetic studies are not conclusive as they might be confounded by the presence of the coastal and marine ecotypes, often not considered in these studies. Thus, although some genetic and morphometric evidences for the separation of the Gulf of Cadiz anchovy population from that in the western Iberia (although results from the Algarve are generally absent) exists, this need to be confirmed with additional studies considering the complex evolutionary history of this species.

Despite the complex genetic evolutionary history of the species that deserves future dedicated studies, there are a large number of evidences presented in this working document, that leads WGHANSA to supports the separation of the western and southern components of the anchovy 27.9a into two stock units; the population in Subdivision 9a South and the populations from Subdivisions in the western coast (9a North, Central-North and Central-South), and therefore submits this WD to the ICES Stock Identification Methods Working Group (SIMWG) for consideration.

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Life history parameters of Anchovy 9a - western component

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Last compiled on 06 June, 2022

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1 Background

The anchovy stock in the ICES division 27.9a is managed as a single stock but two different components are considered: -Southern component comprises the southern Portuguese coast and the Gulf of Cadiz. -Western component distributed from Cape Finisterra to Cape S. Vincente, along the west coast of Spain and Portugal; Fishing opportunities for both components are advised following category 3 data limited short-lived stocks of ICES - 1-over-2 rule constrained by a cap of +/- 80%. However, it's acknowledged that the current 1-over-2 rule cannot accommodate the huge fluctuations in biomass of the western component of this anchovy stock. Moreover, the 1-over-2 rule does not guarantee an MSY exploitation, therefore ICES recommends to use it as a provisional harvest control rule until it can be replaced by a better approach, such as a constant harvest rate derived from a management strategy evaluation or F_{MSY} obtained from a surplus production model. In this sense, a dedicated working group was assembled to compile new data to revise the anchovy stock structure and evaluate alternative assessment and harvest rule approaches.

This working document presents the work developed so far to build a Management Strategy Evaluation simulation framework (MSE) to evaluate the performance of an alternative harvest control rule for the western component of the stock. The simulations will be carried out using the FLBEIA software and the operating model will be based on life-history parameters. Specifically, this working document presents a biology model that tries to capture the dynamics of the population (maturity information will be presented in a separate WD).

2 Growth model

Using data from both the Autumn (JUVESAR and IBERAS) and Spring (PELACUS and PELAGO) acoustic surveys that cover the area of the western component of the Iberian anchovy stock, a von Bertalanffy growth function expressed as $L_t = L_{inf} * (1 - exp(-K * (age - t_0)))$ was estimated. Two different approaches were explored, length frequency analysis (ELEFAN method with new optimisation techniques by Taylor & Mildenberger (2017)) and length-at-age analysis. Only the later is presented in this working document because it had the best fit.

Figure 1 shows the length density distribution of the anchovy population in the Spring (joint index from PELACUS 9aN area and PELAGO 9aCN and 9aCS areas) and the Autumn (first JUVESAR then IBERAS) acoustic surveys since 2008. The smaller and younger anchovies are usually observed in the Autumn acoustic surveys (Figure 2).

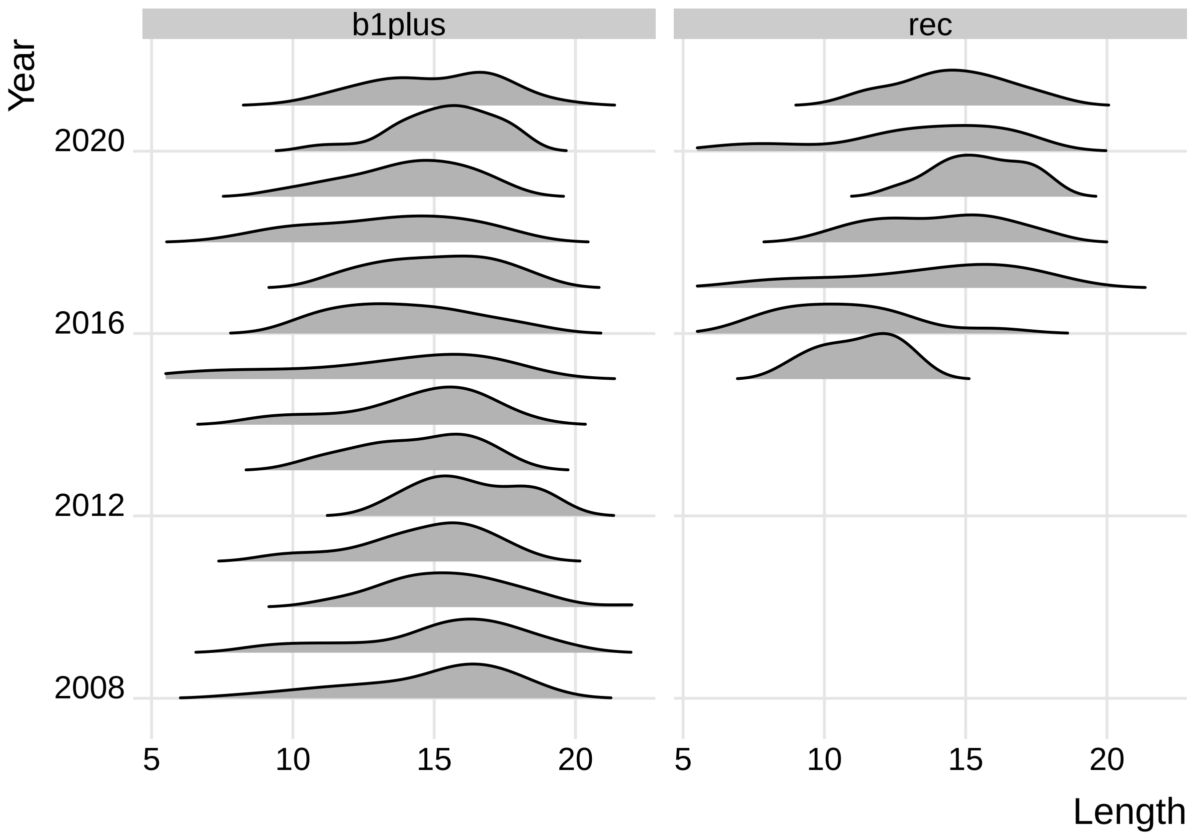

Figure 1: Length density distribution of the western component of the 9a anchovy population in the Spring (left) and the Autumn (right) acoustic surveys.

2.1 Observed mean length at age

Mean length at age within areas is stable along years (Figure 3). Differences observed between mean length at age in PELAGO and JUVESAR/IBERAS are probably due to the timing of the survey. In the recruitment surveys mean length at age increases from north to south (9aN -> 9aCN -> 9aCS). However, in the spring surveys mean length at age are higher in 9aN (Figure 4).

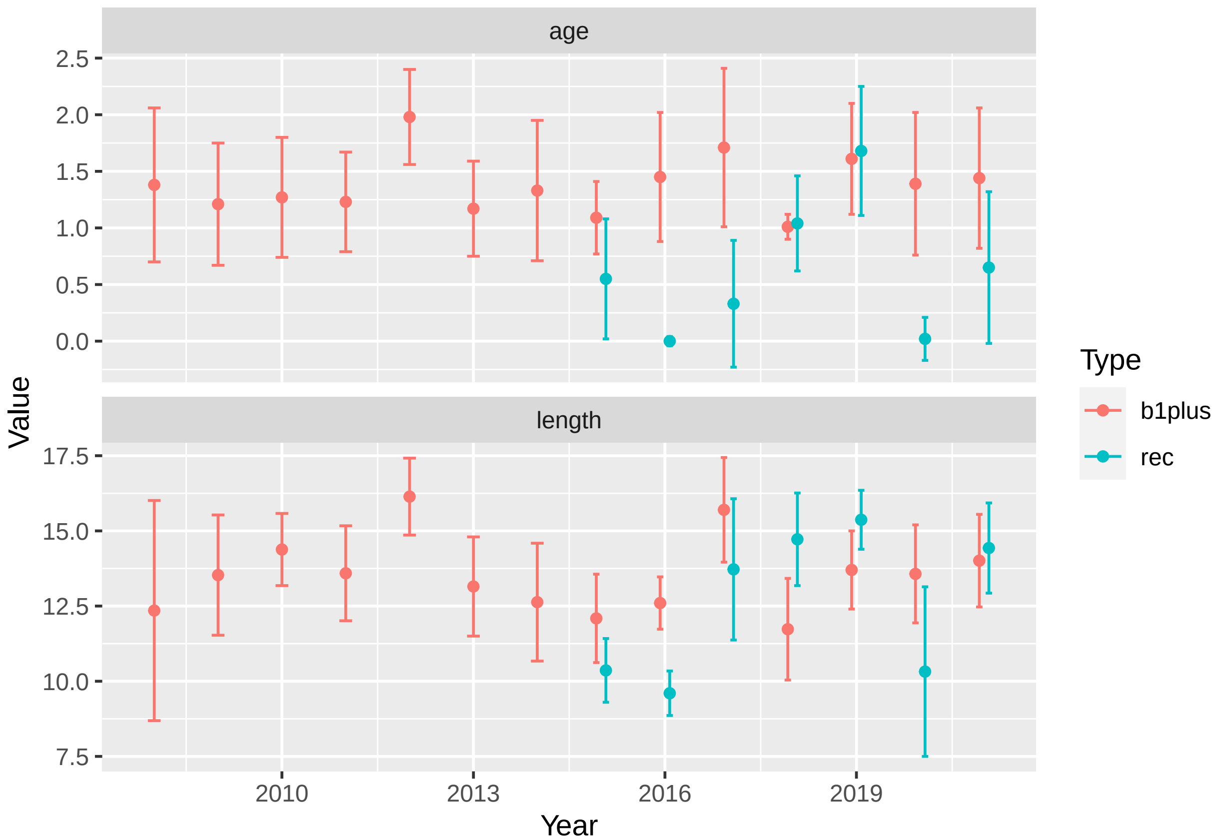

Figure 2: Mean age (top panel) and length (bottom panel) of the western component of the 9a anchovy observed in the Spring (red) and Autumn (blue) acoustic surveys. Error bars represent mean values plus/minus the standard deviation.

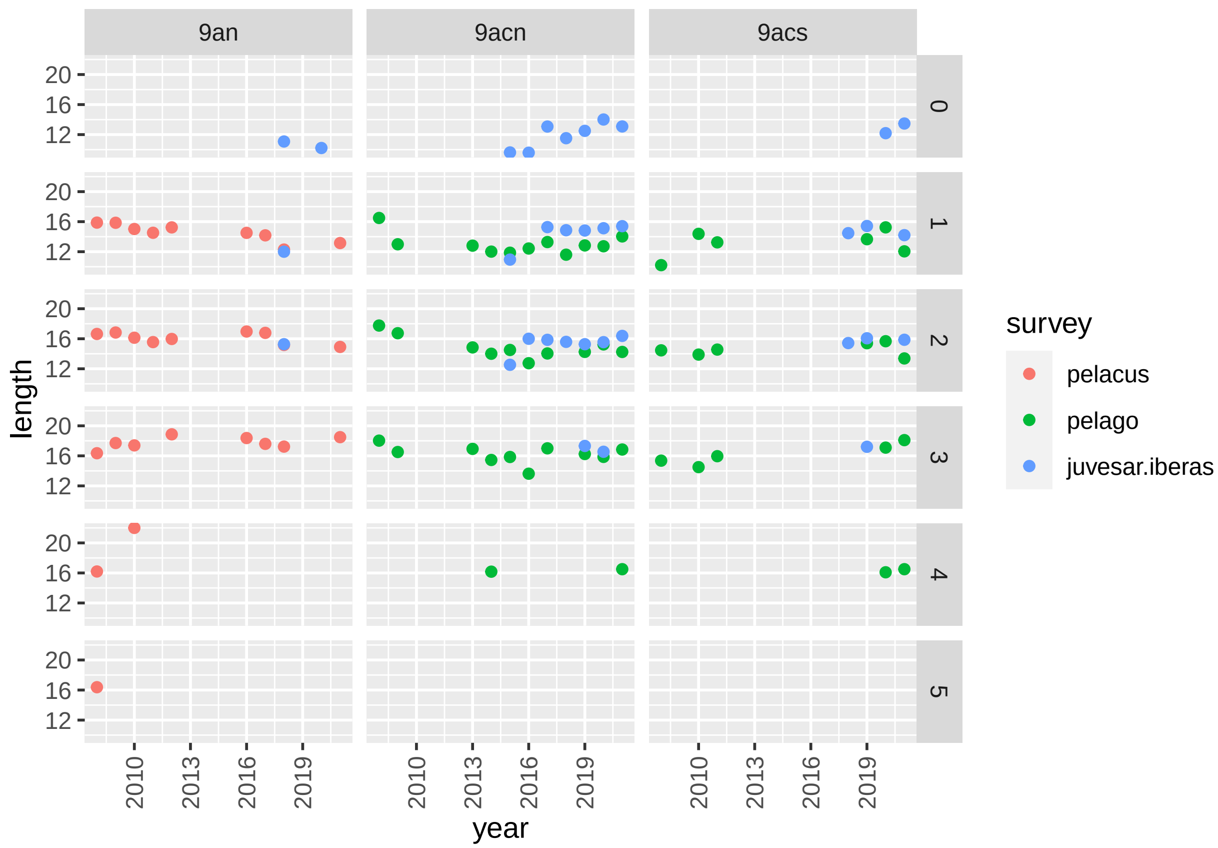

Figure 3: Mean length at age of the western component of the 9a anchovy by survey (color) and area (columns).

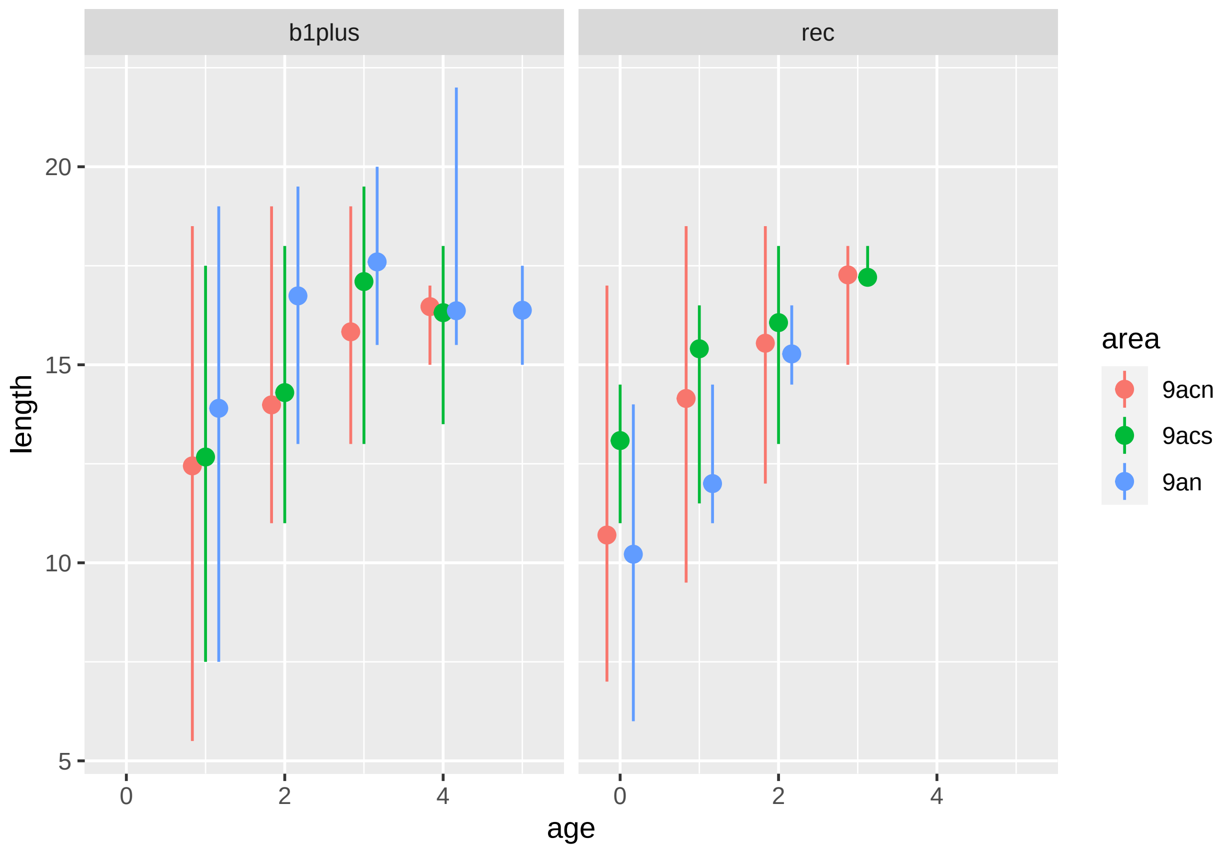

Figure 4: Mean length at age of the western component of the 9a anchovy in the Spring (left) and Autumn (right) surveys by area (colors). Error bars represent mean values plus/minus the standard deviation.

2.2 Cohort tracking

Annual autumn acoustic surveys were conducted in different times of the year (Nov/Dec/Sep) and there is a potential spatial mismatch between juvenile anchovy distribution - known to expand beyond the shelf in other areas such as Bay of Biscay - and survey coverage by JUVESAR/IBERAS (shelf waters only), although this has not been tested in WGACEGG. However, in general, both Spring and Autumn acoustic surveys can follow cohorts (Figure 5).

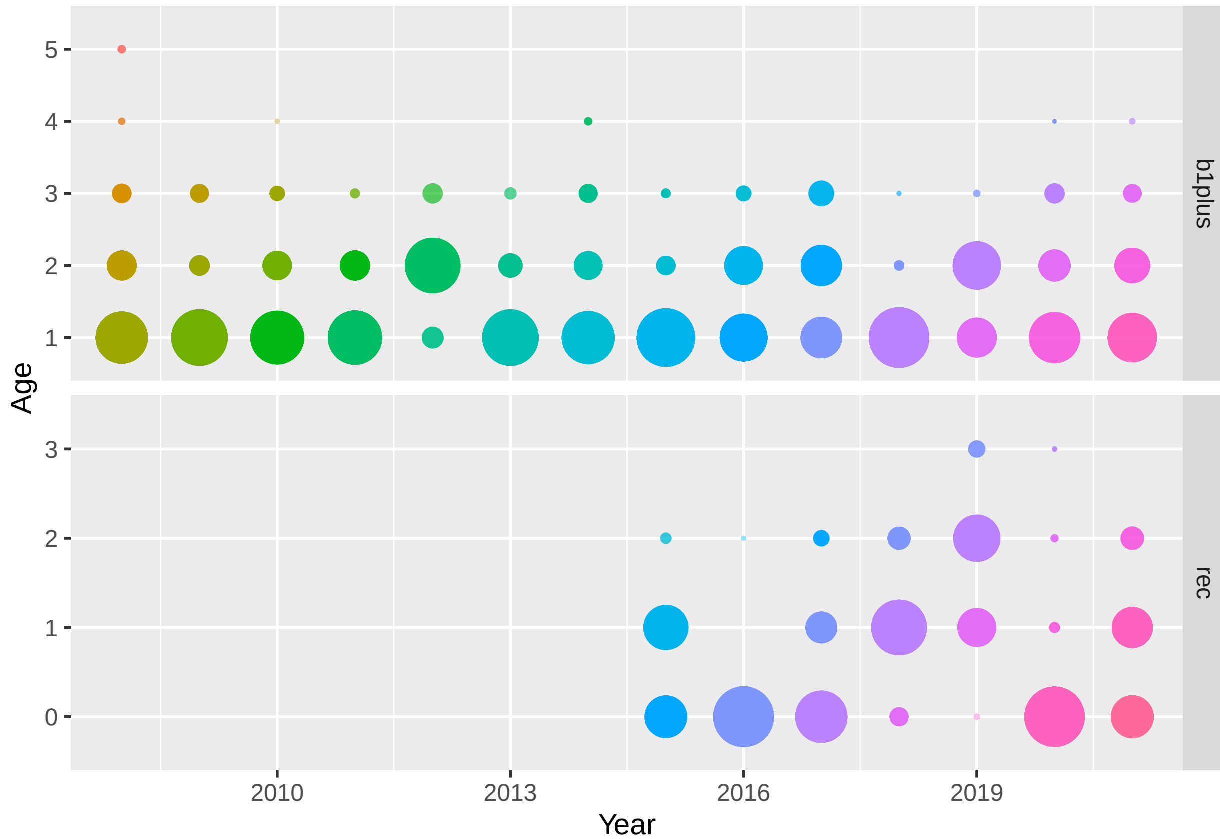

Figure 5: Age structure of the estimated population (proportion observed in the survey) of the western component of the 9a anchovy observed in the Spring (top panel) and Autumn (bottom panel) acoustic surveys. Colors correspond to cohorts.

2.3 Survey consistency

Survey consistency was evaluated by estimating the Pearson correlation between Age zero in the Autumn acoustic surveys in year y and Age one in the Spring acoustic surveys of the following year $(y + 1)$ (Figure 5). No correlation was found mainly due to the cohort of 2019. Even when the data from the 2019 cohort is removed the Pearson correlation is not significant (Figure 6).

2.4 von Bertalanfy growth model

The von Bertalanffy growth model (VBGM) was estimated using the R package FSA: Fisheries Stock Analysis (Ogle et al., 2021). Mean length at age data from the Spring and Autumn acoustic surveys was used. Starting values for k, $t0$ and $Linf$ were estimated using the function vbStarts().

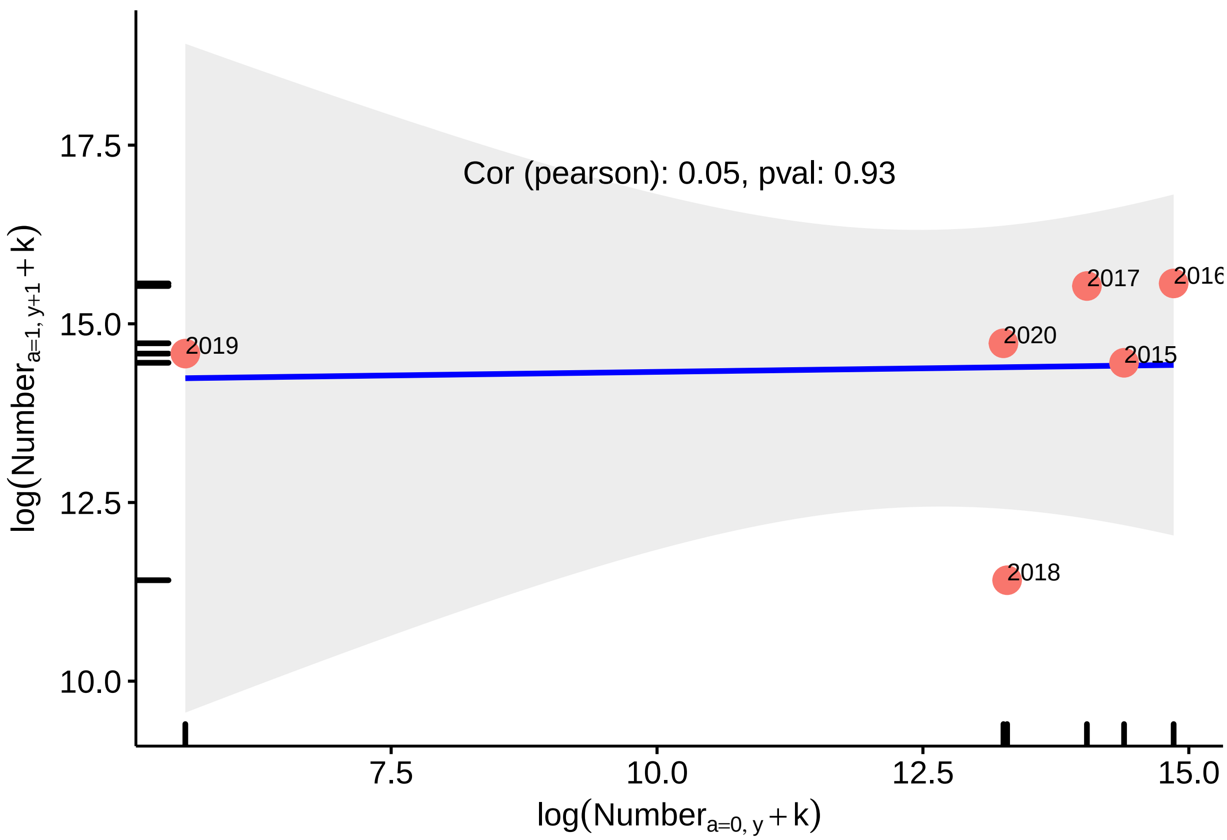

Figure 6: Pearson correlation between the abundance of anchovy in the western Iberia Age zero in the Autumn acoustic surveys in year y and Age one in the Spring acoustic surveys of the following year $(y + 1)$.

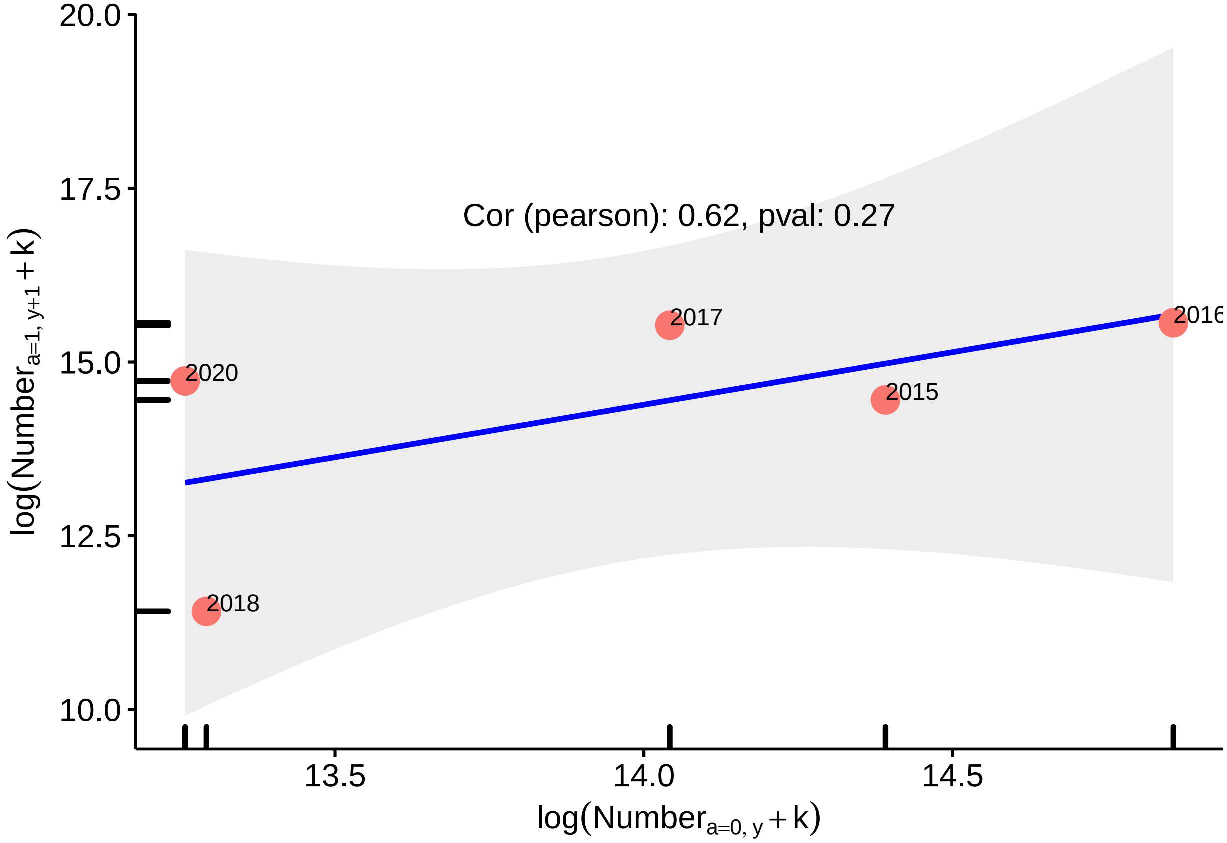

Figure 7: Pearson correlation between the abundance of anchovy in the western Iberia Age zero in the Autumn acoustic surveys in year y and Age one in the Spring acoustic surveys of the following year $(y+1)$ without the 2019 cohort data.

Different data subsets were used to estimate the VBGM. Data from age group 5 was omitted since it only appears in 1 survey (2008). First we tried to fit a VBGM to the subset data of the Spring surveys (subset ss). Then we removed the bigger individuals (subset ss22) since they only appeared in one survey and area (PELACUS 2010) and then we also fitted the model using decimal years (ss22D). A fitting of the model was also done to the recruitment survey data (subset rs) since these include mean length at age for age zero. Finnaly, we combined both survey and removed individuals equal or bigger than 22 cm; subset all).

The starting values estimated from the different data sets using vbStarts() are shown in Table 1 while The point estimate, standard error and respective t-value and p-value for the VBGM parameters are shown in Table 2.

Table 1 - Initial parameters of the VBGM used for the different subsets.

Parameters	Linf	K	t0
pp	15.36	0.38	−2.43
ss	19.53	0.38	−1.86
ss22	16.57	0.96	−0.56
ss22D	16.13	1.00	−0.80
rs	18.40	0.47	−2.20

Table 2 - Fitted parameters of the VBGM for the different subsets.

Parameter	Data Set	Estimate	Std Error	t-value	Pr(>|t|)
rs					
Linf	rs	17.80	3.64	4.88	0.00
K	rs	0.50	0.53	0.93	0.36
t0	rs	−2.20	1.64	−1.34	0.20
ss22D					
Linf	ss22D	17.54	1.19	14.76	0.00
K	ss22D	0.68	0.35	1.92	0.06
t0	ss22D	−1.01	0.80	−1.26	0.21
ss22					
Linf	ss22	17.20	1.06	16.23	0.00
K	ss22	0.73	0.38	1.92	0.06
t0	ss22	−0.88	0.78	−1.13	0.27
ss					
Linf	ss	19.69	3.73	5.28	0.00
K	ss	0.37	0.31	1.18	0.24
t0	ss	−1.89	1.56	−1.21	0.23
all					
Linf	pp	17.77	1.13	15.70	0.00
K	pp	0.59	0.23	2.59	0.01
t0	pp	−1.26	0.58	−2.18	0.03

Residual plots of each fit are shown in the next Figures (Figures 8-12).

```
##
##  Number of bootstraps was 995 out of 999 attempted

##
```

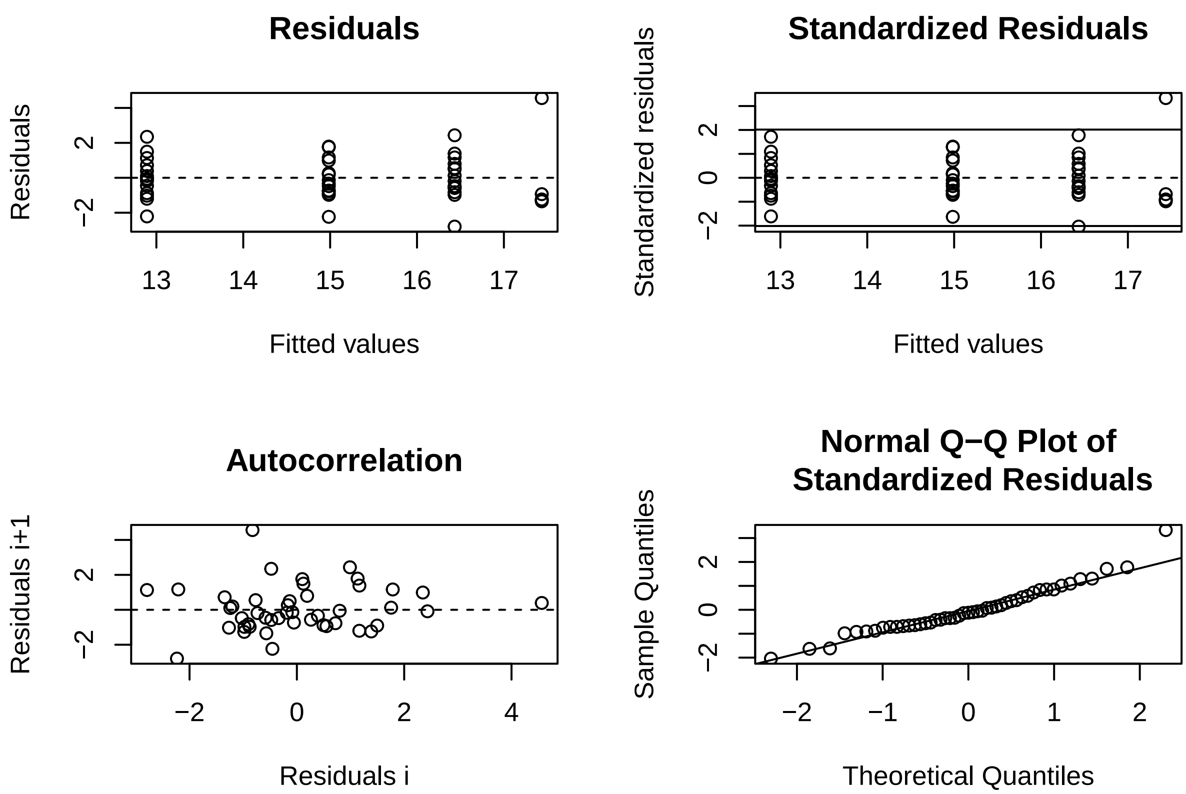

Figure 8: Residuals plots of fit to data subset ss.

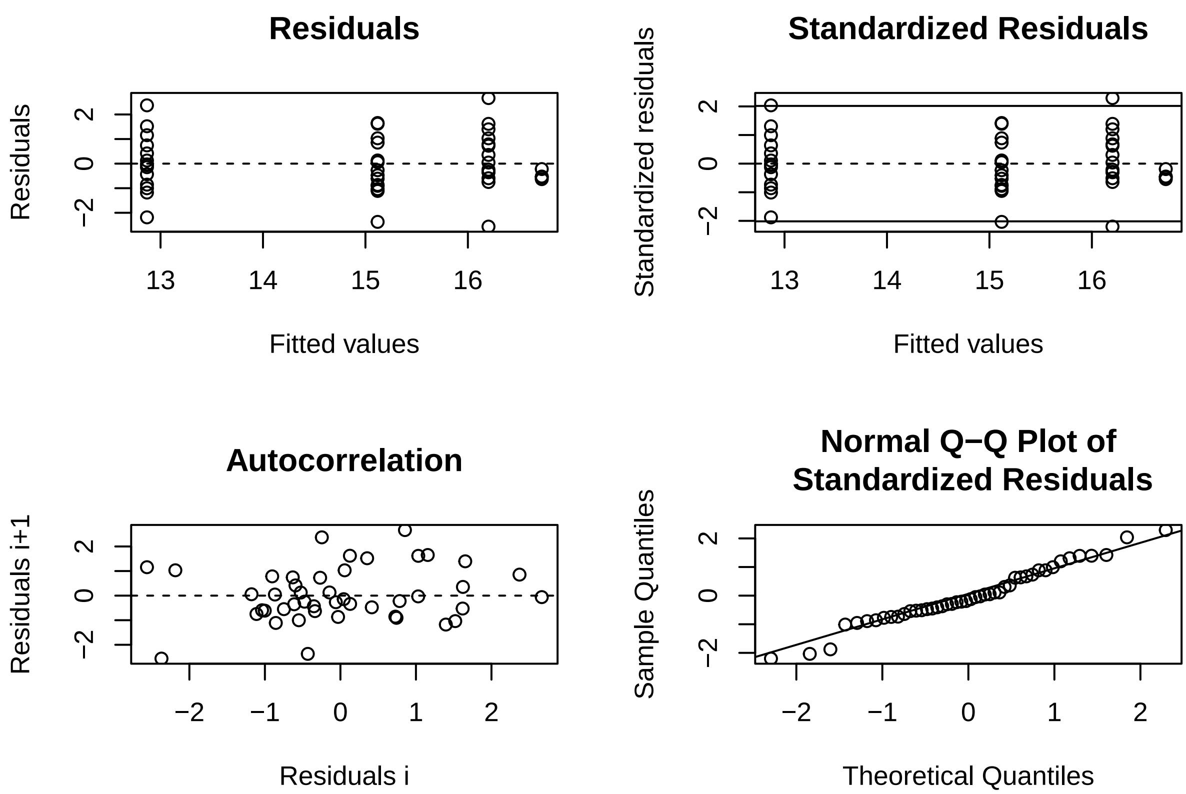

Figure 9: Residuals plots of fit to data subset ss22.

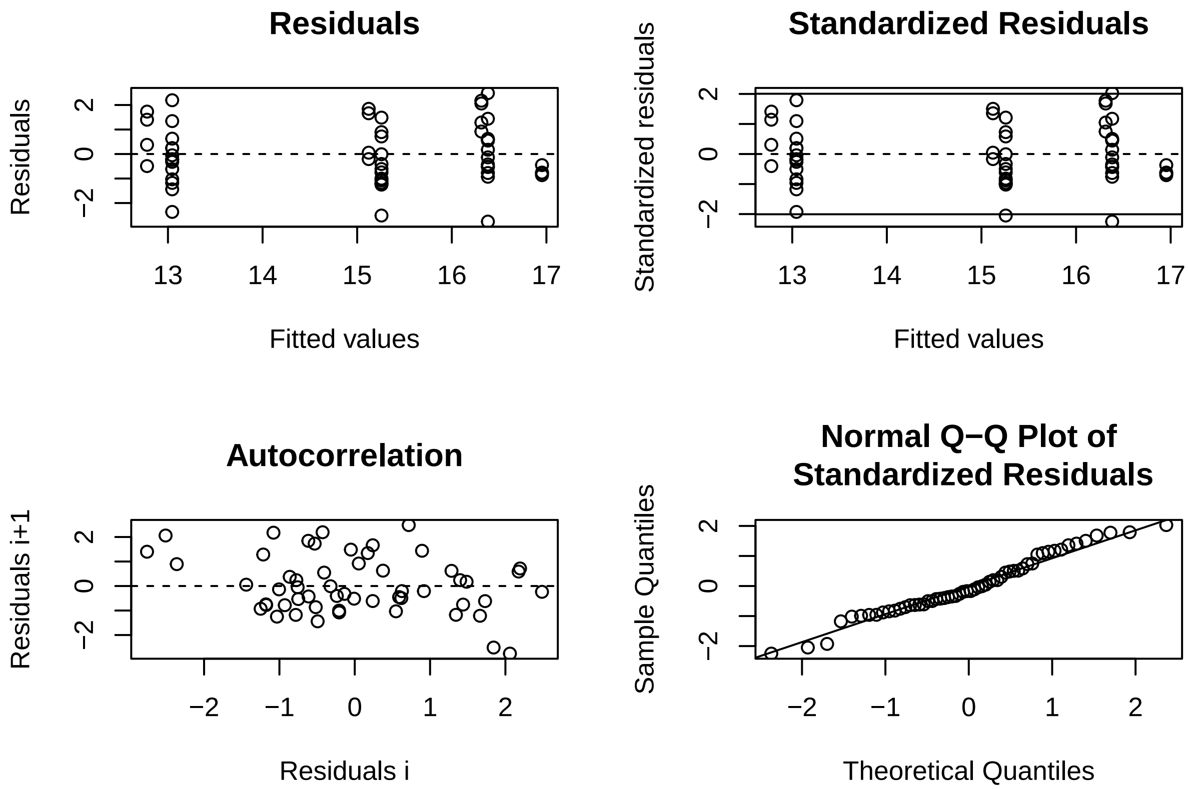

Figure 10: Residuals plots of fit to data subset ss22D.

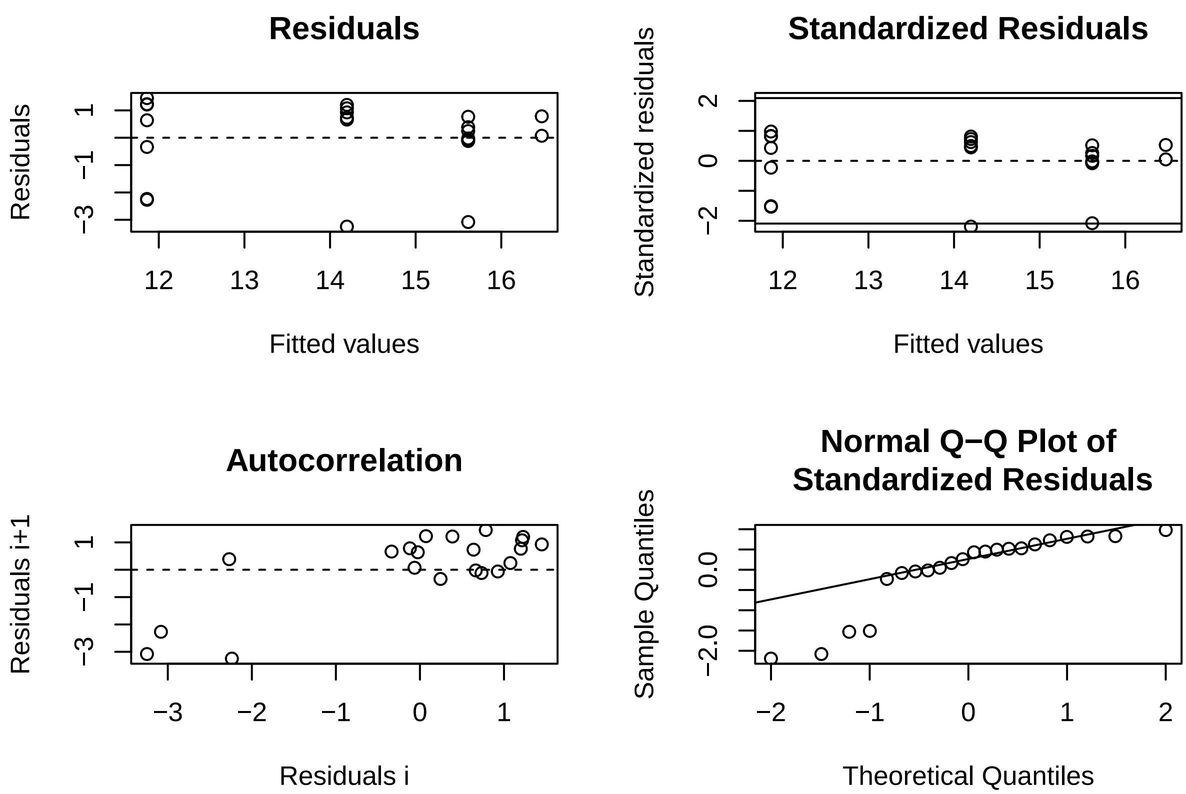

Figure 11: Residuals plots of fit to data subset rs.

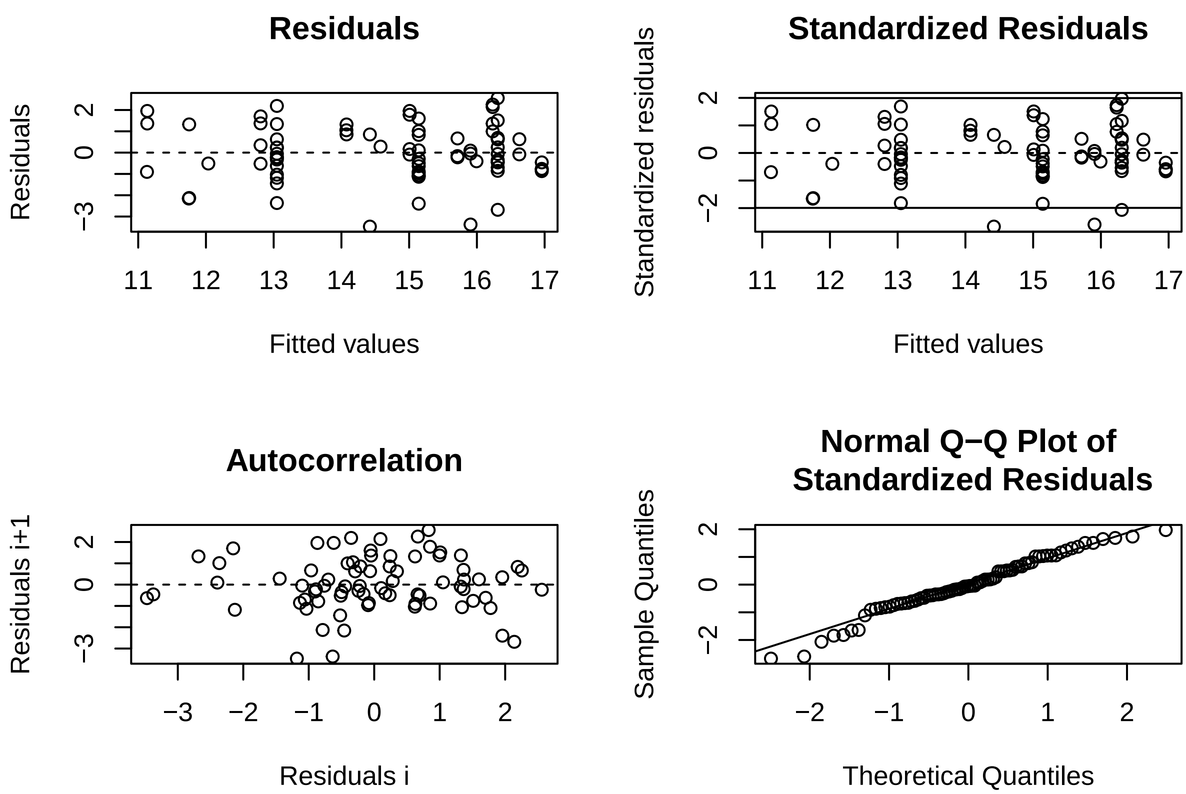

Figure 12: Residuals plots of fit to data subset all.

```
##  Number of bootstraps was 794 out of 999 attempted

##
##  Number of bootstraps was 996 out of 999 attempted

##
##  Number of bootstraps was 992 out of 999 attempted

##
##  Number of bootstraps was 801 out of 999 attempted
```

Figure 13 shows the fit of the different estimated VBGM with confidence intervals estimated with bootstrap. Since only the model fitted to all data (red line and text) has significant estimated parameters, we propose this model as one candidate model for the base operating model of the MSE.

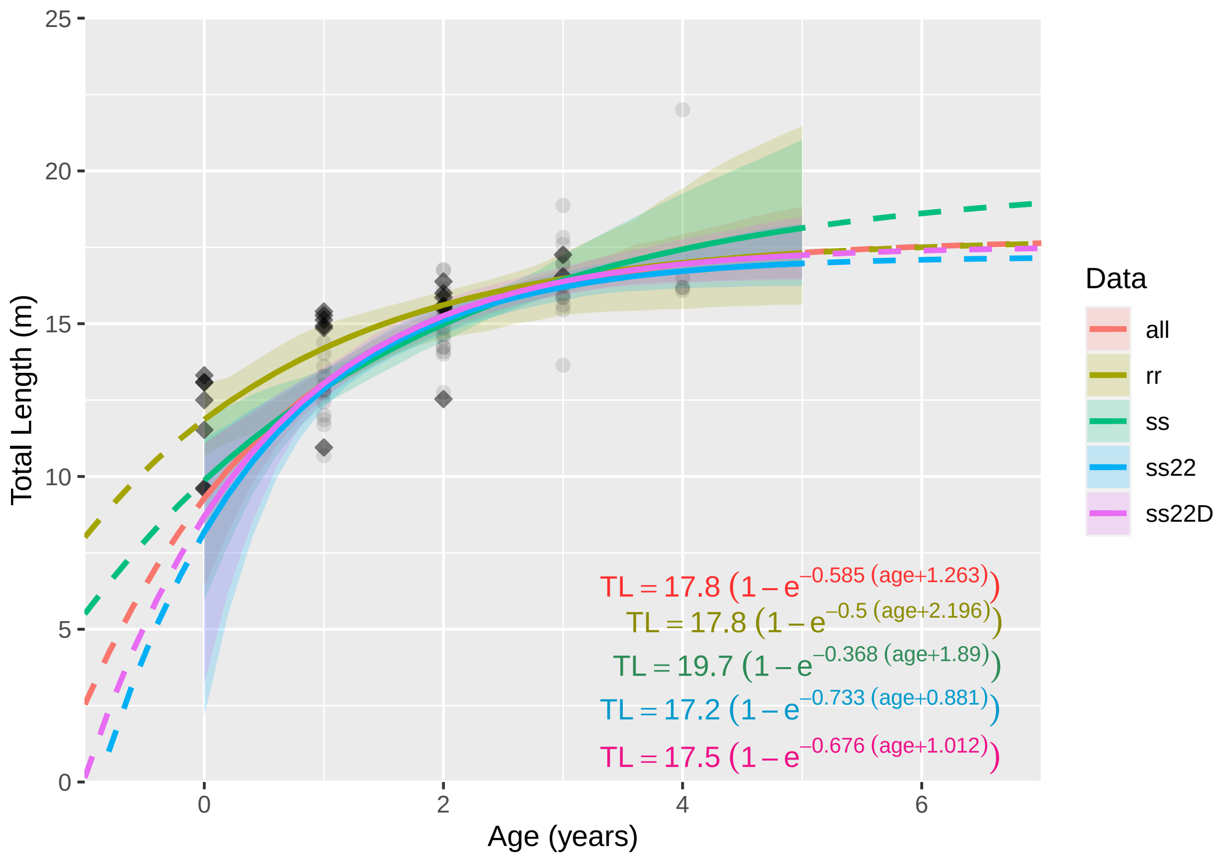

Figure 13: Fitted VBGM.

The parameters estimated with bootstrap sampling and their corresponding standard deviation are showned in Table 3.

Table 3 - Estimated parameters with bootstrap sampling and their standard deviation.

	Estimate	Std Error	Median	2.5%	97.5%
Linf					
all	18.30	1.97	17.81	16.45	23.26

ss	20.67	4.68	19.15	16.66	34.65
ss22	17.78	1.93	17.24	15.96	23.22
ss22D	18.09	2.21	17.46	16.23	24.09
rs	19.54	5.51	17.68	15.14	35.81
K					
all	0.60	0.22	0.58	0.18	1.04
ss	0.49	0.31	0.43	0.09	1.22
ss22	0.80	0.43	0.72	0.19	1.80
ss22D	0.77	0.48	0.72	0.18	1.63
rs	0.70	0.59	0.55	0.08	2.18
t0					
all	−1.40	0.69	−1.26	−3.32	−0.50
ss	−1.85	1.25	−1.59	−4.73	−0.13
ss22	−1.07	0.91	−0.88	−3.32	0.14
ss22D	−1.14	0.92	−0.90	−3.50	0.06
rs	−2.26	1.18	−2.01	−5.17	−0.64

2.5 Other growth models

Other growth models (Gompertz and Logistic) were fitted and compared with the VBGM fitted to all the data subset (Figure 14). The model with the best AIC was the logistic model but differences between AIC are so small that are considered negligible (Table 4).

Table 4 - AIC estimated for each growth model.

Model	AICc	AIC diff	Weight
VB	267.67	0.33	0.30
Log	267.34	0.00	0.36
Gom	267.48	0.14	0.34

3 Length - weight relationship

A length-weight relationship was fitted to the transformed data $log_{10}(weight) - log_{10}(length)$ from the biological samples collected during the Spring and Autumn surveys (Figure 15). Both coefficients of the estimated model were significant ($p < 2e^{-16}$) and the model adjusted R-squared value is 0.97.

4 Natural mortality

Natural mortality was estimated with classical indirect formulations based on life history parameters. The R package FSA was used to obtain empirical estimates of natural mortality. For the estimation of the natural mortality rate, the Von Bertalanffy growth parameters and the maximum age that the species can live were used. Growth parameters of the Von Bertalanffy function were taken from the model estimated in section 2.4 (Table 2) (L_{inf} = 17.77, k = 0.59, t_0 = -1.26). For the maximum observed age we assumed age 4 as adequate. A total of 13 estimators were produced using the R package FSA and the mean value of $M = $1.134 was chosen.

Table 5 - Estimaded natural mortality rate estimated with a VBGM estimated in previous section and the VBGM estimated by Bellido et al (2000).

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Model
0.88	1.05	1.08	1.13	1.24	1.38	VB all surveys
0.93	1.08	1.33	1.28	1.44	1.52	Bellido et al.

Natural mortality at age was then estimated assuming two different length-at-age vectors, the first with the mean length-at-age observed in the data and the second one with the mean length-at-age estimated with the VBGM estimated in section 2.4 (Table 6). Two methods were used, the Gislason and the Charnov methods, both implemented within the FSA R package (Figure 16).

Table 6 - Length at age vectors (observed and estimated).

Age	Observed	VB
0	11.38	9.32
1	13.07	13.09
2	14.96	15.17
3	16.54	16.33
4	16.24	16.97

5 Discussion

The following bullet points reflect the discussion in the group plenary:

- When estimating a growth model using decimal years the spawning time and birth date assumed must be in accordance with what will be the assumptions made in the MSE. In this WD, spawning time was assumed to be in March. If a different spawning time is assumed in the MSE the growth model must be re-estimated accordingly;
- The MSE may consider different operating models so there might not be necessary to choose just one natural mortality vector. The same comment may be applied to the growth model estimated.

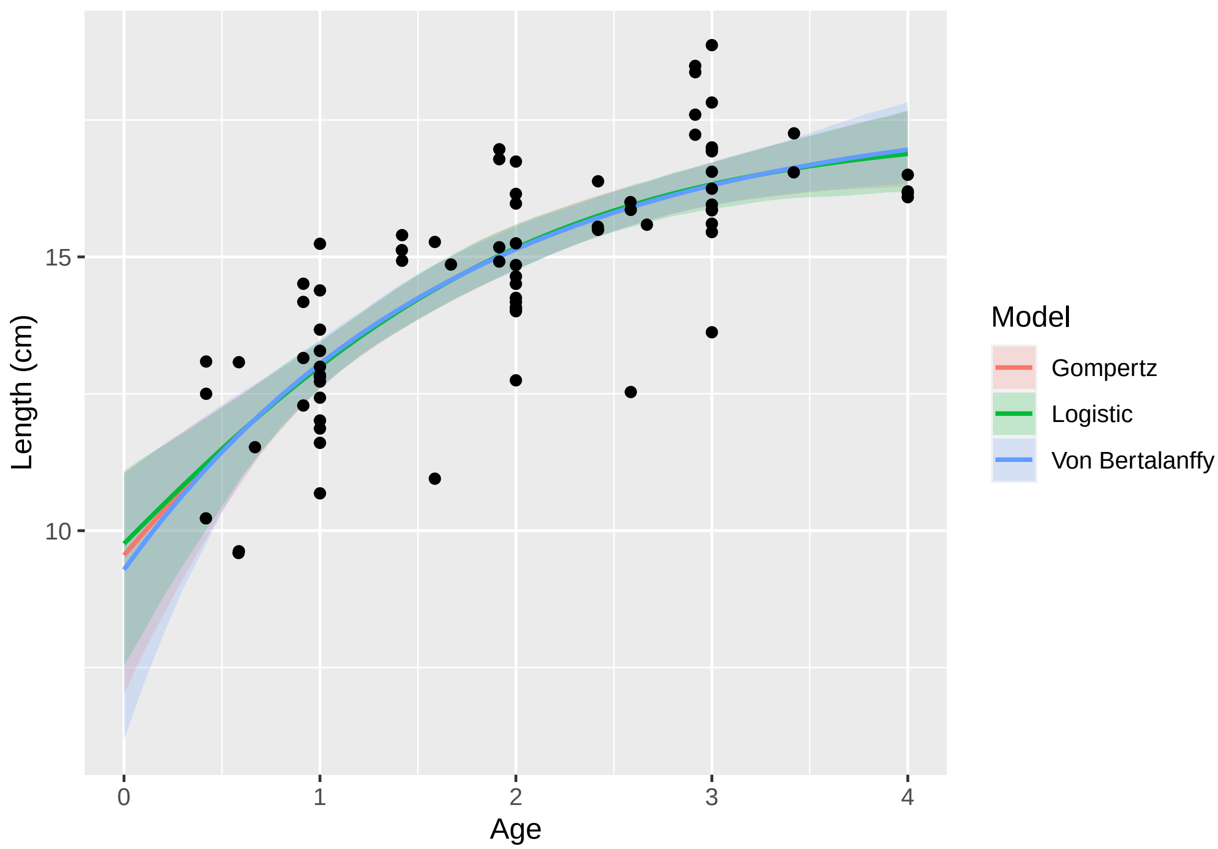

Figure 14: Von Bertalanffy, Gompertz and Logistic models.

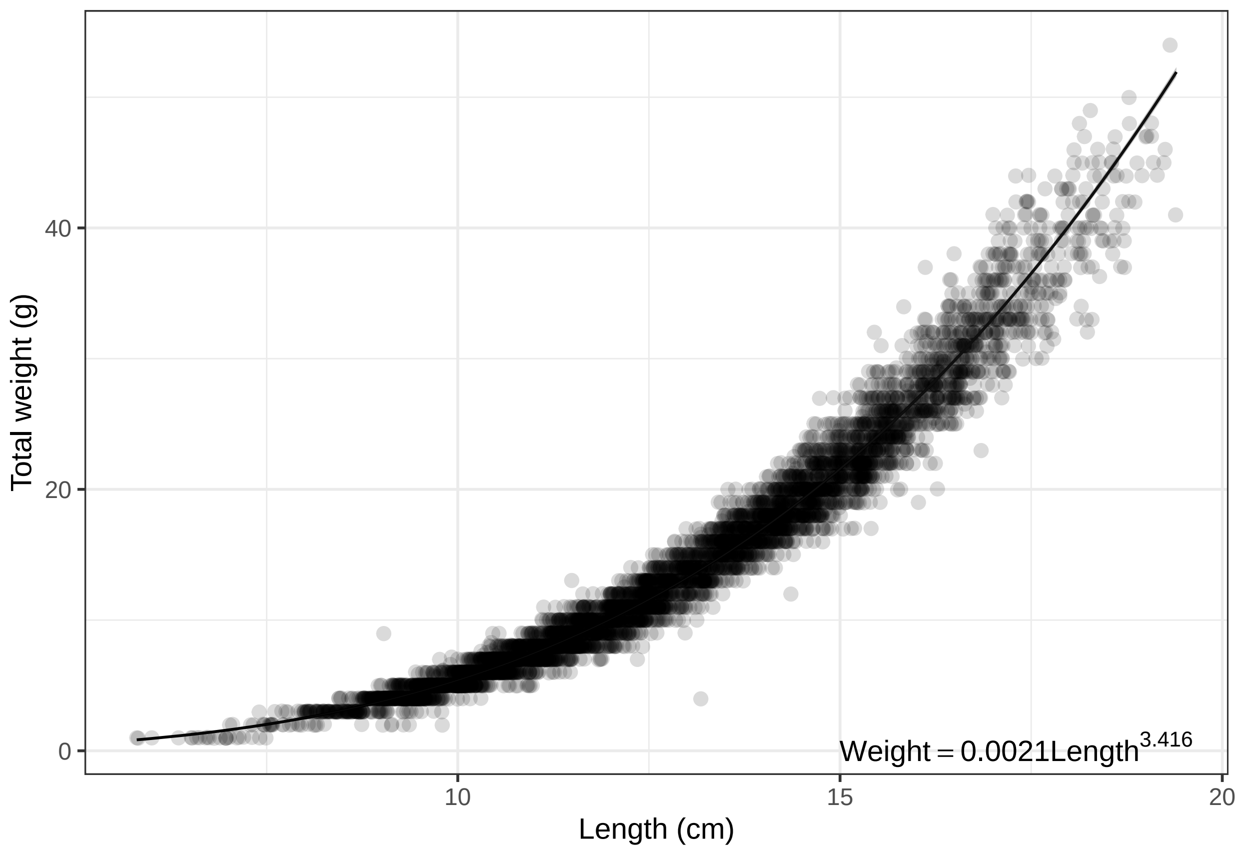

Figure 15: Length-weight relationship estimated for the western component of the 9a anchovy stock.

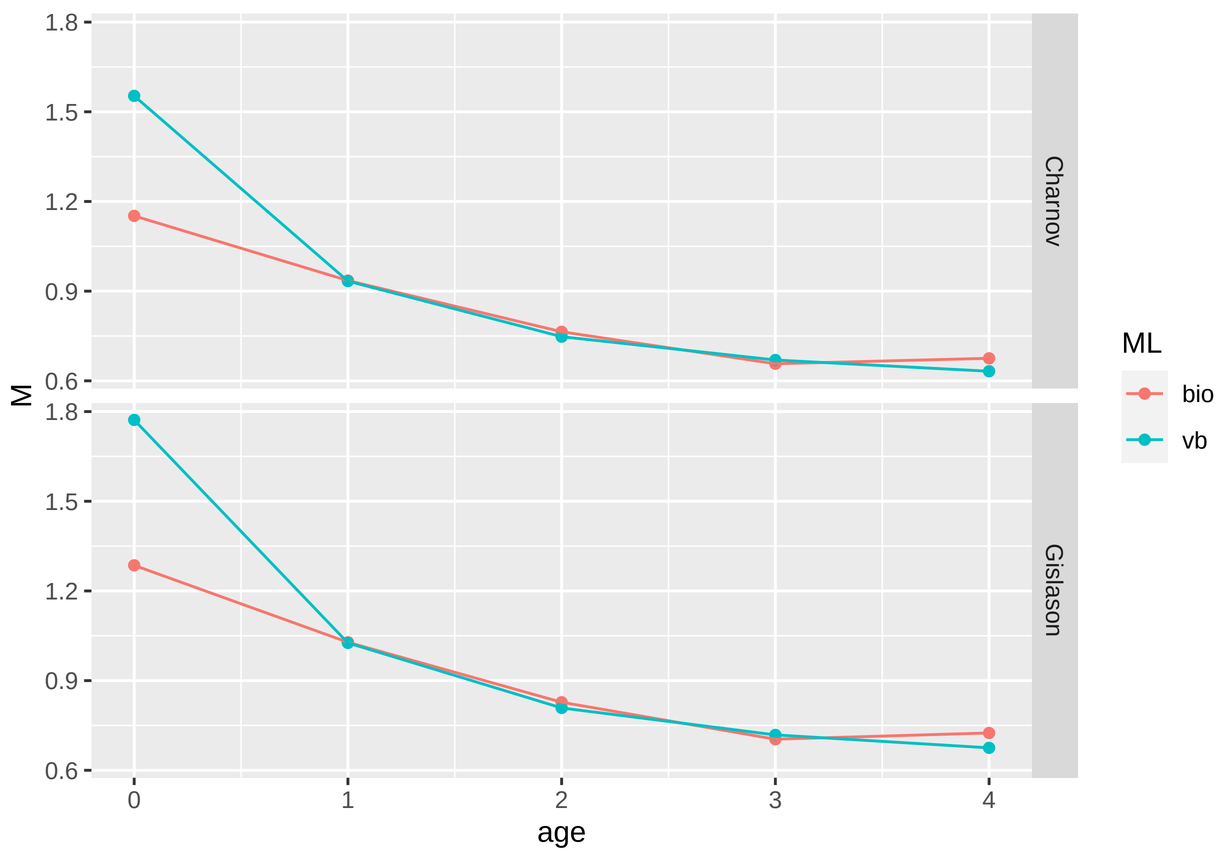

Figure 16: Natural mortality at age estimated with the Gislason (bottom panel) and the Charnov (top panel) methods assuming two different mean length at age vectors (observed in red and estimated in blue).

Working document presented to the:

ICES Working Group on Horse mackerel, anchovy and sardine (WGHANSA 2022). 23-27 May 2022.

REPRODUCTIVE CHARACTERISTICS OF WESTERN COMPONENT 27.9.A ANCHOVY

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ABSTRACT

Information on the reproductive biology is key for the assessment of the fraction of the population that is mature, contributing for the stock reproductive output, and the population renewal. Currently, there is no information on the reproductive biology of anchovy in the western Iberian coast. In this work, we have collected juvenile and adult fish from the Portuguese western coast and analysed gonads for histology to: 1) try to validate the macroscopic scale of maturity, 2) describe the seasonal cycle of reproduction and 3) estimate the percentage of mature and immature individuals by size and age. As for other fish species, the macroscopic maturity scale did not validate, failing to correctly distinguish immature from resting females and males, meaning that anchovy reproductive state should be assessed histologically. Seasonality of spawning assessed by the monthly variation of gonadosomatic index and by the percentage of active females (microscopic stages 2,3 and 4) identified a similar spawning season as for other anchovy populations in the Iberia, ranging from April/May to July. The proportion of active females and males during the spawning season was very high for all fish analysed (ranging from 9.5 to 17 cm total length) which strongly affected the fitting of the logistic curve relating maturity with length class or age. An extra sampling effort will be carried out in the current year to try to collect smaller fish to improve the fitting of the maturity ogive.

1. SAMPLE COLLECTION

Anchovy individuals were collected from January 2018 to July 2019 from commercial landings and IPMA's research surveys off the Portuguese west coast. Biological information was recorded for each fish (total length, total weight, gutted and gonad weights, age, sex, macroscopic maturity stage (Appendix I), fat content, stomach fullness). Gonads were collected and processed for histology embedded in parafin, stained with hematoxylin and eosin. Two readers analysed the histological slides and microscopically identified maturity stages.

In total, 375 individuals were analysed microscopically, mostly collected from the 9a.CN sub-division (351 individuals), while the remaining 24 individuals were collected from the 9a.CS sub-division. Sexes were equally represented, with 190 females and 185 males, ranging from 9.5 to 17 cm (median 14.0 cm, mean 13.79 ± 2.21 cm).

2. Validation of the maturity scale

Most fish analysed in this study were mature (78%) and only 10% were immature. For the remaining 10% of the individuals it was not possible to attribute a consensual maturity stage with microscopic analysis.

Comparing the results of the macroscopic and microscopic staging of gonads (Table 1), it is shown that for anchovy, as for many other species, it is not possible to distinguish immature individuals from resting females and males macroscopically, therefore their reproductive state should be assessed histologically. Only 22% and 50% of the immature females and males were correctly assigned as immature, respectively. Regarding mature fish, 98% and 86% of mature females and males were correctly assigned as mature, respectively. Main problems encountered were in the incorrect assignment of immature fish as stage 2 and 5.

Table 1 – Number of anchovy individuals classified as 1 (immature) and 2-5 (mature) by macroscopically staging and classified as mature, immature or in doubt using microscopically examination, by sex. Last two columns show percentage of correct/incorrect classification.

Number of fish

		Macroscopical maturity stage						
sex	**Microscopic maturity stage**	**1**	**2**	**3**	**4**	**5**	**% correct**	**% incorrect**
female	**Stage 1 - immat**	8	24			5	22	78
	mat	2	16	57	22	27	98	2
	doubt	6	14			9		
male	**Stage 1 - immat**	2	1			1	50	50
	mat	23	24	96		26	86	14
	doubt	6	3			3		

3. Seasonality of spawning

Anchovy reproduce off the Portuguese West coast mostly in spring-summer months (April to July), with a peak in May-July (Fig. 1). Males and females are synchronized and at peak spawning, nearly all fish in the population are reproductively active (Fig. 2).

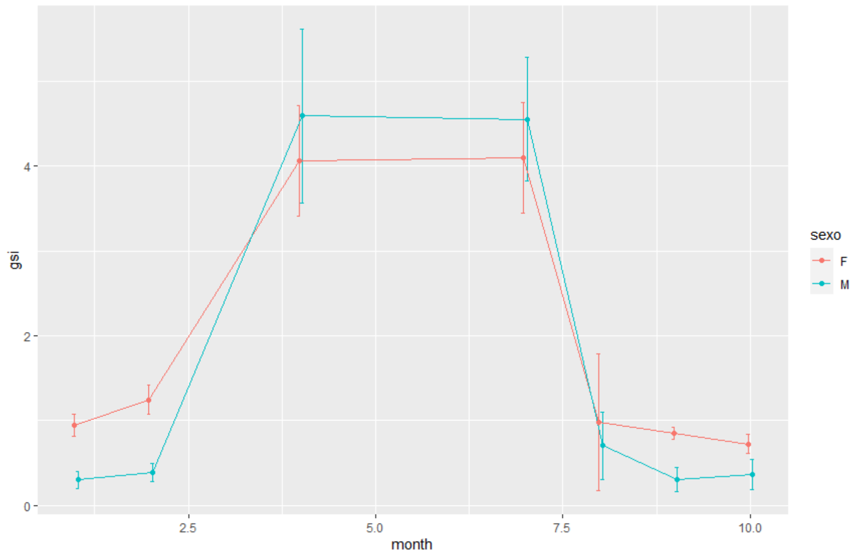

Figure 1 - Monthly values (mean ± CI) of gonadossomatic index of male and female anchovy collected in the western Portuguese coast.

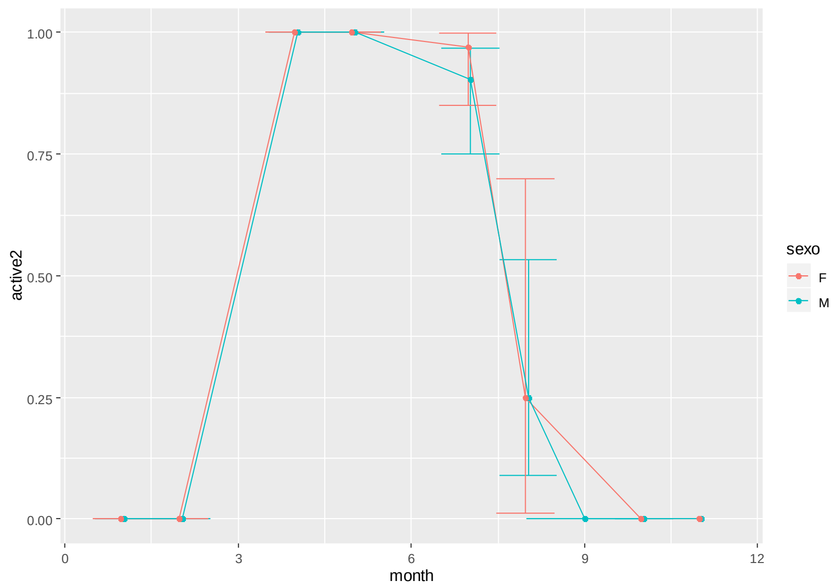

Figure 2 - Monthly values (mean ± CI Wilson) of active (1) and inactive (0) anchovy collected in the western Portuguese coast, by sex.

4. Maturity Ogive

In order to construct the maturity ogive, only fish collected in the spawning season (April to July) were selected. In total, 193 fish were collected during this period, ranging from length class 9.5 to 17 cm and ages 0 to 2 (Tables 2 and 3). Fish in stage 1 and 2 were classified as immature and those in stage 3,4 and 5 classified as mature, following Millan et al. (1999).

Table 2 – Percentage of fish classified microscopically as mature or immature and number of fish collected during the spawning season by size class

length class	imatur 1+2	matur 3+
9.5		5
10	1	5
10.5	1	13
11		15
11.5	1	11
12		8
12.5		15
13	1	10
13.5		15
14		16
14.5		18
15	1	17
15.5		12
16		6
16.5		12
17		4
Total Geral	**17**	**891**

Table 3 – Percentage of fish classified microscopically as mature or immature and number of fish collected during the spawning season by age

Age	1+2	3+
0	1	5
1	7	103
2	2	59
no age info		16
Total Geral	**11**	**182**

The proportion of mature fish is assumed to increase with size and age. Data was adjusted to a logistic function following the method described in Silva *et al.* (2017), using the software R (R Core Team, 2021) with a glm function using the binomial as the response variable distribution and a logit link.

The majority of fish collected from the smallest length class were classified as mature (71%), while the percentage was >80% for the following length classes (Table 2). For this reason, the fitted logistic regression is highly uncertain reflected in the large confidence intervals of smaller fish and the maturity ogive should be considered unreliable (Fig. 3).

Most fish collected during the spawning season were age 1 and 2 individuals, only 3.4% (6 fish) were age 0 and no fish age 3 was collected. Most of age 0 fish analysed were mature, which is probably related to their large size (>9 cm). Again, confidence interval for age 0 are very large (Fig. 4).

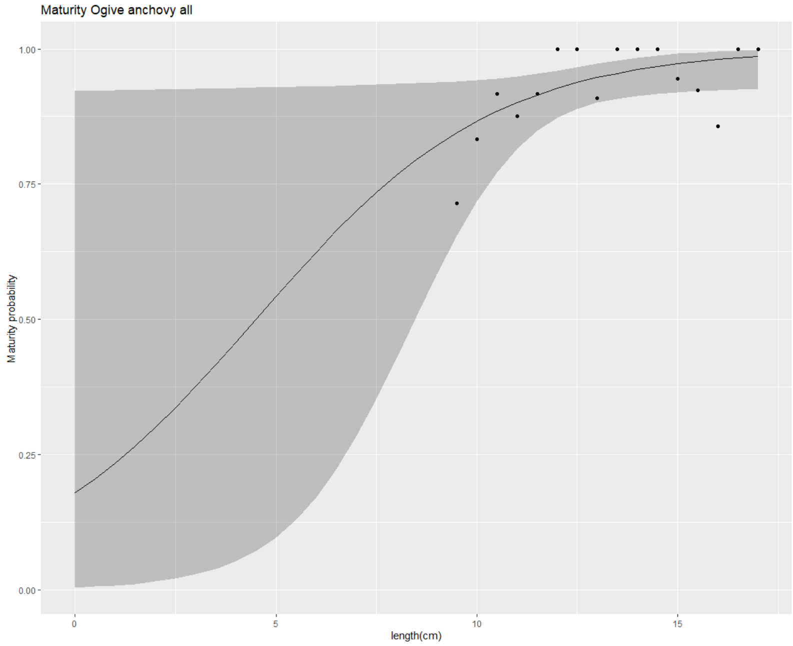

Figure 3 – Fitted logistic regression for combined proportion of male and female anchovy mature by length from samples collected in the western Portuguese coast in 2018 and 2019. The shaded area represents the 95% confidence interval.

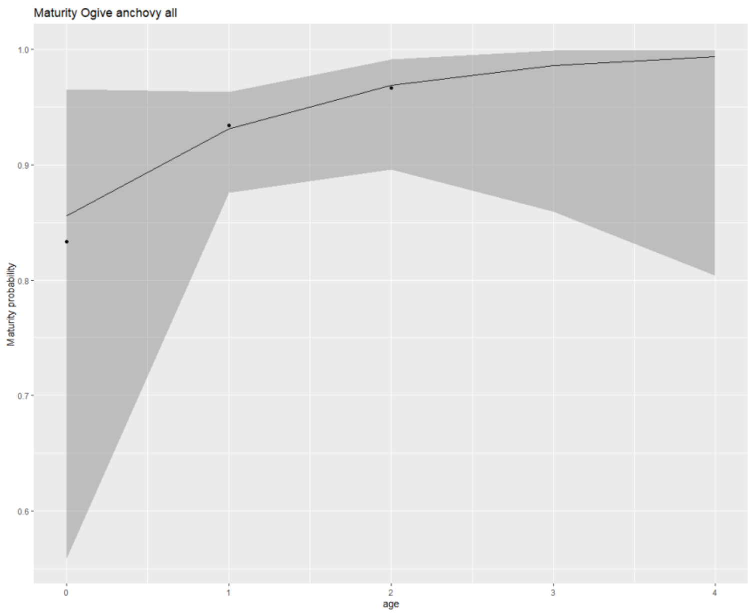

Figure 4 – Fitted logistic regression for combined proportion of male and female anchovy mature by age from samples collected in the western Portuguese coast in 2018 and 2019. The shaded area represents the 95% confidence interval.

5. Maturity Ogive - Stage 1 as immature

Some studies consider only stage 1 as immature and stage 2 as mature, since the development of anchovy gonads is very fast and it is possible that fish in stage 2 can complete development within the spawning season. Therefore, an alternative, the maturity ogive was constructed as explained in section 3 of the current WD, but this time fish in stage 1 were classified as immature and those in stage 2, 3,4 and 5 classified as mature. Again, only fish collected in the spawning season (April to July) were selected and in total, 193 fish were analysed during this period, ranging from length class 9.5 to 17 cm and ages 0 to 2 (Tables 4 and 5).

Table 4 – Percentage of fish classified microscopically as mature or immature and number of fish collected during the spawning season by size class.

length class	imatur 1	matur 2+
9.5		7
10	1	5
10.5	1	13
11		17
11.5	1	11
12		8
12.5		15
13	1	10
13.5		15
14		16
14.5		18
15	1	17
15.5		13
16		7
16.5		12
17		4
Total Geral	**5**	**14**

Table 5 – Percentage of fish classified microscopically as mature or immature and number of fish collected during the spawning season by age.

Age	1	2+
0	1	5
1	4	106
2		61
no age info		16
Total Geral	**5**	**188**

The proportion of mature fish is assumed to increase with size and age. Data was adjusted to a logistic function following the method described in Silva *et al.* (2017), using the software R (R Core Team, 2021) with a glm function using the binomial as the response variable distribution and a logit link.

The majority of fish collected from the smallest length class were classified as mature (71%), while the percentage was >80% for the following length classes (Table 2). For this reason, the fitted logistic regression is highly uncertain reflected in the large confidence intervals of smaller fish and the maturity ogive should be considered unreliable (Fig. 5).

Most fish collected during the spawning season were age 1 and 2 individuals, only 3.4% (6 fish) were age 0 and no fish age 3 was collected. Most of age 0 fish analysed were mature, which is probably related to their large size (>9 cm). Again, confidence interval for age 0 are very large (Fig. 6).

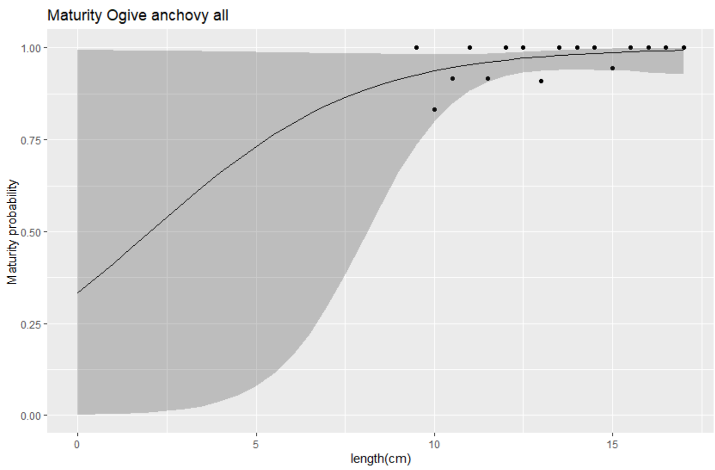

Figure 5 – Fitted logistic regression for combined proportion of male and female anchovy mature by length from samples collected in the western Portuguese coast in 2018 and 2019. The shaded area represents the 95% confidence interval.

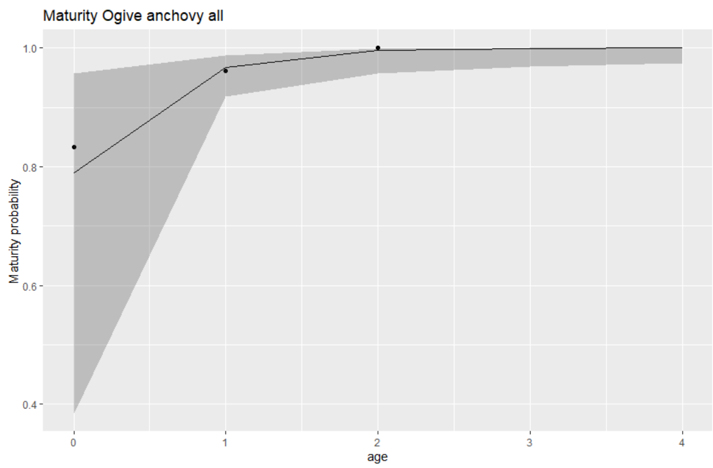

Figure 6 – Fitted logistic regression for combined proportion of male and female anchovy mature by age from samples collected in the western Portuguese coast in 2018 and 2019. The shaded area represents the 95% confidence interval.

There are additional data from the Gulf of Cadiz (unpublished, F Ramos pers. Comm.) that point to maturation at smaller sizes than those presented in Millan et al. 1999, and similar to those found for the western Iberia in the present work.

6. Data from neighbour population

There is data of the maturity at length and age for nearby areas, such as the Gulf of Cadiz (Millan *et al*. 1999, Fig. 7). In this study, length at first maturity (L50) was estimated as 11.09 ± 1.35 cm for males, and 11.20 ± 1.84 cm for females, although no significant differences were found between sexes. Length range at maturation (L25–75) was estimated as 10.25–11.93 cm for males, and 10.41–11.99 cm for females. Length at full maturity (L95) was 13.3 cm in both sexes.

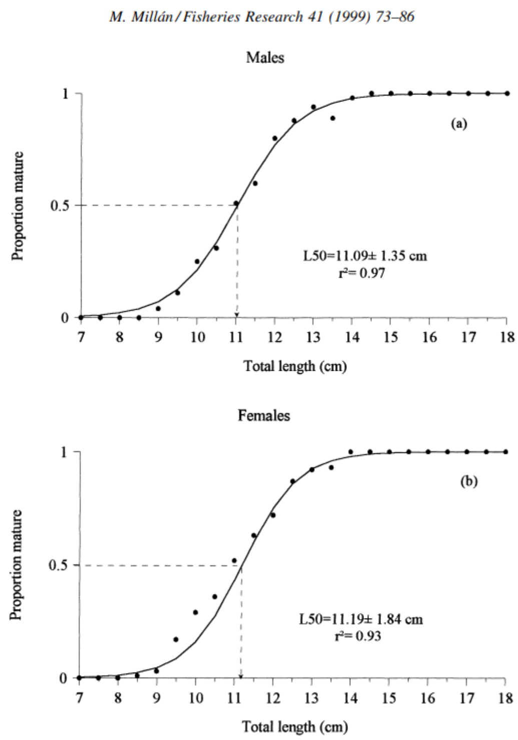

Figure 7. Maturity ogive and length at first maturity (L50) in (a) males and (b) females of *E. encrasicolus* for the whole study period (1989–1992). Millan *et al.* 1999, https://doi.org/10.1016/S0165-7836(99)00010-7

7. Conclusion

The macroscopic scale of reproduction does not validate for the anchovy, as for many other fish species, which means the reproductive biology of the species should be studied by microscopic analysis.

Spawning seasonality for western anchovy is similar to other anchovy populations in the Iberia, ranging from April/May to July, as observed by the monthly variation of gonadosomatic index and by the percentage of active females

The proportion of active females and males during the spawning season was very high for all fish analysed (ranging from 9.5 to 17 cm) which strongly affected the fitting of the logistic curve relating maturity with length class or age.

Uncertain results of maturity at age/size for younger fish are mainly a consequence of the absence of small fish in this study. An extra sampling effort will be carried out during the current spawning season of 2022 to try to collect smaller fish to improve the fitting of the maturity ogive.

An intercalibration with colleagues analysing histological sampled of anchovy is foreseen, and doubts of staging gonads based on microscopic analysis is expected to decrease.

The maturity data to be used in the MSE approach can use values of the neighbour population for the smaller size classes until data is available for the western component.

References

M Millán (1999) Reproductive characteristics and condition status of anchovy Engraulis encrasicolus L. from the Bay of Cadiz (SW Spain). Fisheries Research 41 Issue 1: 73-86. https://doi.org/10.1016/S0165-7836(99)00010-7.

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APPENDIX I – Maturity scale used in this study

Males Maturity stage		Macroscopic description
1	Virgin or resting	Lamella shape testicles with sharp edge in the inferior side; variable size in adults and small in virgin specimens; almost transparent; sperm not visible.
2	Maturing	Testicles very firm in texture; ivory white to grayish colored; no blood vessels or other structures.
3	Pre-spawning or post- spawning/ recovery	Testicles taking up all visceral cavity; white-pink color to red color; Sperm is free-running or freed with light pressure in the gonads
4	Spawning	Bloated and vascularized testicles; white marble color; visible sperm.
5	Post-spawning	Testicles are flaccid; color changes between white-rose or grey; residual or no sperm.

Females Maturity stage		Macroscopic description
1	Virgin or resting	Small ovaries; translucent; taking up ¼ of the visceral cavity
2	Maturing	Ovary granular and opaque; visible oocytes in development.
3	Pre-spawning or post- spawning/ recovery	Ovaries with granular appearance; oocytes visible and distributed in parallel bands.
4	Spawning	Big ovaries, taking up all the visceral cavity; translucid oocytes.
5	Post-spawning	Ovaries flaccid and very vascularized; reddish color; oocytes visible or not.

Working document presented in the ICES Working Group on Southern horse mackerel, Anchovy and Sardine (WGHANSA). On-line meeting, 23-27 May 2022.

Acoustic assessment and distribution of the main pelagic fish species in ICES Subdivision 9a South during the *ECOCADIZ-RECLUTAS 2021-10* Spanish survey (October 2021).

By

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ABSTRACT

The present working document summarises the main results obtained from the *ECOCADIZ-RECLUTAS 2021-10* Spanish (pelagic ecosystem-) acoustic-trawl survey conducted by IEO between 21st October and 07th November 2021 in the Portuguese and Spanish shelf waters (20-200 m isobaths) off the Gulf of Cadiz (GoC) onboard the R/V *Ramón Margalef*. The survey suffered a ten-day delay in relation to the usual starting dates. The survey's main objective is the acoustic assessment of anchovy and sardine juveniles (age 0 fish) in the GoC recruitment areas. The 21 foreseen acoustic transects were sampled. A total of 18 valid fishing hauls were carried out for echo-trace ground-truthing purposes. Chub mackerel, anchovy and sardine were the most frequent captured species in the fishing hauls, followed by horse mackerel, bogue, Atlantic mackerel, Mediterranean horse mackerel and blue jack mackerel. Boarfish, longspine snipefish and pearlside showed an incidental occurrence in the hauls performed in the surveyed area. Sardine and chub mackerel showed the highest yields in these hauls, followed by anchovy and Mediterranean horse mackerel. Total and Spanish estimates of total NASC allocated to the "pelagic fish species assemblage" in this survey showed lower values than those recorded last year, whereas the Portuguese estimates showed an increasing trend. GoC anchovy was widely distributed in the surveyed area, although avoided the easternmost waters. Higher densities were recorded between Alfanzina and west of Cape Santa Maria, in the Algarve, and between Isla Cristina and Bay of Cadiz. Anchovy acoustic estimates in autumn 2021, 17 512 t and 1973 million fish, experienced 38% and 51% decreases in abundance and biomass, respectively, in relation to the last year's autumn estimates and they were lower than their time-series averages. The population was composed by fishes not older than 2 years. As usual, the bulk of the population, including juveniles, was located in Spanish waters. Age-0 anchovies accounted for 83% (1629 million) and 69% (12 063 t) of the total estimated abundance and biomass, respectively. Age-0 estimates experienced a similar decreasing trend than the one showed by the whole population in relation to the historical peak recorded in 2019, but with values close to the time-series average. GoC sardine was widely distributed all over the surveyed area (also avoiding the easternmost waters) and recorded a relatively high acoustic echo-integration in autumn 2021 as a consequence of the occurrence of dense mid-water schools in the Algarve coastal and inner shelf waters (20-78 m). Abundance (2986 million fish) and biomass (151 320 t) estimates were the second historical records within its respective series, although they represented 83% and 38% decreases in relation to the last year's estimates. GoC sardine population was mainly concentrated in Portuguese waters. Age-5 group was the oldest age group in the population, although the occurrence of fishes older than 4 years was incidental. The population was mainly composed by fishes belonging to the age-0 to age-2 groups. Juvenile sardines (age-0 group) were not the dominant group, accounting for 21% (638 million) and 9% (12 854 t) of the total abundance and biomass, respectively. The bulk of this juvenile fraction was recorded in Spanish coastal waters. Chub mackerel was also widely distributed in the surveyed area, but showing higher densities in three between Cape San Vicente and Mazagón. Chub mackerel estimates were of 13 115 t and 106 million fish, accounting for 64% and 43% strong decreases in relation to the estimates in the previous year and with the above values being lower than their time-series average. The population was mainly concentrated in Portuguese waters and it was composed by fishes not older than 5 years, with the age-1 group being the dominant one. Age-0 fish was the second most important age group in the estimated population ((24%, 26 million

fish, and 13%, 1689 t, of the total abundance and biomass estimates). The bulk of the age-0 and age-1 groups were recorded in the Portuguese waters, whereas older age-groups were more frequent in Spanish waters.

INTRODUCTION

The first attempt by the IEO of acoustically assessing the abundance of anchovy and sardine juveniles in their main recruitment areas off the Gulf of Cadiz dates back to 2009 (*ECOCADIZ-RECLUTAS 1009* survey). However, that survey was unsuccessful as to the achievement of their objectives because of the succession of a series of unforeseen problems which led to drastically reduce the foreseen sampling area to only the 6 easternmost transects. The continuation of this survey series was not guaranteed for next years and, in fact, no survey of these characteristics was carried out in 2010 and 2011. In 2012, the *ECOCADIZ-RECLUTAS 1112* survey was financed by the Spanish Fisheries Secretariat and planned and conducted by the IEO with the aim of obtaining an autumn estimate of Gulf of Cadiz anchovy biomass and abundance. The survey was conducted with the R/V *Emma Bardán*. Although the survey was restricted to the Spanish waters only it has been considered as the first survey within its series (Ramos *et al*., 2013). *ECOCADIZ-RECLUTAS 2014-10* re-started the series and it was conducted with the R/V *Ramón Margalef*. The 2017 survey should be the fifth survey within its series. However, an unexpected a serious breakdown of the vessel's propulsion system led to an early termination of the survey, which restricted the surveyed area to the one comprised by the seven easternmost transects only.

The general objective of these surveys is the acoustic assessment by vertical echo-integration and mapping of the abundance and biomass of recruits of small pelagic species (especially anchovy and sardine), as well as the mapping of both the oceanographic and biological conditions featuring the recruitment areas of these species in the Division 9a. The long term objective of the surveys would be to be able to assess the strength of the incoming recruitment to the fishery of these species the next year.

The present Working Document reports the main results from the *ECOCADIZ-RECLUTAS 2021-10* survey (the seventh survey within its series), namely the acoustic estimates of abundance and biomass (age-structured for anchovy, sardine and chub mackerel) and the spatial distribution of the assessed species.

MATERIAL AND METHODS

The *ECOCADIZ-RECLUTAS 2021-10* survey was conducted between 21st October and 07th November onboard the Spanish R/V *Ramón Margalef* covering a survey area which comprised 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**).

The survey suffered a ten-day delay in relation to the usual starting dates, resulting in ending dates very close to the starting ones of the WGACEEG meeting. Causes for such a delay were of logistic (a delay in R/V's dry-dock repair works) and unforeseen (monitoring of the *Cumbre Vieja* volcano eruption) nature. Furthermore, the ship-time available was shortened in two days, and one day more was lost because stormy weather and rough sea.

Echo-integration was carried out with a recently installed *Simrad™ EK80* echo-sounder working in the multi-frequency fashion (18, 38, 70, 120, 200, 333 kHz) and in CW mode. 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 *Myriax Software Echoview™* software package. Acoustic equipment was calibrated between 23rd and 24th October in the Bay of Algeciras following the ICES standard procedures (Demer *et al*., 2015; see also Foote *et al*., 1987).

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 later by the *Working Group on Acoustic and Egg Surveys for Small Pelagic Fish in NE Atlantic* (WGACEGG; ICES, 2006a,b; see also ICES TIMES 64 report, Doray *et al*., 2021).

Fishing hauls for echo-trace ground-truthing were opportunistic, according to the echogram information, and they were carried out using a *Gloria HOD 352* pelagic trawl gear (ca. 10 m-mean vertical opening net) at an average speed of 4-4.5 knots. Gear performance and geometry during the effective fishing was monitored with *Simrad™ Mesotech FS20* trawl sonar, a *Marport™ Narrow Band Trawl Eye* and *Scanmar™* trawl door sensors for inter-doors distance and depth. Trawl sonar 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 (2 spp.) and horse-mackerel species (3 spp.), and bogue. Otoliths were extracted from anchovy, sardine and chub mackerel sampled specimens.

The following TS/length relationship table was used for acoustic estimation of assessed species (recent IEO standards after ICES, 1998; and recommendations by ICES, 2006a,b):

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* software (J. Miquel, IEO, unpublished) has got implemented the needed procedures and routines for the acoustic assessment following the above approach and it has been the software package used for the acoustic estimation.

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 collect some hydrographical variables (sub-surface sea temperature, salinity, and in vivo fluorescence). Vertical profiles of hydrographical variables were also recorded by night from 168 $CTDO_2$ casts over 22 transects (from the 23-transect planned grid) using a *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) profiler (**Figure 2**). *VMADCP RDI 150 kHz* records were also continuously recorded by night between CTD stations. Census of top predators was not recorded during the survey.

A detailed description of protocols and methods followed in this survey series is reported in Doray *et al*. (2021).

RESULTS

Acoustic sampling

The acoustic sampling was restricted to the period comprised between 25th October and 06th November. The complete grid (21 transects) was acoustically sampled (**Table 1**; **Figure 1**). The sampling scheme followed to accomplish this grid was conditioned by the conduction of Spanish Navy and Army exercises (*FLOTEX 21*) during the survey, which occupied all the Spanish shelf waters. The sampling experienced one “jump” looking for space-time opportunity windows for the acoustic surveying trying to avoid such military exercises. Thus, the order and/or direction of the realization of the acoustic transects RA01 to RA04 had to be modified on 25th and 26th October. The acoustic sampling was partially interrupted on 28th-29th October in order to satisfy the R/V’s refueling and provisioning needs. All works at sea were totally interrupted on 30th October because a stormy weather and rough sea. In order to perform the acoustic sampling with daylight, the acoustic sampling started at 06:40-06:45 UTC until 31st October, and at 07:15-07:20 UTC later on, although this time might vary depending on the duration of the works related with the hydrographic sampling the previous night.

Groundtruthing hauls

A total of eighteen (18) fishing operations for echo-trace ground-truthing (all of them were valid according to a correct gear performance and resulting catches), were carried out during the survey (**Table 2**, **Figure 3**). 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. Only one haul was performed over a determined isobath instead of being conducted over the acoustic transect. According to the above, the sampled depth range in the valid hauls oscillated between 25 and 202 m.

During the survey were captured 3 Chondrichthyan, 44 Osteichthyes, 8 Cephalopod, 3 Echinoderm, and several Cnidarian and Ascidian species. The percentage of occurrence of the fish species (sharks excluded) in the hauls is shown in the enclosed Text Table below (see also **Figure 4**). The pelagic ichthyofauna was both 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 and anchovy (both with 78% presence index) and sardine (61%) were the most frequent species in the valid hauls, followed by horse mackerel and bogue (both 56%), mackerel (44%), Mediterranean horse mackerel (39%) and Blue jack mackerel (28%). Round sardinella (17%) and blue whiting (11%) showed very low occurrences. Boarfish, longspine snipefish and pearlside showed an incidental occurrence (6% each) in the hauls performed in the surveyed area.

For the purposes of the acoustic assessment, anchovy, sardine, mackerel species, horse & jack mackerel species, bogue, boarfish, snipefish and pearlside were initially considered as the survey target species. All the invertebrates, skates, rays and benthic fish species 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 fish species were included in an operational category termed as “Others”.

According to the above premises, during the survey were captured a total of 10 889 kg and 182 thousand fish (**Table 3**). Forty nine per cent (49%) of this “total” fished biomass corresponded to sardine, 38% to chub mackerel, 5% to anchovy, 4% to Mediterranean horse mackerel, 1% to horse mackerel and contributions lower than 1% for the remaining species. The most abundant species in ground-truthing trawl hauls was sardine (50%), followed by anchovy (24%), chub mackerel (21%), and horse mackerel (3%), with each of the remaining species accounting for equal to or less than 1%.

The species composition of these fishing hauls (as expressed in terms of percentages in number) is shown in **Figure 4**.

Species	OCCURRENCE (Number of valid hauls)	OCCURRENCE (% over Total valid hauls)	Total weight (Kg)	Total number
Scomber colias	14	78 %	4167,685	37825
Engraulis encrasicolus	14	78 %	559,681	44176
Sardina pilchardus	11	61 %	5357,42	90324
Trachurus trachurus	10	56 %	141,529	1361
Boops boops	10	56 %	15,798	108
Merluccius merluccius	10	56 %	4,072	34
Scomber scombrus	8	44 %	18,903	133
Trachurus mediterraneus	7	39 %	388,923	2007
Spondyliosoma cantharus	7	39 %	13,401	105
Pagellus erythrinus	7	39 %	7,605	44
Trachurus picturatus	5	28 %	66,589	1462
Lepidopus caudatus	5	28 %	0,107	12
Diplodus vulgaris	4	22 %	7,720	41
Spicara flexuosa	4	22 %	3,402	99
Pagellus bellottii bellottii	4	22 %	2,540	29
Pagellus acarne	4	22 %	2,038	15
Sardinella aurita	3	17 %	3,712	15
Pomatomus saltatrix	3	17 %	3,450	10
Diplodus annularis	3	17 %	0,221	5
Brama brama	2	11 %	6,605	15
Diplodus bellottii	2	11 %	4,785	107
Pomadasys incisus	2	11 %	3,875	44
Caranx rhonchus	2	11 %	2,580	8
Stromateus fiatola	2	11 %	1,955	3
Liza ramada	2	11 %	1,620	6
Zeus faber	2	11 %	0,905	2
Sparus aurata	2	11 %	0,862	2
Micromesistius poutassou	2	11 %	0,209	7
Mola mola	1	6 %	49,850	2
Macroramphosus scolopax	1	6 %	18,705	1849
Dentex gibbosus	1	6 %	10,770	2
Sarda sarda	1	6 %	5,455	3
Zenopsis conchifer	1	6 %	1,79	1
Maurolicus muelleri	1	6 %	1,62	1684
Spicara maena	1	6 %	1,55	40
Capros aper	1	6 %	0,962	129
Alosa fallax	1	6 %	0,625	4
Parapristipoma octolineatum	1	6 %	0,262	1
Trachinotus ovatus	1	6 %	0,19	1
Umbrina canariensis	1	6 %	0,131	1
Mullus barbatus	1	6 %	0,128	1
Trachinus draco	1	6 %	0,054	1
Chelidonichthys obscurus	1	6 %	0,038	1

Back-scattering energy attributed to the "pelagic assemblage" and individual species

A total of 305 nmi (ESDU) from 21 transects has been acoustically sampled by echo-integration for assessment purposes. 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	PIL	ANE	MAC	VMA	HOM	HMM	JAA	BOG	BOC	SNS	MAV
TOTAL AREA	149445	82051	24291	22	13402	6722	8536	3590	603	197	5337	4693
%	100	54,9	16,3	0,01	9,0	4,5	5,7	2,4	0,4	0,1	3,6	3,1
Portugal	108617	73657	6033	18	9497	6603	148	3590	421	197	5337	3116
%	72,7	89,8	24,8	82,2	70,9	98,2	1,7	100	69,7	100	100	66,4
Spain	40828	8394	18258	4	3905	119	8388	0	182	0	0	1577
%	27,3	10,2	75,2	17,8	29,1	1,8	98,3	0	30,3	0	0	33,6

For this "pelagic fish assemblage" has been estimated a total of 149 445 m^2 nmi^{-2}, a lower value than the maximum value recorded throughout the time-series the last year (229 241 m^2 nmi^{-2}), but still above the historical mean (120 817 m^2 nmi^{-2}). The highest NASC value (15 415 m^2 nmi^{-2}) was recorded in the inner-shelf waters (50 m) in front of Vila Real de Sto. Antonio (transect R12, **Figure 5**), with relatively high values being also recorded in the inner- and mid-shelf waters (20-123 m depth) of transects R06, R07, R13, R19 and R20. By species, sardine accounted for 55% of this total back-scattered energy, followed by anchovy (16%) and chub mackerel (9%), and the remaining species with relative contributions of acoustic energies lower than 6%.

According to the resulting values of integrated acoustic energy and the availability and representativeness of the length frequency distributions, the species acoustically assessed in the present survey finally were anchovy, sardine, mackerel, chub mackerel, blue jack mackerel, horse mackerel, Mediterranean horse mackerel, bogue, boarfish, 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**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 6**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent strata considered for the acoustic estimation are shown in **Figure 7**. The estimated abundance and biomass by size class are given in **Table 5** and **Figure 8**. **Figure 9** shows the acoustic estimates by age group. **Table 6** shows the time-series of estimates for the whole population and Age-0 fish.

Gulf of Cadiz anchovy (16% of the total NASC attributed to fish) was widely distributed in the surveyed area, although avoided the easternmost waters. Higher densities were mainly recorded in two areas: between Alfanzina and west of Cape Santa Maria, in the Algarve, and between Isla Cristina and Bay of Cadiz (**Figure 7**). The whole size class range for the pooled catches varied between the 2.0 and 18.5 cm size classes, with 3 modal classes, the main mode at 10.0 cm, a secondary mode at 14.5 cm and a third mode at 3.0 cm.

Ten (10) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the representative fishing hauls (**Figure 7**). Overall anchovy acoustic estimates in autumn

2021 were of 1973 million fish and 17 512 tones (**Table 5**; **Figure 8**), entailing 38% and 51% decreases in abundance and biomass, respectively, in relation to the last year's estimates (3197 million, 36 070 t). The current overall estimates are lower than the time-series average (i.e. 3258 million; 25 627 t), (see **Table 6** and **Figure 42**). By geographical strata, the Spanish waters yielded 89% (1763 million) and 76% (13 370 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 211 million and 4143 t (**Table 5; Figure 8**).

The size class range of the assessed anchovy population in autumn 2021 varied between the 2.0 and 18.5 cm size classes. The size distribution showed a mixed composition, with several modal classes, the main mode at 10.0 cm, a secondary mode at 14.0 cm, and less important modes at 8.0 and 3.0 cm size class. It is noticeable the occurrence of this last modal size, as a consequence of the record of very tiny juveniles (size class range: 2.0 – 4.5 cm) in the coastal waters located between Mazagón and Punta Umbría. 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 (**Figures 6** and **8**).

The population was composed by fishes not older than 2 years. Age 0 fish accounted for 83% (1629 million) and 69% (12 063 t) of the total estimated abundance and biomass, respectively (**Table 6**; **Figure 9**). Spanish waters concentrated the bulk (97%) of this juvenile fraction. The estimates of age-0 fish experienced a similar decreasing trend than the one showed by the whole population in relation to the historical peak recorded in 2019 and the values recorded in 2020, but with values close to the time-series average (**Table 6**). Age 1 fish represented 16% and 28% of the total abundance and biomass (**Figure 9**).

The 2021 autumn estimates of mean size and weight of the whole population (11.2 cm, 8.9 g) were somewhat lower than their respective time-series averages (11.3 cm, 9.5 g). Regional mean size and weights in the estimated population were estimated at 14.6 cm and 19.6 g in Portuguese waters and 10.7 cm and 7.6 g in Spanish ones.

Sardine

Parameters of the survey's size-weight relationship for sardine are shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 10**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 11**. Estimated abundance and biomass by size class are given in **Table 7** and **Figure 12**. **Figure 13** shows the acoustic estimates by age group. **Table 8** shows the time-series of estimates for the whole population and Age-0 fish.

GoC sardine recorded a relatively high acoustic echo-integration in autumn 2021 (55% of the total NASC attributed to pelagic fish species assemblage), as a consequence of the occurrence of dense mid-water schools in the Algarve coastal and inner shelf waters (20-78 m), with a main hotspot between Cape Santa María and the Guadiana river mouth and another one between Burgau and Portimão (**Figure 11**). Sardine was widely distributed all over the surveyed area (avoiding the easternmost waters) and, as a consequence of the abovementioned occurrence of dense schools in coastal waters, with very high densities in the inner-middle shelf waters.

The whole size class range for the pooled catches varied between the 10.0 and 21.5 cm size classes, with 2 modal classes, the main mode at 19.0 cm and a secondary mode at 12.5 cm. The size composition of sardine catches 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 Portuguese waters and the smallest (and youngest) ones concentrated in the coastal waters between Chipiona and El Rompido (**Figure 10**).

Five (5) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the fishing hauls (**Figure 11**). GoC sardine abundance and biomass in autumn 2021 were estimated at 2986 million fish and 151 320 t, the second historical record within its respective series, values which, however, entailed 83% and 38% decreases in relation to the last year's estimates (5451 million and 208 400 t, the historical record in the series; **Table 7**, **Figure 12**). Portuguese waters concentrated 82% and 94% of the total estimated abundance and biomass, respectively (2448 million and 142 532 t). The estimates for the Spanish waters were 538 million and 8 788 t.

Sizes of the assessed sardine population in autumn 2021 ranged between 10.0 and 21.5 cm size classes. The length frequency distribution of the population was clearly bimodal, with one main mode at 18.0 cm size class and a secondary one at 12.5 cm (**Table 7**; **Figure 12**).

Age-5 group was the oldest age group occurring in the population, although the occurrence of fishes older than 4 years was relatively low. The population was mainly composed by fishes belonging to the age-0 to age-2 groups. Juvenile sardines (age-0 group) were not the dominant group, accounting for 21% (638 million) and 9% (12 854 t) of the total abundance and biomass, respectively. The bulk of the juvenile fraction (82% of the juvenile total abundance) was recorded in Spanish waters, especially in the relatively shallow waters along the coastal fringe comprised between the Guadiana river mouth and the Bay of Cadiz (**Table 8**; **Figures 10** and **13**).

The 2021 autumn estimates of mean length and weight of the whole population (17.7 cm, 50.6 g), are both higher than both the last year's estimates and the time-series averages (i.e. 15.6 cm, 37.4 g).

Mackerel

Parameters of the survey's length-weight relationship are shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 14**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 15**. Estimated abundance and biomass by size class are given in **Table 9** and **Figure 16**.

Atlantic mackerel (0.01% of the total NASC) showed a main density nucleus in the westernmost Algarve and a relatively lower density in the outer shelf waters off the central zone of the surveyed area (**Figure 15**).

Two (2) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the fishing stations (**Figure 15**). Mackerel abundance and biomass in autumn 2021 in the GoC shelf waters were estimated at only 6 million fish and 803 t (**Table 9**; **Figure 16**). Almost the whole estimated population (84.0% of the total abundance) was located in Portuguese waters (5 million, 675 t). The estimates for the Spanish waters were c.a. 1 million and 128 t.

The size range of the estimated population in autumn 2021 varied between 24.0 and 35.5 cm size classes, with a dominant mode at 24.5 cm size class and a secondary mode at 27.0 cm (**Table 9**; **Figure 16**). No clear spatial pattern in mean size was observed; perhaps the smallest fish were more common in Portuguese waters.

Chub mackerel

Parameters of the survey's length-weight relationship are shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 17**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 18**. Estimated abundance and biomass by size class are given in **Table 10** and **Figure 19**. **Figure 20** shows the acoustic estimates by age group. **Table 11** shows the time-series of estimates for the whole population and Age-0 fish.

Chub mackerel (9% of the total NASC) was widely distributed in the surveyed area, but showing higher densities in three between Cape San Vicente and Mazagón (**Figure 18**). The species' positive hauls did not show a clear spatial pattern in (mean) size. The largest fish were commonly captured in Spanish waters, with smaller fish occurring in Portuguese waters and the smallest ones in the middle-outer shelf waters between Albufeira and Alfanzina (**Table 10**; **Figures 17** and **19**).

Five (5) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the fishing stations (**Figure 18**). Chub mackerel abundance and biomass in the surveyed area were estimated in 106 million fish and 13 115 t, accounting for 64% and 43% strong decreases in relation to the estimates in the previous year (295 million, 22 918 t; **Table 10**, **Figure 19**). Portuguese waters accounted for 81% (86 million) and 62% (8075 t) of the total abundance and biomass, respectively. Spanish waters yielded a population of 21 million and 5040 t.

The size range recorded for the estimated population was comprised between 17.0 and 37.5 cm size classes, showing a very mixed composition, with a dominant modal class at 24.0 cm, a secondary mode at 20.0 cm and less represented modes at 28.0 cm and 32.0 cm size classes. A rather similar size composition is also recorded for the estimated biomass, although the mode at 24.0 cm clearly dominates over the smaller modes (**Table 10**, **Figure 19**). Regional size compositions showed different shapes, with larger modes dominating in the size distribution off Spanish waters whereas smaller modes are the most important in the Portuguese shelf.

The population was composed by fishes not older than 5 years, with the age-1 group being the dominant one (54%, 57 million, and 47%, 6134 t, of the total abundance and biomass estimated in the surveyed area, respectively; **Figure 20**). Age-0 fish was the second most important age group in the estimated population (24%, 26 million fish, and 13%, 1689 t, of the total abundance and biomass estimates). The bulk of the age-0 (99.8%) and age-1 groups (94%) was recorded in the Portuguese waters, whereas older age-groups were more frequent in Spanish waters.

Horse mackerel

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 21**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 22**. Estimated abundance and biomass by size class are given in **Table 12** and **Figure 23**.

Horse mackerel (4.5% of the total NASC) showed a very scattered distribution, with the main density nucleus being located in the western Algarve shelf waters (**Figure 22**).

The size range recorded in positive hauls was comprised between 7.5 and 28.5 cm size classes, with a dominant mode at 18.5 cm size class and a secondary mode at 23.0 cm. Small fish were recorded in the Spanish waters (**Figure 21**).

Six (6) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the fishing hauls (**Figure 22**). Horse mackerel abundance and biomass in the surveyed area were estimated in 59 million fish and 6141 t (**Table 12**, **Figure 23**). Portuguese waters accounted for 97% (57 million) and 99% (6066 t) of the total abundance and biomass, respectively. Spanish waters yielded a population of 2 million and 75 t.

The size range recorded for the estimated population was comprised between 15.5 and 30.5 cm size classes, with two distinct modes, the dominant one at 23.0 cm (exclusively recorded in Portuguese waters) and a secondary mode at 18.0 cm size class (mainly distributed in Spanish waters; **Table 12**, **Figure 23**).

Mediterranean horse-mackerel

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 24**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 25**. Estimated abundance and biomass by size class are given in **Table 13** and **Figure 26**.

Mediterranean horse mackerel (5.7% of the total NASC) was a typically Spanish species in autumn 2021. The species distributed over the Spanish eastern and central waters, not further west than Fuzeta, mainly over the inner-mid shelf waters (**Figure 25**). The size class range for the pooled catches varied between the 20.0 and 39.0 cm size classes, with one modal class at 27.0 cm. No clear spatial pattern in mean size was observed, although the largest fish occurred in the easternmost Spanish waters (**Figure 24**).

Four (4) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the fishing hauls (**Figure 25**). Mediterranean horse mackerel abundance and biomass in the surveyed area were estimated in 47 million fish and 9711 t, with the bulk of the population (99% of abundance and biomass; 47 million, 9595 t) being located in Spanish waters, as usual (**Table 13**, **Figure 26**).

The size range recorded for the estimated population was comprised between 20.0 and 39.0 cm size classes, with at least one clearly distinct mode at 27.0 cm size class, and other secondary modes at 29.5 44.5 cm size class. Largest fish occurred in the easternmost waters of the Spanish shelf, as previously evidenced by the positive hauls raw data (**Table 13**, **Figure 26**).

Blue jack mackerel

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 27**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 28**. Estimated abundance and biomass by size class are given in **Table 14** and **Figure 29**.

Blue jack mackerel (2.4% of the total NASC) was restricted exclusively to the Portuguese waters, showing the highest acoustic densities in the western Algarve shelf waters (**Figure 28**). The size class range for the pooled catches varied between the 15.5 and 23.0 cm size classes. No clear spatial pattern in mean size was observed (**Figure 27**).

Two (2) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the fishing hauls (**Figure 28**). Blue Jack mackerel abundance and biomass in the surveyed area were estimated in 53 million fish and 2236 t, with all the estimated population being located in Portuguese waters (**Table 14**, **Figure 29**).

The size range recorded for the estimated population was comprised between 15.5 and 20.5 cm size classes, with a single modal size class at 17.0 cm (**Table 12**, **Figure 23**).

Bogue

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 30**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 31**. Estimated abundance and biomass by size class are given in **Table 15** and **Figure 32**.

Bogue (0.4% of the total NASC) showed a scattered distribution, showing relatively low acoustic densities, although the highest densities were recorded in the westernmost Algarve shelf waters (**Figure 31**). The size class range for the pooled catches varied between the 10.5 and 34.5 cm size classes, with one modal class at 23.0 cm. No clear spatial pattern in mean size was observed, although the largest fish occurred in the easternmost Spanish waters (**Figure 30**).

Five (5) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the representative fishing hauls (**Figure 31**). Bogue abundance and biomass in the surveyed area were estimated in about 4 million fish and 412 t (**Table 15**, **Figure 32**). Portuguese waters accounted for 71% of both total abundance (3 million) and biomass (291 t), respectively. Spanish waters yielded a population of 1 million and 121 t.

The size range recorded for the estimated population was comprised between 18.5 and 25.0 cm size classes, with one mode at 23.0 cm size class (**Table 15**, **Figure 32**).

Boarfish

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 33**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 34**. Estimated abundance and biomass by size class are given in **Table 16** and **Figure 35**.

The occurrence of boarfish (0.1%) was incidental and restricted to the westernmost Algarve outer shelf waters, co-occurring with longspine snipefish (**Figure 34**). The size range recorded in the only positive haul was comprised between 5.0 and 9.0 cm size classes, with one single modal class at 6.5 cm (**Figure 33**).

One (1) coherent post-stratum has been differentiated according to the S_A value distribution and the size composition in the representative fishing hauls (**Figure 31**). Boarfish abundance and biomass in the surveyed area were estimated in 11 million fish and 21 t, with the whole population being restricted to the westernmost Algarve outer shelf waters (**Table 16**, **Figure 35**).

The size range recorded for the estimated population was comprised between 5.0 and 9.0 cm size classes, with a single mode at 7.5 cm size class (**Table 16**, **Figure 35**).

Longspine snipefish

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 36**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 37**. Estimated abundance and biomass by size class are given in **Table 17** and **Figure 38**.

Comparatively, longspine snipefish (3.6%) showed relatively high acoustic densities, although they were restricted to the westernmost Algarve outer shelf waters (**Figure 37**). The species showed a concurrent distribution with boarfish. The size range recorded in the only positive haul was comprised between 9.0 and 14.5 cm size classes, with 2 modal classes, the main mode at 12.0 cm and a secondary mode at 9.0 cm. No spatial pattern in mean size was observed (**Figure 36**).

One (1) coherent post-stratum, located in the westernmost Algarve outer shelf waters, has been differentiated according to the S_A value distribution and the size composition in the representative fishing hauls (**Figure 37**). Longspine snipefish abundance and biomass in the surveyed area were estimated in 2454 million fish and 78 026 t, as a consequence of the occurrence of a very dense aggregation located over the shelf break in the R20 transect (**Table 17**, **Figure 38**).

The size range recorded for the estimated population was comprised between 9.0 and 14.5 cm size classes, with 2 modal classes, the main mode at 12.0 cm and a secondary mode at 9.0-9.5 cm size classes (**Table 17**, **Figure 38**).

Pearlside

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 39**. The mapping of the backscattering energy (nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species and the coherent post-strata considered for the acoustic estimation are shown in **Figure 40**. Estimated abundance and biomass by size class are given in **Table 18** and **Figure 41**.

Pearlside (3.1%) was relatively common over the shelf break, especially in the western Algarve waters (**Figure 40**). The size range in the only positive haul (Cape Santa Maria area in Portuguese waters) varied between 3.5 and 5.5 cm size class (mode at 4.5 cm size class; **Figure 39**).

Two (2) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the representative fishing hauls (**Figure 40**). Pearlside abundance and biomass in the surveyed area were estimated in 1907 million fish and 2013 t. Portuguese waters accounted for 54% (1023 million, 1080 t) of both the total abundance and biomass, respectively. Spanish waters yielded a population of 884 million and 933 t. (**Table 16**, **Figure 35**).

The size range recorded for the estimated population was comprised between 3.5 and 5.5 cm size classes, with a dominant mode at 4.5 cm size class (**Table 18**, **Figure 41**).

(SHORT) DISCUSSION

The time series of anchovy, sardine and chub mackerel estimates from this survey series are described in **Tables 6**, **8** and **11** and **Figure 42**.

GoC anchovy population in autumn 2021 (1973 million fish, 17 512 t) experienced 38% and 51% decreases in abundance and biomass, respectively, in relation to the last year's autumn estimates (3197 million, 36 070 t; **Table 6**; **Figure 42**). Spanish waters concentrated the bulk of the total estimated abundance and biomass in the Gulf, confirming the importance of these waters in the species' distribution. The current overall estimates are lower than the time-series average (i.e. 3258 million; 25 627 t). Age 0 fish accounted for 83% (1629 million) and 69% (12 063 t) of the total estimated abundance and biomass, respectively (**Table 6**; **Figure 9**). Spanish waters concentrated the bulk (97%) of this juvenile fraction. The estimates of age-0 fish experienced a similar decreasing trend than the one showed by the whole population in relation to the historical peak recorded in 2019 and the values recorded in 2020, but with values close to the time-series average (**Table 6**).

GoC sardine abundance (2986 million fish) and biomass (151 320 t) in autumn 2021 peaked at their second historical maximum within its series, representing however 83% and 38% decreases in relation to the last year's estimates (5451 million and 208 400 t, the historical record in the series; **Table 7**, **Figure 12**). Portuguese waters concentrated the bulk of the total estimated abundance and biomass. The GoC sardine population was mainly composed by fishes belonging to the age-0 to age-2 groups and in a lesser extent by age-3 fish (incidental occurrence of 4 to 5 year old fishes). Juvenile sardines (age-0 group) were not the dominant group, accounting for 21% (638 million) and 9% (12 854 t) of the total abundance and biomass, respectively. The bulk of the juvenile fraction (82% of the juvenile total abundance) was recorded in Spanish waters, especially in the relatively shallow waters along the coastal fringe comprised between the Guadiana river mouth and the Bay of Cadiz (**Table 8**; **Figures 10** and **13**).

Chub mackerel abundance (106 million fish) and biomass (13 115 t) in autumn 2021 experienced 64% and 43% strong decreases in relation to the estimates in the previous year (295 million, 22 918 t; **Table 10**, **Figure 19**), and they are below their respective time-series averages (i.e. 214 million, 15 487 t) (**Table 11**, **Figure 42**). Portuguese waters concentrated the great part of the total population abundance and biomass. The population was composed by fishes not older than 5 years, with the age-1 group being the dominant one (54%, 57 million, and 47%, 6134 t, of the total abundance and biomass estimated in the surveyed area, respectively; **Figure 20**). Age-0 fish was the second most important age group in the estimated population (24%, 26 million fish, and 13%, 1689 t, of the total abundance and biomass estimates). The bulk of the age-0 (99.8%) and age-1 groups (94%) was recorded in the Portuguese waters, whereas older age-groups were more frequent in Spanish waters.

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Table 1. *ECOCADIZ-RECLUTAS 2021-10* survey. 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**	26/10/21	36º 02.01’ N	06º 29.12’ W	13:30	240	36º 13.03’ N	06º 08.84’ W	15:35	23
R02	**Sancti-Petri**	26/10/21	36º 19.31’ N	06º 14.93’ W	6:50	26	36º 08.79’ N	06º 34.30’ W	10:35	204
R03	**Cádiz**	25/10/21	36º 17.40º N	06º 36.24’ W	11:23	181	36º 29.79’ N	06º 18.93’ W	15:09	23
R04	**Rota**	25/10/21					36º 24.53’ N	06º 40.80’ W	10:34	199
R05	**Chipiona**	27/10/21	36º 40.36’ N	06º 29.41’ W	6:46	21	36º 31.25’ N	06º 46.24’ W	10:15	193
R06	**Doñana**	27/10/21	36º 38.00’ N	06º 51.65’ W	11:10	200	36º 46.60’ N	06º 35.70’ W	14:46	19
R07	**Matalascañas**	29/10/21	36º 54.45’ N	06º 38.95’ W	12:20	16	36º 43.90’ N	06º 58.32’ W	16:15	220
R08	**Mazagón**	31/10/21	36º 49.39’ N	07º 06.06’ W	7:25	198	36º 01.08’ N	06º 44.78’ W	11:37	20
R09	**Punta Umbría**	31/10/21	37º 04.30’ N	06º 56.08’ W	13:53	23	36º 49.68’ N	07º 06.55’ W	15:34	198
R10	**El Rompido**	01/11/21	36º 50.03’ N	07º 07.21’ N	7:22	191	37º 07.93’ N	07º 07.21’ W	11:18	18
R11	**Isla Cristina**	01/11/21	37º 06.84’ N	07º 17.06’ W	13:57	22	36º 53.47’ W	07º 17.14’ W	15:16	200
R12	**V.R. do Sto. Antonio**	02/11/21	37º 06.35’ N	7º 17.26’ W	7:16	18	36º 56.26’ N	07º 27.11’W	10:18	202
R13	**Tavira**	02/11/21	36º 57.10’ N	07º 37.12’ W	11:05	189	37º 05.19’ N	07º 37.17’ W	11:55	16
R14	**Fuzeta**	02/11/21	36º 59.27’ N	07º 46.96’ W	14:33	42	36º 55.48’ N	07º 47.02’ W	14:55	193
R15	**Cabo Sta. María**	03/11/21	36º 56.13’ N	07º 56.99’ W	7:21	51	36º 52.15’ N	07º 56.91’ W	7:46	187
R16	**Cuarteira**	03/11/21	37º 01.77’ N	08º 07.05’ W	10:19	19	36º 49.82’ N	08º 06.85’ W	11:41	162
R17	**Albufeira**	04/11/21	36º 49.39’ N	08º 16.83’ W	7:22	196	36º 01.8’ N	08º 17.01’ W	8:36	21
R18	**Alfanzina**	04/11/21	37º 04.30’ N	<u>08º 26.99’ W</u>	11:34	24	36º 50.23’ W	08º 26.69’ W	14:57	209
R19	**Portimão**	05/11/21	37º 06.02’ N	08º 37.07’ W	7:36	21	36º 51.88’ W	08º 36.62’ W	9:01	148
R20	**Burgau**	05/11/21	36º 51.17’ N	08º 46.68’ W	9:52	217	37º 02.47’ N	08º 46.96’ W	13:31	45
R21	**Punta de Sagres**	06/11/21	36º 59.13’ N	08º 56º.79’ W	7:07	24	36º 50.56’ N	8º 56.58’ W	8:01	206

Table 2. *ECOCADIZ-RECLUTAS 2021-10* survey. Descriptive characteristics of the fishing hauls.

Fishing haul	Date	Start		End		UTC Time		Depth (m)		Duration (min)		Trawled Distance (nm)	Acoustic Transect	Zone (landmark)
		Latitude	Longitude	Latitude	Longitude	Start	End	Start	End	Effective Trawling	Total Manoeuvre			
1	25-10-2021	36º 27.8394 N	6º 34.7840 W	83,46	36º 28.9480 N	6º 32.7166 W	68,48	08:47	09:14	00:27	01:13	2,002	R04	Rota
2	25-10-2021	36º 23.6390 N	6º 24.7175 W	51,45	36º 21.5517 N	6º 28.5754 W	69,28	12:53	13:44	00:50	01:24	3,748	R03	Cádiz
3	26-10-2021	36º 15.6718 N	6º 21.7453 W	47,41	36º 16.7514 N	6º 19.0876 W	40,79	08:09	08:41	00:32	01:11	2,404	R02	Sancti-Petri
4	26-10-2021	36º 09.3423 N	6º 33.4767 W	156,46	36º 10.5130 N	6º 31.3233 W	116,12	11:17	11:46	00:28	01:27	2,099	R02	Sancti-Petri
5	27-10-2021	36º 36.3974 N	6º 36.7585 W	57,78	36º 38.0278 N	6º 33.7723 W	38,16	07:54	08:34	00:39	01:17	2,903	R05	Chipiona
6	27-10-2021	36º 40.5672 N	6º 46.9273 W	94,71	36º 38.8771 N	6º 49.7937 W	120,81	12:05	12:46	00:40	01:28	2,858	R06	Doñana
7	29-10-2021	36º 50.6064 N	6º 46.4508 W	41,17	36º 52.1859 N	6º 43.6623 W	24,89	13:35	14:12	00:37	01:13	2,738	R07	Matalascañas
8	31-10-2021	36º 53.9092 N	6º 56.8250 W	79,98	36º 52.3850 N	7º 00.6593 W	101,41	08:42	09:20	00:38	01:26	3,432	R08	Mazagón
9	30-10-2021	36º 59.6417 N	6º 47.3898 W	26,91	36º 57.9788 N	6º 50.3552 W	36,97	12:06	12:46	00:40	01:10	2,899	R08	Mazagón
10	01-11-2021	36º 52.3377 N	7º 07.1216 W	123,59	36º 49.9269 N	7º 07.0607 W	201,96	08:10	08:42	00:32	01:26	2,408	R10	El Rompido
11	01-11-2021	37º 05.5373 N	7º 07.0416 W	26,3	37º 03.0531 N	7º 06.5738 W	42,23	12:02	12:36	00:33	01:04	2,509	R10	El Rompido
12	02-11-2021	37º 03.4301 N	7º 27.0741 W	59,9	37º 05.4515 N	7º 27.0567 W	29,39	08:03	08:29	00:26	01:24	2,019	R12	Vila Real do Santo Antonio
13	02-11-2021	37º 00.4410 N	7º 36.9744 W	94,78	36º 58.6553 N	7º 36.9066 W	108,48	12:33	12:57	00:24	01:18	1,784	R13	Tavira
14	03-11-2021	36º 52.6355 N	7º 56.9689 W	102,88	36º 55.2322 N	7º 57.3097 W	66,44	08:13	08:51	00:37	01:22	2,608	R15	Cabo de Santa María
15	03-11-2021	36º 53.9360 N	8º 06.0203 W	87,49	36º 53.9802 N	8º 07.0103 W	84,58	12:48	12:58	00:10	00:55	0,795	R16	Cuarteira
16	04-11-2021	36º 59.1968 N	8º 16.8204 W	45,5	36º 56.3192 N	8º 16.8261 W	72,19	09:09	09:49	00:40	01:22	2,874	R17	Albufeira
17	04-11-2021	36º 54.3264 N	8º 26.7825 W	115,8	36º 57.0316 N	8º 26.7953 W	89,08	13:01	13:39	00:37	01:23	2,702	R18	Alfanzina
18	05-11-2021	36º 54.5772 N	8º 46.6952 W	110,12	36º 57.6744 N	8º 46.7128 W	92,32	11:59	12:41	00:42	01:23	3,093	R20	Burgau

Table 3. *ECOCADIZ-RECLUTAS 2021-10* survey. Catches by species in number (upper panel) and weight (in kg, lower panel) from valid fishing stations.

Fishing haul	CATCH IN NUMBER													
	Anchovy	*Sardine*	*Round sardin.*	*Chub mack.*	*Mackerel*	*Blue Jack mack.*	*Horse-mack.*	*Medit. Horse-mack.*	*Atlantic pomfret*	*Bogue*	*Boarfish*	*Snipefish*	*Pearlside*	**Other spp.**	**TOTAL**
01	1629	1	0	0	0	0	0	0	0	0	0	0	0	1	**1631**
02	0	0	12	244	0	0	0	229	0	19	0	0	0	1	**505**
03	0	0	0	1	0	0	8	81	0	0	0	0	0	155	**245**
04	0	0	0	0	0	0	0	0	0	0	0	0	0	2	**2**
05	820	2024	0	3	0	0	0	168	0	4	0	0	0	22	**3041**
06	17535	238	0	0	4	0	0	0	0	0	0	0	0	7	**17784**
07	0	780	2	44	0	0	14	997	0	1	0	0	0	141	**1979**
08	3181	20	0	2	4	0	0	0	0	0	0	0	0	3	**3210**
09	2776	362	1	879	0	0	3	464	0	5	0	0	0	115	**4605**
10	8505	0	0	0	2	0	0	0	14	0	0	0	0	2	**8523**
11	250	712	0	15	0	0	4	36	0	1	0	0	0	14	**1032**
12	170	74413	0	130	0	0	10	32	0	22	0	0	0	85	**74862**
13	94	4860	0	35853	0	509	55	0	0	12	0	0	0	9	**41392**
14	988	0	0	27	6	25	30	0	0	2	0	0	1684	18	**2780**
15	902	0	0	1	17	0	0	0	1	0	0	0	0	4	**925**
16	66	5979	0	554	9	925	1010	0	0	39	0	0	0	30	**8612**
17	7247	0	0	56	81	1	224	0	0	3	0	0	0	21	**7633**
18	13	935	0	16	10	2	3	0	0	0	129	1849	0	8	**2965**
TOTAL	**44176**	**90324**	**15**	**37825**	**133**	**1462**	**1361**	**2007**	**15**	**108**	**129**	**1849**	**1684**	**638**	**181726**

Table 3. *ECOCADIZ-RECLUTAS 2021-10* survey. Cont'd.

Fishing haul	CATCH IN WEIGHT (kg)														
	Anchovy	*Sardine*	*Round sardin.*	*Chub mack.*	*Mackerel*	*Blue Jack mack.*	*Horse-mack.*	*Medit. Horse-mack.*	*Atlantic pomfret*	*Bogue*	*Boarfish*	*Snipefish*	*Pearlside*	Other spp.	TOTAL
01	15,780	0,022	0	0	0	0	0	0	0	0	0	0	0	0,089	**15,891**
02	0	0	3,220	89,325	0	0	0	49,020	0	5,700	0	0	0	0,090	**147,355**
03	0	0	0	0,422	0	0	0,432	17,636	0	0	0	0	0	27,855	**46,345**
04	0	0	0	0	0	0	0	0	0	0	0	0	0	49,850	**49,850**
05	2,790	37,940	0	0,277	0	0	0	38,880	0	0,800	0	0	0	6,935	**87,622**
06	118,21	5,740	0	0	0,615	0	0	0	0	0	0	0	0	5,435	**130,000**
07	0	14,600	0,380	9,386	0	0	0,902	182,860	0	0,109	0	0	0	14,186	**222,423**
08	21,860	0,352	0	0,235	0,730	0	0	0	0	0	0	0	0	0,338	**23,515**
09	10,340	6,080	0,112	194,720	0	0	0,070	87,990	0	0,735	0	0	0	14,484	**314,531**
10	156,310	0	0	0	0,270	0	0	0	6,205	0	0	0	0	0,018	**162,803**
11	2,0150	11,690	0	4,230	0	0	0,230	6,765	0	0,070	0	0	0	2,532	**27,532**
12	2,048	4527,074	0	13,880	0	0	0,261	5,772	0	2,113	0	0	0	3,719	**4554,867**
13	1,678	324,842	0	3806,339	0	24,425	2,349	0	0	1,431	0	0	0	1,101	**4162,165**
14	17,130	0	0	2,830	1,115	1,330	4,950	0	0	0,405	0	0	1,620	2,743	**32,123**
15	17,600	0	0	0,083	2,530	0	0	0	0,400	0	0	0	0	0,066	**20,679**
16	1,230	359,620	0	37,650	1,470	40,600	105,910	0	0	4,045	0	0	0	6,283	**556,808**
17	192,260	0	0	6,675	10,945	0,059	26,020	0	0	0,390	0	0	0	1,391	**237,740**
18	0,430	69,460	0	1,633	1,228	0,175	0,405	0	0	0	0,962	18,705	0	3,305	**96,303**
TOTAL	**559,681**	**5357,420**	**3,712**	**4167,685**	**18,903**	**66,589**	**141,529**	**388,923**	**6,605**	**15,798**	**0,962**	**18,705**	**1,620**	**140,42**	**10888,552**

Table 4. *ECOCADIZ-RECLUTAS 2021-10* survey. Parameters of the size-weight relationships for the survey's target species susceptible of being assessed. FAO codes for the species: ANE: *Engraulis encrasicolus*; PIL: *Sardina pilchardus*; VAM: *Scomber colias*; MAC: S. *scombrus*; JAA: *Trachurus picturatus*; HOM: *T. trachurus*; HMM: *T. mediterraneus*; BOG: *Boops boops*; POA: *Brama brama*; BOC: *Capros aper*; SNS: *Macroramphosus scolopax*; MAV: *Maurolicus muelleri*.

Parameter	ANE	PIL	SAA	VAM	MAC	JAA	HOM	HMM	POA	BOG	BOC	SNS	MAV
Size range (mm)	27 - 193	104 - 216	260 - 344	182 - 374	240 - 357	162 - 232	69 - 308	200 - 415	342 - 400	181 - 345	91 - 141	54 - 90	35 - 55
n	685	464	13	406	101	128	180	301	14	85	150	129	151
a	0.003213570	0.002008436	0.002717708	0.001264585	0.002786321	0.005100145	0.008084745	0.066215667	0.017383890	0.006246972	0.005225102	0.027534889	0.037865257
b	3.250660	3.503799	3.311204	3.577470	3.296999	3.133309	3.011662	2.386548	2.803991	3.144430	3.014743	2.856752	2.086193
r^2	0.9947721	0.9607988	0.8205893	0.9885517	0.9343625	0.9502970	0.9817678	0.9156734	0.8094138	0.9726588	0.8784573	0.9309560	0.7588735

Table 5. *ECOCADIZ-RECLUTAS 2021-10* 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 7**.

ECOCADIZ-RECLUTAS 2021-10 . Engraulis encrasicolus . ABUNDANCE (in numbers and million fish)																
Size class	POL01	POL02	POL03	POL04	POL05	POL06	POL07	POL08	POL09	POL10	*n*			Millions		
											PORTUGAL	SPAIN	TOTAL	PORTUGAL	SPAIN	TOTAL
2	0	0	0	0	0	0	0	3712239	0	0	0	3712239	3712239	0	4	4
2,5	0	0	0	0	0	0	0	4242559	0	0	0	4242559	4242559	0	4	4
3	0	0	0	0	0	0	0	8485117	0	0	0	8485117	8485117	0	8	8
3,5	0	0	0	0	0	0	0	1590959	0	0	0	1590959	1590959	0	2	2
4	0	0	0	0	0	0	0	2651599	0	0	0	2651599	2651599	0	3	3
4,5	0	0	0	0	0	0	0	1590959	0	0	0	1590959	1590959	0	2	2
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	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	0	0	0
7	0	0	0	0	0	0	0	0	563418	0	0	563418	563418	0	1	1
7,5	0	0	0	0	0	0	1750645	0	18592806	0	0	20343451	20343451	0	20	20
8	0	0	0	0	0	0	2848854	0	56905254	0	0	59754108	59754108	0	60	60
8,5	0	0	0	0	0	0	13466076	0	32114847	0	0	45580923	45580923	0	46	46
9	0	0	0	0	0	0	76785171	655922	5070765	0	0	82511858	82511858	0	83	83
9,5	0	0	0	0	60520	0	279735115	990861	1126837	0	60520	281852813	281913333	0,1	282	282
10	0	0	0	0	30260	0	296143954	1646783	0	3060960	30260	300851697	300881957	0,03	301	301
10,5	0	0	0	0	121041	0	230410511	1646783	1126837	23416342	121041	256600473	256721514	0,1	257	257
11	0	0	0	0	60520	0	153764282	4605409	0	82645912	60520	241015603	241076123	0,1	241	241
11,5	0	0	0	0	166431	0	115494696	2302705	0	65504538	166431	183301939	183468370	0,2	183	183
12	0	95104	0	76	469034	25685	79573472	3628504	0	42853436	564214	126081097	126645311	1	126	127
12,5	0	895993	0	713	499294	241983	33933387	990861	0	18671854	1396000	53838085	55234085	1	54	55
13	100950	13469141	17531	10712	817026	3637636	21629070	0	0	9335927	14415360	34602633	49017993	14	35	49
13,5	988946	30978548	171742	24638	257212	8366434	1750645	0	0	2295720	32421086	12412799	44833885	32	12	45
14	3486321	54263641	605439	43157	90781	14655082	2848854	0	0	0	58489339	17503936	75993275	58	18	76
14,5	6467734	42698538	1123196	33959	0	11531673	1750645	0	0	1530480	50323427	14812798	65136225	50	15	65
15	7711698	18013336	1339224	14326	0	4864895	1098209	0	0	0	27078584	5963104	33041688	27	6	33
15,5	5960717	5557637	1035146	4420	0	1500961	0	0	0	0	12557920	1500961	14058881	13	2	14
16	3474428	3700093	603374	2943	0	999291	0	0	0	0	7780838	999291	8780129	8	1	9
16,5	1905543	330377	330919	263	0	89225	0	0	0	0	2567102	89225	2656327	3	0,1	3
17	1317458	188787	228792	150	0	50986	0	0	0	0	1735187	50986	1786173	2	0,1	2
17,5	522423	94393	90725	75	0	25493	0	0	0	0	707616	25493	733109	1	0,03	1
18	68523	0	11900	0	0	0	0	0	0	0	80423	0	80423	0,1	0	0,1
18,5	33156	0	5758	0	0	0	0	0	0	0	38914	0	38914	0,04	0	0,04
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL *n*	32037897	170285588	5563746	135432	2572119	45989344	1312983586	38741260	115500764	249315169	210594782	1762530123	1973124905	**211**	**1763**	**1973**
Millions	**32**	**170**	**6**	**0,1**	**3**	**46**	**1313**	**39**	**116**	**249**	**211**	**1763**	**1973**			

Table 5. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*E. encrasicolus*). Cont'd.

ECOCADIZ-RECLUTAS 2021-10 . Engraulis encrasicolus . BIOMASS (t)													
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**POL06**	**POL07**	**POL08**	**POL09**	**POL10**	**PORTUGAL**	**SPAIN**	**TOTAL**
2	0	0	0	0	0	0	0	0,167	0	0	0	0,167	0,167
2,5	0	0	0	0	0	0	0	0,365	0	0	0	0,365	0,365
3	0	0	0	0	0	0	0	1,258	0	0	0	1,258	1,258
3,5	0	0	0	0	0	0	0	0,376	0	0	0	0,376	0,376
4	0	0	0	0	0	0	0	0,940	0	0	0	0,940	0,940
4,5	0	0	0	0	0	0	0	0,810	0	0	0	0,810	0,810
5	0	0	0	0	0	0	0	0	0	0	0	0	0
5,5	0	0	0	0	0	0	0	0	0	0	0	0	0
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	1,134	0	0	1,134	1,134
7,5	0	0	0	0	0	0	4,375	0	46,468	0	0	50,843	50,843
8	0	0	0	0	0	0	8,724	0	174,269	0	0	182,993	182,993
8,5	0	0	0	0	0	0	49,932	0	119,081	0	0	169,013	169,013
9	0	0	0	0	0	0	341,086	2,914	22,525	0	0	366,525	366,525
9,5	0	0	0	0	0,319	0	1474,526	5,223	5,940	0	0,319	1485,689	1486,008
10	0	0	0	0	0,188	0	1836,582	10,213	0	18,983	0,188	1865,778	1865,966
10,5	0	0	0	0	0,876	0	1668,200	11,923	8,158	169,537	0,876	1857,818	1858,694
11	0	0	0	0	0,508	0	1290,573	38,654	0	693,663	0,508	2022,890	2023,398
11,5	0	0	0	0	1,609	0	1116,552	22,262	0	633,269	1,609	1772,083	1773,692
12	0	1,053	0	0,001	5,192	0,284	880,879	40,168	0	474,388	6,246	1395,719	1401,965
12,5	0	11,296	0	0,009	6,295	3,051	427,812	12,492	0	235,403	17,60	678,758	696,358
13	1,442	192,429	0,250	0,153	11,673	51,970	309,007	0	0	133,379	205,947	494,356	700,303
13,5	15,937	499,211	2,768	0,397	4,145	134,823	28,211	0	0	36,995	522,458	200,029	722,487
14	63,098	982,102	10,958	0,781	1,643	265,238	51,561	0	0	0	1058,582	316,799	1375,381
14,5	130,944	864,463	22,740	0,688	0	233,467	35,443	0	0	30,986	1018,835	299,896	1318,731
15	173,999	406,434	30,217	0,323	0	109,766	24,779	0	0	0	610,973	134,545	745,518
15,5	149,361	139,261	25,938	0,111	0	37,611	0	0	0	0	314,671	37,611	352,282
16	96,370	102,63	16,736	0,082	0	27,717	0	0	0	0	215,818	27,717	243,535
16,5	58,326	10,112	10,129	0,008	0	2,731	0	0	0	0	78,575	2,731	81,306
17	44,372	6,358	7,706	0,005	0	1,717	0	0	0	0	58,441	1,717	60,158
17,5	19,308	3,489	3,353	0,003	0	0,942	0	0	0	0	26,153	0,942	27,095
18	2,772	0	0,481	0	0	0	0	0	0	0	3,253	0	3,253
18,5	1,464	0	0,254	0	0	0	0	0	0	0	1,718	0	1,718
19	0	0	0	0	0	0	0	0	0	0	0	0	0
19,5	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**757,393**	**3218,838**	**131,530**	**2,561**	**32,448**	**869,317**	**9548,242**	**147,765**	**377,575**	**2426,603**	**4142,770**	**13369,502**	**17512,272**

Table 6. *ECOCADIZ-RECLUTAS* surveys series. Anchovy (*E. encrasicolus*). Acoustic estimates of biomass (t) and abundance (million fish) for the whole Gulf of Cadiz anchovy population and for the juvenile fraction (*i.e*. age 0 fish, between parentheses). Note that the 2012 survey only surveyed the Spanish waters. The 2017 estimates correspond to an incomplete coverage (only the seven easternmost transects) of the standard surveyed area due to a research vessels' breakdown.

Estimate/Year	Total Population (Recruits at age 0)								
	2012	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Biomass (t)	13680 (13354)	8113 (5131)	30827 (29219)	19861 (15969)	7642 (7290)	10493 (3834)	48357 (36405)	36070 (21060)	17512 (12063)
Abundance (millions)	2469 (2619)	986 (814)	5227 (5117)	3667 (3445)	1492 (1433)	953 (543)	5505 (4845)	3197 (2385)	1973 (1629)

Table 7. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina 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 11**.

***ECOCADIZ-RECLUTAS 2021-10* . *Sardina pilchardus* . ABUNDANCE (in numbers and million fish)**											
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	***n***			**Millions**		
						PORTUGAL	**SPAIN**	**TOTAL**	**PORTUGAL**	**SPAIN**	**TOTAL**
8	0	0	0	0	0	0	0	0	0	0	0
8,5	0	0	0	0	0	0	0	0	0	0	0
9	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
10	0	0	0	371003	0	0	371003	371003	0,00	0	0
10,5	0	0	0	1669512	0	0	1669512	1669512	0,0	2	2
11	0	0	0	9779828	0	0	9779828	9779828	0,0	10	10
11,5	0	63241	95937	46569152	121920	159178	46691072	46850250	0,2	47	47
12	0	84321	127916	122853804	284481	212237	123138285	123350522	0	123	123
12,5	0	252964	383749	151718034	1137925	636713	152855959	153492672	1	153	153
13	0	1016070	1541390	108500302	1584966	2557460	110085268	112642728	3	110	113
13,5	0	1058231	1605348	29847214	934724	2663579	30781938	33445517	3	31	33
14	0	1226873	1861180	13805319	1300485	3088053	15105804	18193857	3	15	18
14,5	0	695650	1055308	9588810	1219205	1750958	10808015	12558973	2	11	13
15	0	274044	415728	8847975	650243	689772	9498218	10187990	1	9	10
15,5	0	2174073	3298093	12217421	812803	5472166	13030224	18502390	5	13	19
16	0	4813326	7301869	4733619	447042	12115195	5180661	17295856	12	5	17
16,5	0	38113987	57819343	3378984	487682	95933330	3866666	99799996	96	3,9	100
17	0	96855106	146930276	2389888	528322	243785382	2918210	246703592	244	2,9	247
17,5	924790	138311454	209820019	756386	162561	349056263	918947	349975210	349	0,92	350
18	2774369	148113529	224689876	1095045	0	375577774	1095045	376672819	375,6	1	376,7
18,5	12106338	137508501	208601931	0	0	358216770	0	358216770	358,22	0	358,22
19	17823220	136821379	207559559	0	0	362204158	0	362204158	362	0	362,204158
19,5	21522378	126992904	192649652	185501	0	341164934	185501	341350435	341	0	341,350435
20	15553281	61232531	92890433	0	0	169676245	0	169676245	170	0	169,676245
20,5	5464666	41658883	63196990	0	0	110320539	0	110320539	110	0	110,320539
21	2017723	3921788	5949396	0	0	11888907	0	11888907	12	0	11,888907
21,5	420359	0	0	0	0	420359	0	420359	0	0	0,420359
22	0	0	0	0	0	0	0	0	0	0	0
TOTAL *n*	78607124	941188855	1427793993	528307797	9672359	2447589972	537980156	2985570128	**2448**	**538**	**2986**
Millions	**79**	**941**	**1428**	**528**	**10**	**2448**	**538**	**2986**			

Table 7. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina pilchardus*). Cont'd.

ECOCADIZ-RECLUTAS 2021-10 . *Sardina pilchardus* . BIOMASS (t)								
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**PORTUGAL**	**SPAIN**	**TOTAL**
8	0	0	0	0	0	0	0	0
8,5	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
9,5	0	0	0	0	0	0	0	0
10	0	0	0	2,539	0	0	2,539	2,539
10,5	0	0	0	13,523	0	0	13,523	13,523
11	0	0	0	93,050	0	0	93,050	93,050
11,5	0	0,702	1,065	516,834	1,353	1,767	518,187	519,954
12	0	1,085	1,645	1580,237	3,659	2,730	1583,896	1586,626
12,5	0	3,749	5,687	2248,472	16,864	9,436	2265,336	2274,772
13	0	17,255	26,177	1842,601	26,917	43,432	1869,518	1912,950
13,5	0	20,490	31,083	577,914	18,099	51,573	596,013	647,586
14	0	26,958	40,895	303,340	28,575	67,853	331,915	399,768
14,5	0	17,270	26,199	238,055	30,268	43,469	268,323	311,792
15	0	7,656	11,614	247,183	18,166	19,270	265,349	284,619
15,5	0	68,086	103,287	382,615	25,455	171,373	408,070	579,443
16	0	168,378	255,432	165,590	15,638	423,810	181,228	605,038
16,5	0	1484,314	2251,721	131,591	18,992	3736,035	150,583	3886,618
17	0	4185,950	6350,133	103,288	22,833	10536,083	126,121	10662,204
17,5	44,223	6614,047	10033,584	36,170	7,774	16691,854	43,944	16735,798
18	146,383	7814,854	11855,221	57,777	0	19816,458	57,777	19874,235
18,5	702,913	7983,954	12111,748	0	0	20798,615	0	20798,615
19	1135,908	8719,888	13228,168	0	0	23083,964	0	23083,964
19,5	1502,028	8862,722	13444,847	12,946	0	23809,597	12,946	23822,543
20	1185,918	4668,901	7082,775	0	0	12937,594	0	12937,594
20,5	454,259	3462,957	5253,345	0	0	9170,561	0	9170,561
21	182,480	354,681	538,055	0	0	1075,216	0	1075,216
21,5	41,280	0	0	0	0	41,280	0	41,280
22	0	0	0	0	0	0	0	0
TOTAL	**5395,392**	**54483,897**	**82652,681**	**8553,725**	**234,593**	**142531,970**	**8788,318**	**151320,288**

Table 8. *ECOCADIZ-RECLUTAS* surveys series. Sardine (*Sardina pilchardus*). Acoustic estimates of biomass (t) and abundance (million fish) for the whole Gulf of Cadiz anchovy population and for the juvenile fraction (*i.e*. age 0 fish, between parentheses). Note that the 2012 survey only surveyed the Spanish waters. The 2017 estimates correspond to an incomplete coverage (only the seven easternmost transects) of the standard surveyed area due to a research vessels' breakdown.

Estimate/Year	**Total Population (Recruits at age 0)**								
	2012	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Biomass (t)	22119 (9182)	36571 (705)	30992 (8645)	35173 (21899)	12119 (8778)	20679 (15224)	36465 (7858)	208400 (49259)	151320 (12854)
Abundance (millions)	603 (359)	507 (26)	861 (509)	2379 (1940)	591 (483)	1134 (1036)	937 (384)	5451 (2454)	2986 (638)

Table 9. *ECOCADIZ-RECLUTAS 2021-10* survey. Atlantic mackerel (*Scomber scombrus*). 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 15**.

***ECOCADIZ-RECLUTAS 2021-10 . Scomber scombrus* . ABUNDANCE (in numbers and million fish)**								
Size class	**POL01**	**POL02**	***n***			**Millions**		
			PORTUGAL	**SPAIN**	**TOTAL**	**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	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0
17,5	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0
18,5	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0
19,5	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0
20,5	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0
21,5	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0
22,5	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0
23,5	0	0	0	0	0	0	0	0
24	506504	96128	506504	96128	602632	0,506504	0,1	1
24,5	949694	180240	949694	180240	1129934	0,949694	0,2	1
25	886381	168224	886381	168224	1054605	0,886381	0,2	1
25,5	823068	156208	823068	156208	979276	0,823068	0,2	1
26	633130	120160	633130	120160	753290	0,63313	0,1	1
26,5	316565	60080	316565	60080	376645	0,316565	0,1	0,4
27	506504	96128	506504	96128	602632	0,506504	0,1	1
27,5	189939	36048	189939	36048	225987	0,2	0,04	0,2
28	0	0	0	0	0	0	0	0
28,5	126626	24032	126626	24032	150658	0,1	0,02	0,2
29	0	0	0	0	0	0	0	0
29,5	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
30,5	0	0	0	0	0	0	0	0
31	63313	12016	63313	12016	75329	0,063313	0,01	0,1
31,5	63313	12016	63313	12016	75329	0,063313	0,01	0,1
32	0	0	0	0	0	0	0	0
32,5	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0
33,5	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0
34,5	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0
35,5	63313	12016	63313	12016	75329	0,1	0,01	0,1
36	0	0	0	0	0	0	0	0
36,5	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0
37,5	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0
TOTAL *n*	5128350	973296	5128350	973296	6101646	**5**	**1**	**6**
Millions	**5**	**1**						

Table 9. *ECOCADIZ-RECLUTAS 2021-10* survey. Atlantic mackerel (*Scomber scombrus*). Cont'd.

ECOCADIZ-RECLUTAS 2021-10 . Scomber scombrus . BIOMASS (t)					
Size class	**POL01**	**POL02**	**PORTUGAL**	**SPAIN**	**TOTAL**
14	0	0	0	0	0
14,5	0	0	0	0	0
15	0	0	0	0	0
15,5	0	0	0	0	0
16	0	0	0	0	0
16,5	0	0	0	0	0
17	0	0	0	0	0
17,5	0	0	0	0	0
18	0	0	0	0	0
18,5	0	0	0	0	0
19	0	0	0	0	0
19,5	0	0	0	0	0
20	0	0	0	0	0
20,5	0	0	0	0	0
21	0	0	0	0	0
21,5	0	0	0	0	0
22	0	0	0	0	0
22,5	0	0	0	0	0
23	0	0	0	0	0
23,5	0	0	0	0	0
24	51,881	9,846	51,881	9,846	61,727
24,5	104,047	19,747	104,047	19,747	123,794
25	103,731	19,687	103,731	19,687	123,418
25,5	102,754	19,501	102,754	19,501	122,255
26	84,216	15,983	84,216	15,983	100,199
26,5	44,810	8,504	44,810	8,504	53,314
27	76,211	14,464	76,211	14,464	90,675
27,5	30,345	5,759	30,345	5,759	36,104
28	0	0	0	0	0
28,5	22,734	4,315	22,734	4,315	27,049
29	0	0	0	0	0
29,5	0	0	0	0	0
30	0	0	0	0	0
30,5	0	0	0	0	0
31	14,964	2,840	14,964	2,840	17,804
31,5	15,768	2,993	15,768	2,993	18,761
32	0	0	0	0	0
32,5	0	0	0	0	0
33	0	0	0	0	0
33,5	0	0	0	0	0
34	0	0	0	0	0
34,5	0	0	0	0	0
35	0	0	0	0	0
35,5	23,317	4,425	23,317	4,425	27,742
36	0	0	0	0	0
36,5	0	0	0	0	0
37	0	0	0	0	0
37,5	0	0	0	0	0
38	0	0	0	0	0
TOTAL	**674,778**	**128,064**	**674,778**	**128,064**	**802,842**

Table 10. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber 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 18**.

***ECOCADIZ-RECLUTAS 2021-10* . *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	0	0	0	0	0	0	0	0	0
17	0	52029	0	0	0	52029	0	52029	0,1	0	0,1
17,5	0	52029	0	0	0	52029	0	52029	0,1	0	0,1
18	339195	208116	2864	0	0	547311	2864	550175	1	0,003	1
18,5	0	52029	0	0	0	52029	0	52029	0,1	0	0,1
19	46622	1664924	394	0	0	1711546	394	1711940	2	0,0004	2
19,5	46622	5463033	394	0	0	5509655	394	5510049	6	0,0004	6
20	479249	7023899	4047	0	0	7503148	4047	7507195	8	0,004	8
20,5	1239291	5723177	10465	0	0	6962468	10465	6972933	7	0,01	7
21	1310195	4058253	11063	0	0	5368448	11063	5379511	5	0,01	5
21,5	2654696	2341300	22417	0	0	4995996	22417	5018413	5	0,02	5
22	3982044	728404	33625	0	0	4710448	33625	4744073	5	0,03	5
22,5	5279736	780433	44583	0	0	6060169	44583	6104752	6	0,04	6
23	4759739	312173	40192	0	0	5071912	40192	5112104	5	0,04	5
23,5	6635979	156087	56035	0	0	6792066	56035	6848101	7	0,1	7
24	10518954	52029	88823	16389	0	10570983	105212	10676195	11	0,1	11
24,5	9863779	156087	83291	90138	0	10019866	173429	10193295	10	0,2	10
25	3602220	0	30418	40972	0	3602220	71390	3673610	4	0,1	4
25,5	3723927	0	31445	335782	0	3723927	367227	4091154	4	0,4	4
26	1251070	0	10564	466892	0	1251070	477456	1728526	1	0,5	2
26,5	479592	0	4050	467078	0	479592	471128	950720	0,5	0,5	1
27	432969	0	3656	688139	0	432969	691795	1124764	0,4	1	1
27,5	46622	0	394	1793445	0	46622	1793839	1840461	0,05	2	2
28	0	0	0	2333714	23062	0	2356776	2356776	0	2	2
28,5	0	0	0	2153624	0	0	2153624	2153624	0	2	2
29	292229	0	2468	1981543	0	292229	1984011	2276240	0,3	2	2
29,5	0	0	0	2031081	0	0	2031081	2031081	0	2	2
30	0	0	0	630779	92249	0	723028	723028	0	1	1
30,5	0	0	0	557030	207560	0	764590	764590	0	1	1
31	0	0	0	483280	253685	0	736965	736965	0	1	1
31,5	0	0	0	73749	576556	0	650305	650305	0	1	1
32	0	0	0	204673	922490	0	1127163	1127163	0	1	1
32,5	0	0	0	40972	945552	0	986524	986524	0	1	1
33	0	0	0	0	876365	0	876365	876365	0	1	1
33,5	0	0	0	0	530432	0	530432	530432	0	1	0,5
34	0	0	0	16389	415120	0	431509	431509	0	0,4	0,4
34,5	0	0	0	0	276747	0	276747	276747	0	0,3	0,3
35	0	0	0	0	138373	0	138373	138373	0	0,1	0,1
35,5	0	0	0	0	207560	0	207560	207560	0	0,2	0,2
36	0	0	0	0	69187	0	69187	69187	0	0,1	0,1
36,5	0	0	0	0	23062	0	23062	23062	0	0,02	0,02
37	0	0	0	0	46124	0	46124	46124	0	0,05	0,05
37,5	0	0	0	0	23062	0	23062	23062	0	0,02	0,02
38	0	0	0	0	0	0	0	0	0	0	0
TOTAL *n*	56984730	28824002	481188	14405669	5627186	85808732	20514043	106322775	**86**	**21**	**106**
Millions	**57**	**29**	**0,5**	**14**	**6**						

Table 10. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber colias*). Cont'd.

***ECOCADIZ-RECLUTAS 2021-10 . 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	0	0	0	0	0	0
17	0	1,749	0	0	0	1,749	0	1,749
17,5	0	1,937	0	0	0	1,937	0	1,937
18	13,949	8,558	0,118	0	0	22,507	0,118	22,625
18,5	0	2,357	0	0	0	2,357	0	2,357
19	2,320	82,862	0,020	0	0	85,182	0,020	85,202
19,5	2,543	298,013	0,021	0	0	300,556	0,021	300,577
20	28,589	419,009	0,241	0	0	447,598	0,241	447,839
20,5	80,670	372,545	0,681	0	0	453,215	0,681	453,896
21	92,869	287,657	0,784	0	0	380,526	0,784	381,310
21,5	204,495	180,354	1,727	0	0	384,849	1,727	386,576
22	332,726	60,863	2,810	0	0	393,589	2,810	396,399
22,5	477,662	70,606	4,033	0	0	548,268	4,033	552,301
23	465,445	30,527	3,930	0	0	495,972	3,930	499,902
23,5	700,243	16,471	5,913	0	0	716,714	5,913	722,627
24	1195,875	5,915	10,098	1,863	0	1201,79	11,961	1213,751
24,5	1206,328	19,089	10,186	11,024	0	1225,417	21,210	1246,627
25	473,224	0	3,996	5,382	0	473,224	9,378	482,602
25,5	524,763	0	4,431	47,317	0	524,763	51,748	576,511
26	188,852	0	1,595	70,479	0	188,852	72,074	260,926
26,5	77,451	0	0,654	75,430	0	77,451	76,084	153,535
27	74,711	0	0,631	118,742	0	74,711	119,373	194,084
27,5	8,586	0	0,073	330,268	0	8,586	330,341	338,927
28	0	0	0	458,111	4,527	0	462,638	462,638
28,5	0	0	0	450,144	0	0	450,144	450,144
29	64,967	0	0,549	440,528	0	64,967	441,077	506,044
29,5	0	0	0	479,768	0	0	479,768	479,768
30	0	0	0	158,153	23,129	0	181,282	181,282
30,5	0	0	0	148,098	55,184	0	203,282	203,282
31	0	0	0	136,122	71,454	0	207,576	207,576
31,5	0	0	0	21,986	171,883	0	193,869	193,869
32	0	0	0	64,525	290,824	0	355,349	355,349
32,5	0	0	0	13,648	314,961	0	328,609	328,609
33	0	0	0	0	308,175	0	308,175	308,175
33,5	0	0	0	0	196,758	0	196,758	196,758
34	0	0	0	6,408	162,302	0	168,71	168,710
34,5	0	0	0	0	113,960	0	113,96	113,960
35	0	0	0	0	59,967	0	59,967	59,967
35,5	0	0	0	0	94,600	0	94,60	94,600
36	0	0	0	0	33,140	0	33,14	33,140
36,5	0	0	0	0	11,601	0	11,601	11,601
37	0	0	0	0	24,352	0	24,352	24,352
37,5	0	0	0	0	12,771	0	12,771	12,771
38	0	0	0	0	0	0	0	0
TOTAL	**6216,268**	**1858,512**	**52,491**	**3037,996**	**1949,588**	**8074,780**	**5040,075**	**13114,855**

Table 11. *ECOCADIZ-RECLUTAS* surveys series. Chub mackerel (*Scomber colias*). Acoustic estimates of biomass (t) and abundance (million fish) for the whole Gulf of Cadiz anchovy population and for the juvenile fraction (*i.e*. age 0 fish, between parentheses). Note that the 2012 survey only surveyed the Spanish waters. The 2017 estimates correspond to an incomplete coverage (only the seven easternmost transects) of the standard surveyed area due to a research vessels' breakdown.

Estimate/Year	**Total Population (Recruits at age 0)**								
	2012	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Biomass (t)	11155 (n.a.)	17471 (n.a.)	5683 (n.a.)	13689 (n.a.)	11726 (n.a.)	6950 (n.a.)	26212 (5265)	22918 (2759)	13115 (1689)
Abundance (millions)	157 (n.a.)	148 (n.a.)	65 (n.a.)	297 (n.a.)	86 (n.a.)	108 (n.a.)	367 (88)	295 (51)	106 (26)

Table 12. *ECOCADIZ-RECLUTAS 2021-10* survey. Horse mackerel (*Trachurus trachurus*). 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 22**.

***ECOCADIZ-RECLUTAS 2021-10 . Trachurus trachurus .* ABUNDANCE (in numbers and million fish)**												
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**POL06**	***n***			**Millions**		
							PORTUGAL	**SPAIN**	**TOTAL**	**PORTUGAL**	**SPAIN**	**TOTAL**
12	0	0	0	0	0	0	0	0	0	0	0	0
12,5	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
13,5	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
14,5	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
15,5	0	0	0	22704	61674	118316	22704	179990	202694	0,02	0,2	0,2
16	0	0	0	22704	61674	118316	22704	179990	202694	0,02	0,2	0,2
16,5	0	0	0	22704	61674	118316	22704	179990	202694	0,02	0,2	0,2
17	0	0	0	22704	61674	118316	22704	179990	202694	0,02	0,2	0,2
17,5	83765	0	0	22704	61674	118316	106469	179990	286459	0,1	0,2	0,3
18	0	0	0	60544	164463	315509	60544	479972	540516	0,1	0,5	1
18,5	0	0	0	22704	61674	118316	22704	179990	202694	0,0	0,2	0,2
19	83765	0	0	11352	30837	59158	95117	89995	185112	0,1	0,1	0,2
19,5	614276	0	0	0	0	0	614276	0	614276	1	0	1
20	530511	0	0	0	0	0	530511	0	530511	1	0	1
20,5	1689507	0	0	0	0	0	1689507	0	1689507	2	0	2
21	1564109	0	0	0	0	0	1564109	0	1564109	2	0	2
21,5	2779946	8810	6212	0	0	0	2794968	0	2794968	3	0	3
22	4679115	8810	6212	0	0	0	4694137	0	4694137	5	0	5
22,5	9767830	0	0	0	0	0	9767830	0	9767830	10	0	10
23	12983803	0	0	0	0	0	12983803	0	12983803	13	0	13
23,5	9547948	0	0	0	0	0	9547948	0	9547948	10	0	10
24	5340010	8810	6212	0	0	0	5355032	0	5355032	5	0	5
24,5	2739310	17619	12425	0	0	0	2769354	0	2769354	3	0	3
25	1537684	35239	24849	0	0	0	1597772	0	1597772	2	0	2
25,5	1327523	26429	18637	0	0	0	1372589	0	1372589	1	0	1
26	671116	0	0	0	0	0	671116	0	671116	1	0	1
26,5	209661	17619	12425	0	0	0	239705	0	239705	0,2	0	0,2
27	125897	35239	24849	0	0	0	185985	0	185985	0,2	0	0,2
27,5	0	35239	24849	0	0	0	60088	0	60088	0,1	0	0,1
28	0	35239	24849	0	0	0	60088	0	60088	0,1	0	0,1
28,5	125897	17619	12425	0	0	0	155941	0	155941	0,2	0	0,2
29	0	0	0	0	0	0	0	0	0	0	0	0
29,5	0	0	0	0	0	0	0	0	0	0	0	0
30	0	8810	6212	0	0	0	15022	0	15022	0,02	0	0,02
30,5	0	8810	6212	0	0	0	15022	0	15022	0,02	0	0,02
31	0	0	0	0	0	0	0	0	0	0	0	0
31,5	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL *n*	56401673	264292	186368	208120	565344	1084563	57060453	1649907	58710360	**57**	**2**	**59**
Millions	**56**	**0,3**	**0,2**	**0,2**	**1**	**1**						

Table 12. *ECOCADIZ-RECLUTAS 2021-10* survey. Horse mackerel (*Trachurus trachurus*). Cont'd.

***ECOCADIZ-RECLUTAS 2021-10 . Trachurus trachurus* . BIOMASS (t)**									
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**POL06**	**PORTUGAL**	**SPAIN**	**TOTAL**
12	0	0	0	0	0	0	0	0	0
12,5	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
13,5	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
14,5	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
15,5	0	0	0	0,741	2,012	3,859	0,741	5,871	6,612
16	0	0	0	0,814	2,210	4,240	0,814	6,450	7,264
16,5	0	0	0	0,891	2,422	4,645	0,891	7,067	7,958
17	0	0	0	0,974	2,646	5,076	0,974	7,722	8,696
17,5	3,916	0	0	1,062	2,884	5,532	4,978	8,416	13,394
18	0	0	0	3,078	8,36	16,039	3,078	24,399	27,477
18,5	0	0	0	1,252	3,401	6,525	1,252	9,926	11,178
19	5	0	0	0,678	1,841	3,531	5,678	5,372	11,050
19,5	39,613	0	0	0	0	0	39,613	0	39,613
20	36,887	0	0	0	0	0	36,887	0	36,887
20,5	126,427	0	0	0	0	0	126,427	0	126,427
21	125,745	0	0	0	0	0	125,745	0	125,745
21,5	239,706	0,760	0,536	0	0	0	241,002	0	241,002
22	432,049	0,813	0,574	0	0	0	433,436	0	433,436
22,5	964,348	0	0	0	0	0	964,348	0	964,348
23	1368,587	0	0	0	0	0	1368,587	0	1368,587
23,5	1073,026	0	0	0	0	0	1073,026	0	1073,026
24	638,987	1,054	0,743	0	0	0	640,784	0	640,784
24,5	348,566	2,242	1,581	0	0	0	352,389	0	352,389
25	207,812	4,762	3,358	0	0	0	215,932	0	215,932
25,5	190,324	3,789	2,672	0	0	0	196,785	0	196,785
26	101,953	0	0	0	0	0	101,953	0	101,953
26,5	33,713	2,833	1,998	0	0	0	38,544	0	38,544
27	21,405	5,991	4,225	0	0	0	31,621	0	31,621
27,5	0	6,329	4,463	0	0	0	10,792	0	10,792
28	0	6,678	4,709	0	0	0	11,387	0	11,387
28,5	25,154	3,52	2,482	0	0	0	31,156	0	31,156
29	0	0	0	0	0	0	0	0	0
29,5	0	0	0	0	0	0	0	0	0
30	0	2,052	1,447	0	0	0	3,499	0	3,499
30,5	0	2,155	1,520	0	0	0	3,675	0	3,675
31	0	0	0	0	0	0	0	0	0
31,5	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0
TOTAL	**5983,218**	**42,978**	**30,308**	**9,490**	**25,776**	**49,447**	**6065,994**	**75,223**	**6141,217**

Table 13. *ECOCADIZ-RECLUTAS 2021-10* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). 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 25**.

ECOCADIZ-RECLUTAS 2021-10 . *Trachurus mediterraneus* . ABUNDANCE (in numbers and million fish)										
Size class	POL01	POL02	POL03	POL04	*n*			Millions		
					PORTUGAL	SPAIN	TOTAL	PORTUGAL	SPAIN	TOTAL
4	0	0	0	0	0	0	0	0	0	0
4,5	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
5,5	0	0	0	0	0	0	0	0	0	0
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	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0
11,5	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0
12,5	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
13,5	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
14,5	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
15,5	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0
16,5	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
17,5	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0
18,5	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0
19,5	0	0	0	0	0	0	0	0	0	0
20	4281	154727	0	0	4281	154727	159008	0,004	0,2	0,2
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	664	24009	17583	31218	664	72810	73474	0,001	0,1	0,1
22	4946	178736	0	0	4946	178736	183682	0,005	0,2	0,2
22,5	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0
23,5	0	0	0	0	0	0	0	0	0	0
24	1546	55869	0	0	1546	55869	57415	0,002	0,1	0,1
24,5	1546	55869	17583	31218	1546	104670	106216	0,002	0,1	0,1
25	1592	57531	38698	68707	1592	164936	166528	0,002	0,2	0,2
25,5	7226	261152	197095	349935	7226	808182	815408	0,01	1	1
26	40170	1451746	123231	218793	40170	1793770	1833940	0,04	2	2
26,5	84793	3064407	296982	527280	84793	3888669	3973462	0,1	4	4
27	136444	4931068	293450	521009	136444	5745527	5881971	0,1	6	6
27,5	119786	4329029	494077	877215	119786	5700321	5820107	0,1	6	6
28	60646	2191750	531848	944276	60646	3667874	3728520	0,1	4	4
28,5	30554	1104213	594266	1055096	30554	2753575	2784129	0,03	3	3
29	49507	1789187	769797	1366744	49507	3925728	3975235	0,05	4	4
29,5	31774	1148314	1353617	2403295	31774	4905226	4937000	0,03	5	5
30	6738	243515	969346	1721036	6738	2933897	2940635	0,01	3	3
30,5	8399	303538	1164886	2068209	8399	3536633	3545032	0,01	4	4
31	8399	303538	751059	1333476	8399	2388073	2396472	0,01	2	2
31,5	464	16761	411847	731219	464	1159827	1160291	0,0005	1	1
32	0	0	381365	677099	0	1058464	1058464	0	1	1
32,5	1993	72028	159549	283273	1993	514850	516843	0,002	1	1
33	4281	154727	119699	212522	4281	486948	491229	0,004	0,5	0,5
33,5	464	16761	70332	124871	464	211964	212428	0,0005	0,2	0,2
34	664	24009	52749	93654	664	170412	171076	0,001	0,2	0,2
34,5	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0
35,5	0	0	0	0	0	0	0	0	0	0
36	9633	348135	0	0	9633	348135	357768	0,01	0,3	0,4
36,5	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0
37,5	0	0	0	0	0	0	0	0	0	0
38	0	0	17583	31218	0	48801	48801	0	0,05	0,05
38,5	0	0	0	0	0	0	0	0	0	0
39	0	0	35166	62436	0	97602	97602	0	0,1	0,1
39,5	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0
40,5	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0
41,5	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0
42,5	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0
43,5	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0
44,5	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0
45,5	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0
46,5	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0
47,5	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0
48,5	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0
49,5	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0
TOTAL *n*	616510	22280619	8861808	15733799	616510	46876226	47492736	**0,6**	**47**	**47**
Millions	**1**	**22**	**9**	**16**						

Table 13. *ECOCADIZ-RECLUTAS 2021-10* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). Cont'd.

ECOCADIZ-RECLUTAS 2021-10 . Trachurus mediterraneus. BIOMASS (t)							
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**PORTUGAL**	**SPAIN**	**TOTAL**
4	0	0	0	0	0	0	0
4,5	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
5,5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
6,5	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
7,5	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0
8,5	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0
9,5	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
10,5	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
11,5	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0
12,5	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0
13,5	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0
14,5	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0
15,5	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0
16,5	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0
17,5	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0
18,5	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0
19,5	0	0	0	0	0	0	0
20	0,372	13,439	0	0	0	13,439	13,811
20,5	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0
21,5	0,068	2,473	1,811	3,216	0,068	7,500	7,568
22	0,538	19,437	0	0	0,538	19,437	19,975
22,5	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0
23,5	0	0	0	0	0	0	0
24	0,206	7,461	0	0	0,206	7,461	7,667
24,5	0,217	7,834	2,465	4,377	0,217	14,676	14,893
25	0,234	8,461	5,691	10,105	0,234	24,257	24,491
25,5	1,114	40,248	30,375	53,931	1,114	124,554	125,668
26	6,482	234,245	19,884	35,303	6,482	289,432	295,914
26,5	14,312	517,230	50,126	88,998	14,312	656,354	670,666
27	24,071	869,906	51,768	91,913	24,071	1013,587	1037,658
27,5	22,069	797,567	91,027	161,615	22,069	1050,209	1072,278
28	11,660	421,382	102,252	181,545	11,660	705,179	716,839
28,5	6,125	221,372	119,138	211,525	6,125	552,035	558,160
29	10,342	373,762	160,811	285,514	10,342	820,087	830,429
29,5	6,912	249,786	294,444	522,775	6,912	1067,005	1073,917
30	1,525	55,120	219,412	389,558	1,525	664,090	665,615
30,5	1,977	71,448	274,194	486,820	1,977	832,462	834,439
31	2,055	74,251	183,724	326,195	2,055	584,170	586,225
31,5	0,118	4,258	104,636	185,777	0,118	294,671	294,789
32	0,000	0,000	100,573	178,563	0	279,136	279,136
32,5	0,545	19,705	43,649	77,498	0,545	140,852	141,397
33	1,214	43,889	33,953	60,283	1,214	138,125	139,339
33,5	0,136	4,927	20,673	36,705	0,136	62,305	62,441
34	0,202	7,309	16,059	28,512	0,202	51,880	52,082
34,5	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0
35,5	0	0	0	0	0	0	0
36	3,358	121,359	0	0	3,358	121,359	124,717
36,5	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0
37,5	0	0	0	0	0	0	0
38	0	0	6,968	12,371	0	19,339	19,339
38,5	0	0	0	0	0	0	0
39	0	0	14,820	26,313	0	41,133	41,133
39,5	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0
40,5	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0
41,5	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0
42,5	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0
43,5	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0
44,5	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0
45,5	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0
46,5	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0
47,5	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0
48,5	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0
49,5	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0
TOTAL	**115,852**	**4186,869**	**1948,453**	**3459,412**	**115,852**	**9594,734**	**9710,586**

Table 14. *ECOCADIZ-RECLUTAS 2021-10* survey. Blue Jack mackerel (*Trachurus picturatus*). 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 28**.

***ECOCADIZ-RECLUTAS 2021-10*. *Trachurus picturatus*. ABUNDANCE (in numbers and million fish)**								
Size class	**POL01**	**POL02**	***n***			**Millions**		
			PORTUGAL	**SPAIN**	**TOTAL**	**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	170332	0	170332	0	170332	0,2	0	0,2
16	3917647	7573	3925220	0	3925220	4	0	4
16,5	8403070	34077	8437147	0	8437147	8	0	8
17	13853709	126842	13980551	0	13980551	14	0	14
17,5	9425064	160919	9585983	0	9585983	10	0	10
18	7381075	213928	7595003	0	7595003	8	0	8
18,5	4428645	187424	4616069	0	4616069	5	0	5
19	1873657	153347	2027004	0	2027004	2	0	2
19,5	2043990	53009	2096999	0	2096999	2	0	2
20	681330	26504	707834	0	707834	1	0	1
20,5	340665	0	340665	0	340665	0,3	0	0,3
21	0	0	0	0	0	0	0	0
21,5	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0
22,5	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0
23,5	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0
24,5	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
25,5	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0
26,5	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0
27,5	0	0	0	0	0	0	0	0
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
29,5	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
30,5	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0
31,5	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0
32,5	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0
33,5	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0
34,5	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0
35,5	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0
36,5	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0
37,5	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0
TOTAL *n*	52519184	963623	53482807	0	53482807	**53**	**0**	**53**
Millions	**53**	**1**						

Table 14. *ECOCADIZ-RECLUTAS 2021-10* survey. Blue Jack mackerel (*Trachurus picturatus*). Cont'd.

***ECOCADIZ-RECLUTAS 2021-10 . Trachurus picturatus* . BIOMASS (t)**					
Size class	**POL01**	**POL02**	**PORTUGAL**	**SPAIN**	**TOTAL**
14	0	0	0	0	0
14,5	0	0	0	0	0
15	0	0	0	0	0
15,5	4,901	0	4,901	0	4,901
16	124,333	0,240	124,573	0	124,573
16,5	293,249	1,189	294,438	0	294,438
17	530,140	4,854	534,994	0	534,994
17,5	394,449	6,735	401,184	0	401,184
18	336,999	9,767	346,766	0	346,766
18,5	220,069	9,314	229,383	0	229,383
19	101,109	8,275	109,384	0	109,384
19,5	119,529	3,100	122,629	0	122,629
20	43,090	1,676	44,766	0	44,766
20,5	23,256	0	23,256	0	23,256
21	0	0	0	0	0
21,5	0	0	0	0	0
22	0	0	0	0	0
22,5	0	0	0	0	0
23	0	0	0	0	0
23,5	0	0	0	0	0
24	0	0	0	0	0
24,5	0	0	0	0	0
25	0	0	0	0	0
25,5	0	0	0	0	0
26	0	0	0	0	0
26,5	0	0	0	0	0
27	0	0	0	0	0
27,5	0	0	0	0	0
28	0	0	0	0	0
28,5	0	0	0	0	0
29	0	0	0	0	0
29,5	0	0	0	0	0
30	0	0	0	0	0
30,5	0	0	0	0	0
31	0	0	0	0	0
31,5	0	0	0	0	0
32	0	0	0	0	0
32,5	0	0	0	0	0
33	0	0	0	0	0
33,5	0	0	0	0	0
34	0	0	0	0	0
34,5	0	0	0	0	0
35	0	0	0	0	0
35,5	0	0	0	0	0
36	0	0	0	0	0
36,5	0	0	0	0	0
37	0	0	0	0	0
37,5	0	0	0	0	0
38	0	0	0	0	0
TOTAL	**2191,124**	**45,150**	**2236,274**	**0**	**2236,274**

Table 15. *ECOCADIZ-RECLUTAS 2021-10* survey. Bogue (*Boops boops*). 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 31**.

***ECOCADIZ-RECLUTAS 2021-10 . Boops boops* . 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	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
17,5	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
18,5	118198	18853	16907	36452	3423	137051	56782	193833	0,1	0,1	0,2
19	59099	9426	8453	18226	1712	68525	28391	96916	0,1	0,03	0,1
19,5	118198	18853	16907	36452	3423	137051	56782	193833	0,1	0,1	0,2
20	59099	9426	8453	18226	1712	68525	28391	96916	0,1	0,03	0,1
20,5	177297	28279	25360	54678	5135	205576	85173	290749	0,2	0,1	0,3
21	295495	47132	42267	91130	8558	342627	141955	484582	0,3	0,1	0,5
21,5	59099	9426	8453	18226	1712	68525	28391	96916	0,1	0,03	0,1
22	413692	65985	59173	127582	11981	479677	198736	678413	0,5	0,2	1
22,5	118198	18853	16907	36452	3423	137051	56782	193833	0,1	0,1	0,2
23	531890	84838	76080	164034	15404	616728	255518	872246	1	0,3	1
23,5	59099	9426	8453	18226	1712	68525	28391	96916	0,1	0,03	0,1
24	0	0	0	0	0	0	0	0	0	0	0
24,5	177297	28279	25360	54678	5135	205576	85173	290749	0,2	0,1	0,3
25	118198	18853	16907	36452	3423	137051	56782	193833	0,1	0,1	0,2
25,5	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0
26,5	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0
27,5	0	0	0	0	0	0	0	0	0	0	0
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
29,5	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0
30,5	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0
31,5	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0
32,5	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0
33,5	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0
34,5	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0
TOTAL *n*	2304859	367629	329680	710814	66753	2672488	1107247	3779735	**3**	**1**	**4**
Millions	**2**	**0,4**	**0,3**	**1**	**0,1**						

Table 15. *ECOCADIZ-RECLUTAS 2021-10* survey. Bogue (*Boops boops*). Cont'd.

ECOCADIZ-RECLUTAS 2021-10 . Boops boops **. 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	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0
17,5	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0
18,5	7,433	1,186	1,063	2,292	0,215	8,619	3,570	12,189
19	4,037	0,644	0,577	1,245	0,117	4,681	1,939	6,620
19,5	8,752	1,396	1,252	2,699	0,253	10,148	4,204	14,352
20	4,734	0,755	0,677	1,460	0,137	5,489	2,274	7,763
20,5	15,334	2,446	2,193	4,729	0,444	17,780	7,366	25,146
21	27,543	4,393	3,940	8,494	0,798	31,936	13,232	45,168
21,5	5,926	0,945	0,848	1,828	0,172	6,871	2,848	9,719
22	44,559	7,107	6,374	13,742	1,290	51,666	21,406	73,072
22,5	13,653	2,178	1,953	4,210	0,395	15,831	6,558	22,389
23	65,783	10,493	9,409	20,287	1,905	76,276	31,601	107,877
23,5	7,815	1,246	1,118	2,410	0,226	9,061	3,754	12,815
24	0	0	0	0	0	0	0	0
24,5	26,691	4,257	3,818	8,232	0,773	30,948	12,823	43,771
25	18,949	3,022	2,711	5,844	0,549	21,971	9,104	31,075
25,5	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0
26,5	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0
27,5	0	0	0	0	0	0	0	0
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
29,5	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
30,5	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0
31,5	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0
32,5	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0
33,5	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0
34,5	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0
TOTAL	**251,209**	**40,068**	**35,933**	**77,472**	**7,274**	**291,277**	**120,679**	**411,956**

Table 16. *ECOCADIZ-RECLUTAS 2021-10* survey. Boarfish (*Capros aper*). 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 34**.

ECOCADIZ-RECLUTAS 2021-10 . Capros aper . ABUNDANCE (in numbers and million fish)							
Size class	POL01	*n*			Millions		
		PORTUGAL	SPAIN	TOTAL	PORTUGAL	SPAIN	TOTAL
4	0	0	0	0	0	0	0
4,5	0	0	0	0	0	0	0
5	81515	81515	0	81515	0,1	0	0,1
5,5	570602	570602	0	570602	1	0	1
6	1548776	1548776	0	1548776	2	0	2
6,5	2608464	2608464	0	2608464	3	0	3
7	2445435	2445435	0	2445435	2	0	2
7,5	2363921	2363921	0	2363921	2	0	2
8	652116	652116	0	652116	1	0	1
8,5	163029	163029	0	163029	0,2	0	0,2
9	81515	81515	0	81515	0,1	0	0,1
9,5	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
TOTAL *n*	10515373	10515373	0	10515373	11	0	11
Millions	11						

ECOCADIZ-RECLUTAS 2021-10 . Capros aper . BIOMASS (t)				
Size class	POL01	PORTUGAL	SPAIN	TOTAL
4	0	0	0	0
4,5	0	0	0	0
5	0,063	0,063	0	0,063
5,5	0,582	0,582	0	0,582
6	2,030	2,030	0	2,030
6,5	4,311	4,311	0	4,311
7	5,014	5,014	0	5,014
7,5	5,926	5,926	0	5,926
8	1,974	1,974	0	1,974
8,5	0,589	0,589	0	0,589
9	0,348	0,348	0	0,348
9,5	0	0	0	0
10	0	0	0	0
TOTAL	20,837	20,837	0	20,837

Table 17. *ECOCADIZ-RECLUTAS 2021-10* survey. Longspine snipefish (*Macroramphosus scolopax*). 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 37**.

ECOCADIZ-RECLUTAS 2021-10 . Macroramphosus scolopax . ABUNDANCE (in numbers and million fish)							
Size class	POL01	*n*			Millions		
		PORTUGAL	SPAIN	TOTAL	PORTUGAL	SPAIN	TOTAL
5	0	0	0	0	0	0	0
5,5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
6,5	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
7,5	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0
8,5	0	0	0	0	0	0	0
9	217676774	217676774	0	217676774	218	0	218
9,5	217676774	217676774	0	217676774	218	0	218
10	163257581	163257581	0	163257581	163	0	163
10,5	108838387	108838387	0	108838387	109	0	109
11	217676774	217676774	0	217676774	218	0	218
11,5	327842459	327842459	0	327842459	328	0	328
12	491100039	491100039	0	491100039	491	0	491
12,5	327842459	327842459	0	327842459	328	0	328
13	327842459	327842459	0	327842459	328	0	328
13,5	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0
14,5	54419194	54419194	0	54419194	54	0	54
15	0	0	0	0	0	0	0
15,5	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0
16,5	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0
17,5	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0
18,5	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0
19,5	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0
TOTAL *n*	2454172900	2454172900	0	2454172900	**2454**	**0**	**2454**
Millions	**2454**						

Table 17. *ECOCADIZ-RECLUTAS 2021-10* survey. Longspine snipefish (*Macroramphosus scolopax*). Cont'd.

ECOCADIZ-RECLUTAS 2021-10 . M. scolopax . BIOMASS (t)				
Size class	**POL01**	**PORTUGAL**	**SPAIN**	**TOTAL**
5	0	0	0	0
5,5	0	0	0	0
6	0	0	0	0
6,5	0	0	0	0
7	0	0	0	0
7,5	0	0	0	0
8	0	0	0	0
8,5	0	0	0	0
9	3449,235	3449,235	0	3449,235
9,5	4009,003	4009,003	0	4009,003
10	3468,520	3468,520	0	3468,520
10,5	2649,376	2649,376	0	2649,376
11	6033,614	6033,614	0	6033,614
11,5	10289,195	10289,195	0	10289,195
12	17361,542	17361,542	0	17361,542
12,5	12993,226	12993,226	0	12993,226
13	14502,438	14502,438	0	14502,438
13,5	0	0	0	0
14	0	0	0	0
14,5	3270,276	3270,276	0	3270,276
15	0	0	0	0
15,5	0	0	0	0
16	0	0	0	0
16,5	0	0	0	0
17	0	0	0	0
17,5	0	0	0	0
18	0	0	0	0
18,5	0	0	0	0
19	0	0	0	0
19,5	0	0	0	0
20	0	0	0	0
TOTAL	**78026,425**	**78026,425**	**0**	**78026,425**

Table 18. *ECOCADIZ-RECLUTAS 2021-10* survey. Pearlside (*Maurolicus muelleri*). 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 40**.

***ECOCADIZ-RECLUTAS 2021-10*. *Maurolicus muelleri*. ABUNDANCE (in numbers and million fish)**								
Size class	**POL01**	**POL02**	***n***			**Millions**		
			PORTUGAL	**SPAIN**	**TOTAL**	**PORTUGAL**	**SPAIN**	**TOTAL**
1	0	0	0	0	0	0	0	0
1,5	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
2,5	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
3,5	19445714	16794850	19445714	16794850	36240564	19	17	36
4	144627500	124911698	144627500	124911698	269539198	145	125	270
4,5	446036073	385231876	446036073	385231876	831267949	446	385	831
5	321461965	277639867	321461965	277639867	599101832	321	278	599
5,5	91759465	79250699	91759465	79250699	171010164	92	79	171
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	0	0	0	0
9	0	0	0	0	0	0	0	0
9,5	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
TOTAL *n*	1023330717	883828990	1023330717	883828990	1907159707	**1023**	**884**	**1907**
Millions	**1023**	**884**						

***ECOCADIZ-RECLUTAS 2021-10*. *Maurolicus muelleri*. BIOMASS (t)**					
Size class	**POL01**	**POL02**	**PORTUGAL**	**SPAIN**	**TOTAL**
1	0	0	0	0	0
1,5	0	0	0	0	0
2	0	0	0	0	0
2,5	0	0	0	0	0
3	0	0	0	0	0
3,5	11,604	10,022	11,604	10,022	21,626
4	112,055	96,780	112,055	96,780	208,835
4,5	435,837	376,423	435,837	376,423	812,260
5	387,045	334,283	387,045	334,283	721,328
5,5	133,569	115,361	133,569	115,361	248,930
6	0	0	0	0	0
6,5	0	0	0	0	0
7	0	0	0	0	0
7,5	0	0	0	0	0
8	0	0	0	0	0
8,5	0	0	0	0	0
9	0	0	0	0	0
9,5	0	0	0	0	0
10	0	0	0	0	0
TOTAL	**1080,110**	**932,869**	**1080,110**	**932,869**	**2012,979**

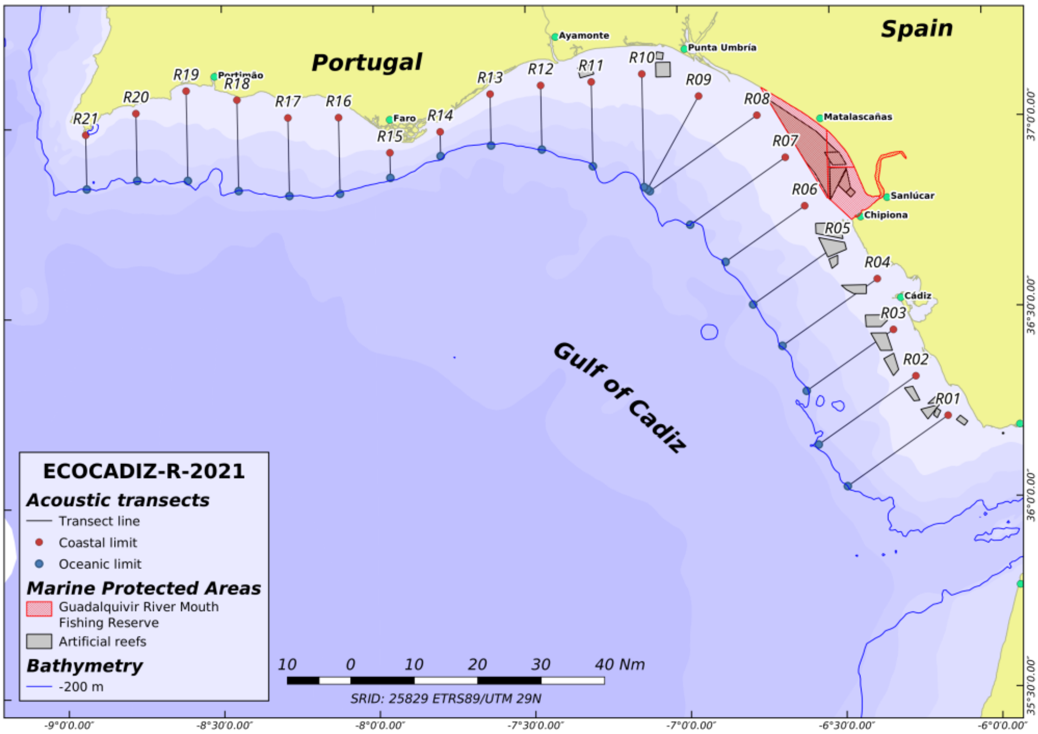


Figure 1. *ECOCADIZ-RECLUTAS 2021-10* survey. Location of the acoustic transects sampled during the survey. The different protected areas inside the Guadalquivir river mouth Fishing Reserve and artificial reef polygons are also shown.

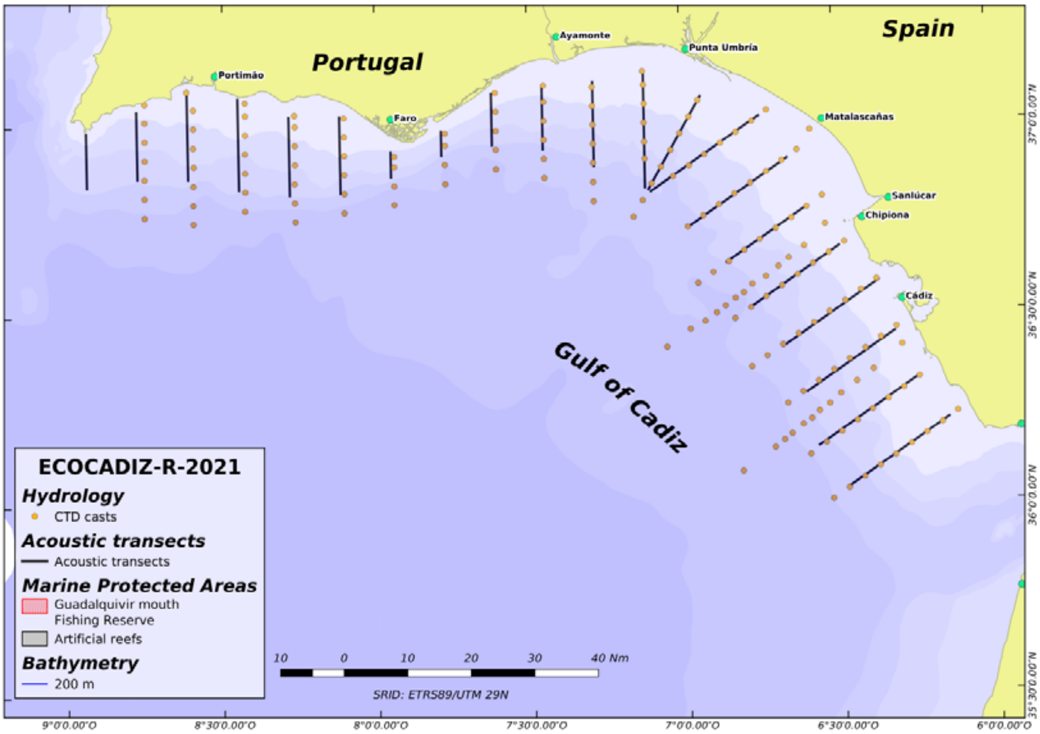


Figure 2. *ECOCADIZ-RECLUTAS 2021-10* survey. Location of CTD stations.

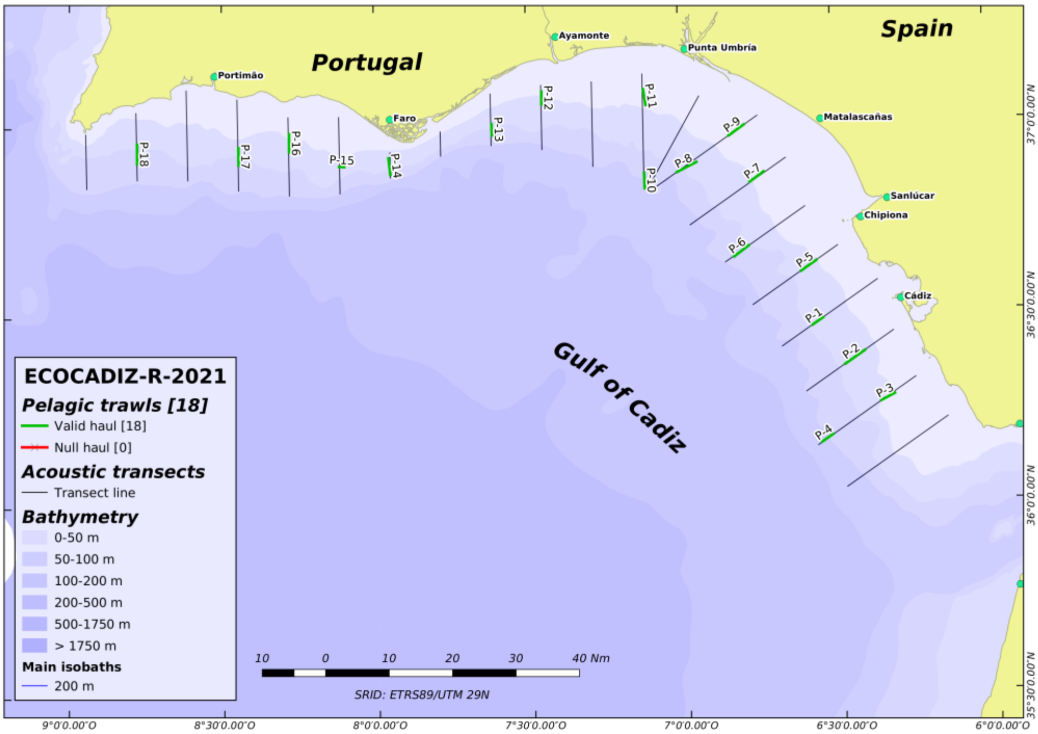


Figure 3. *ECOCADIZ-RECLUTAS 2021-10* survey. Location of ground-truthing fishing hauls.

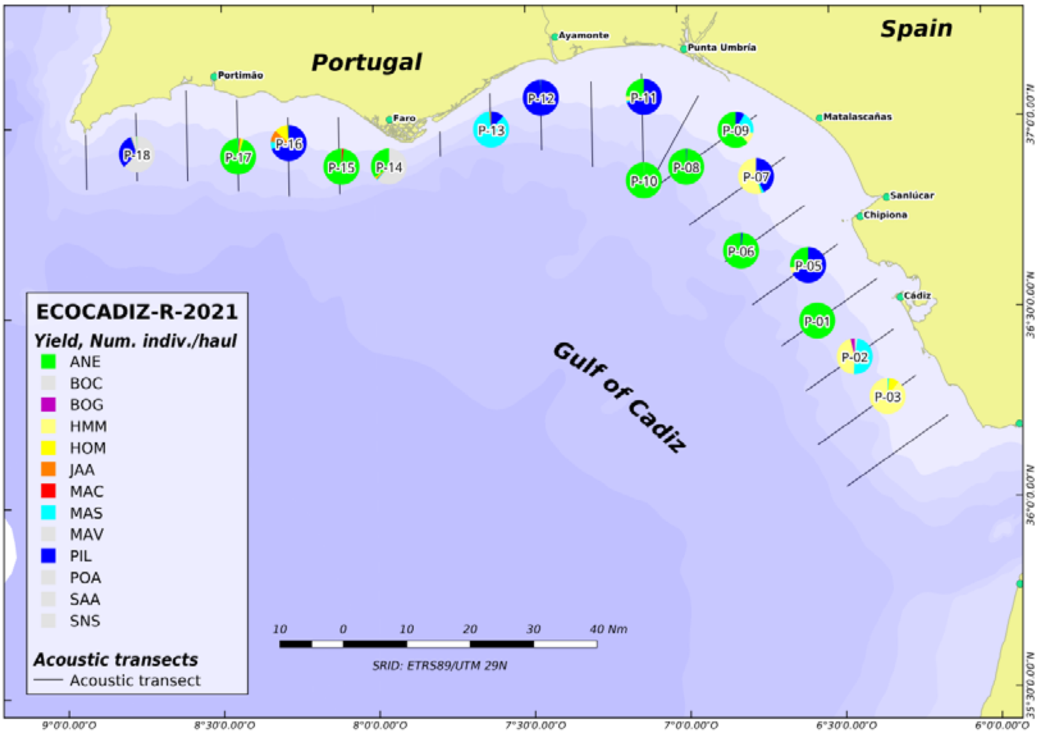


Figure 4. *ECOCADIZ-RECLUTAS 2021-10* survey. Species composition (percentages in number) in valid fishing hauls.

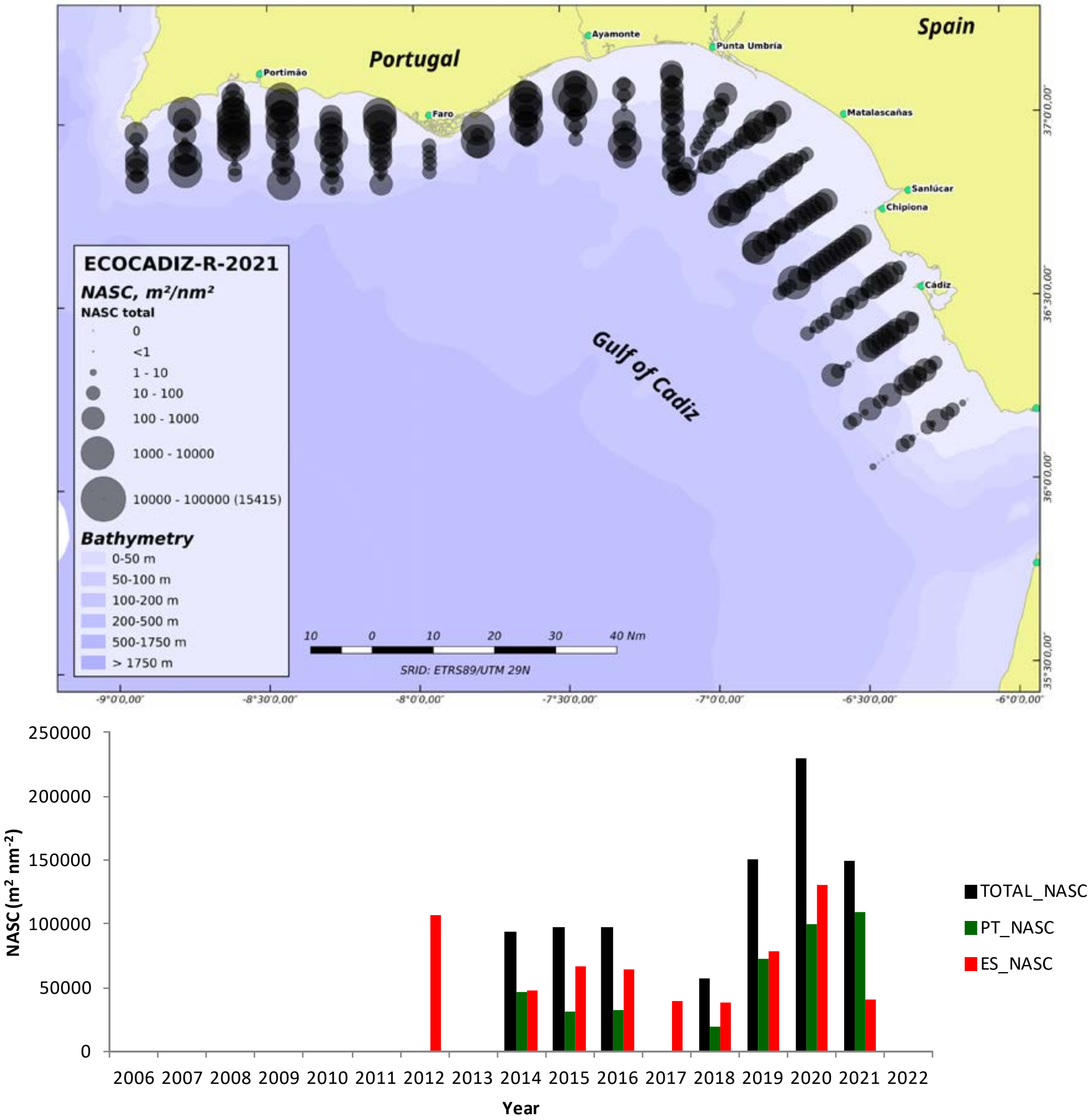


Figure 5. *ECOCADIZ-RECLUTAS 2021-10* survey. Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the pelagic fish species assemblage.

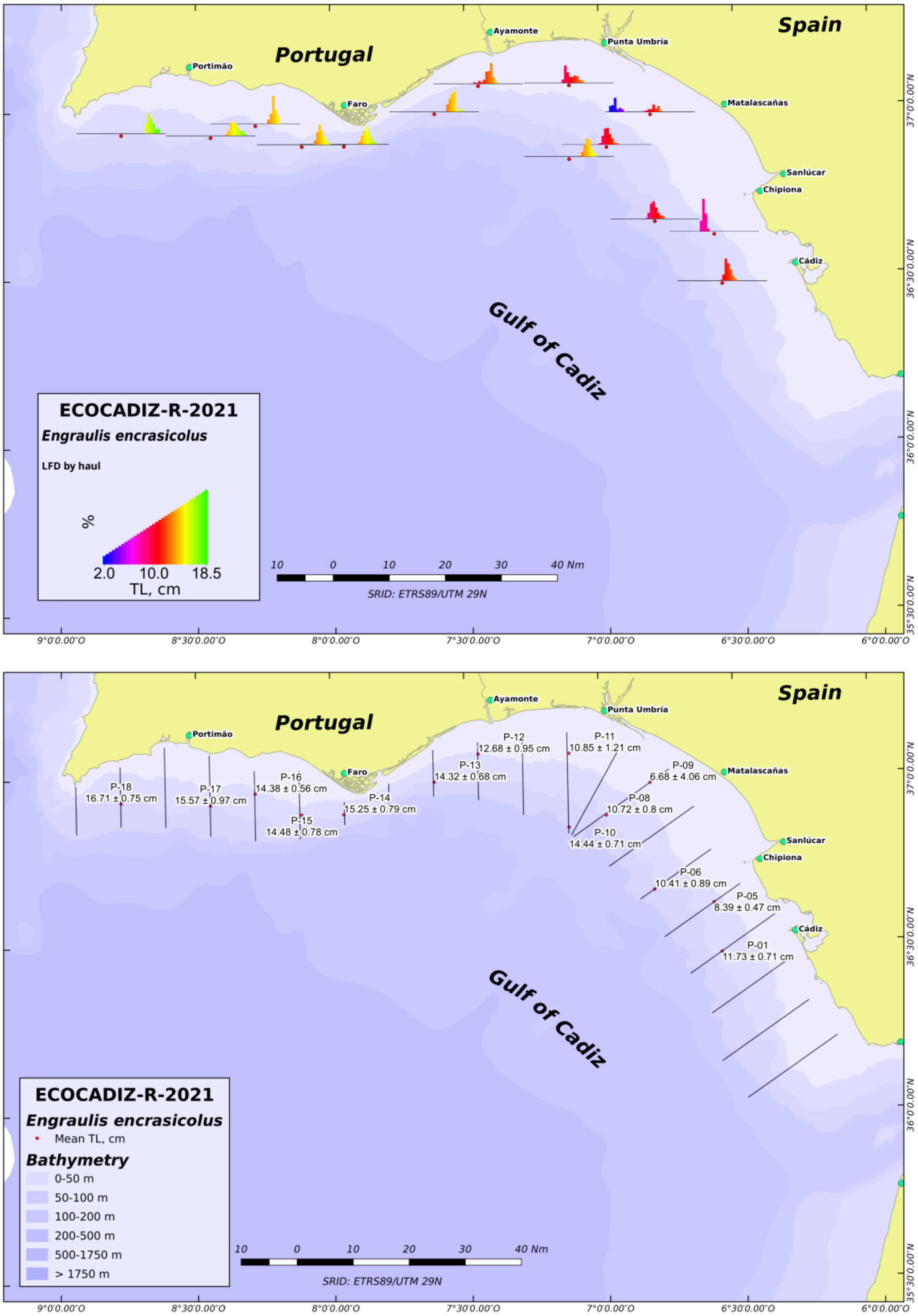
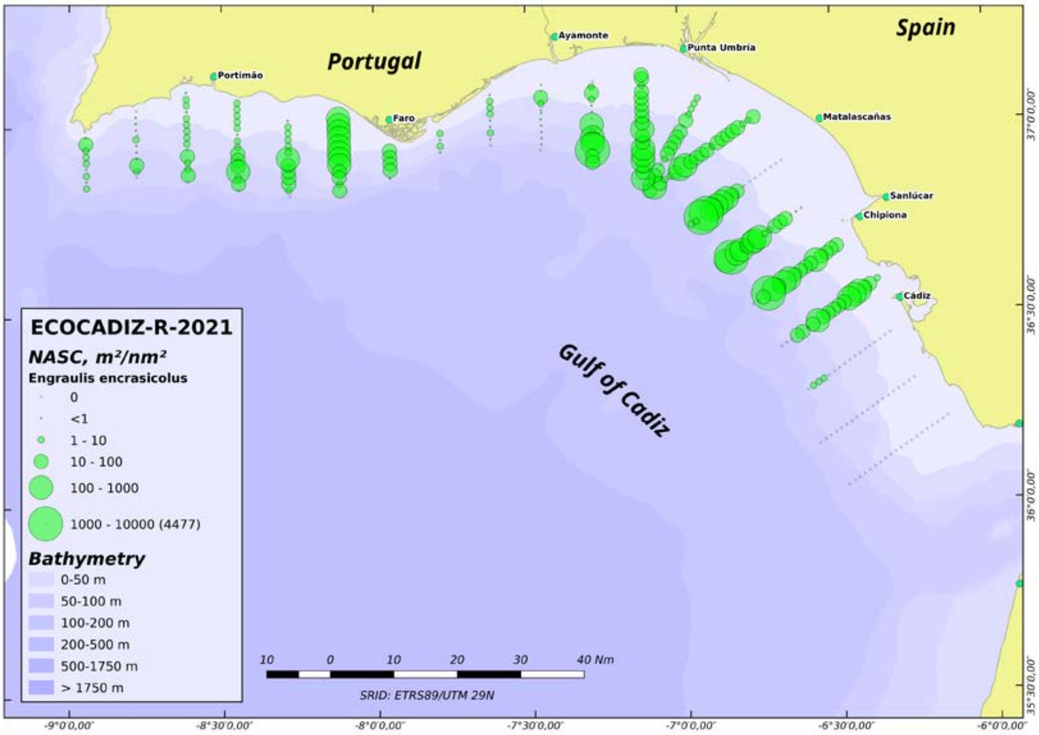


Figure 6. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*Engraulis encrasicolus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.



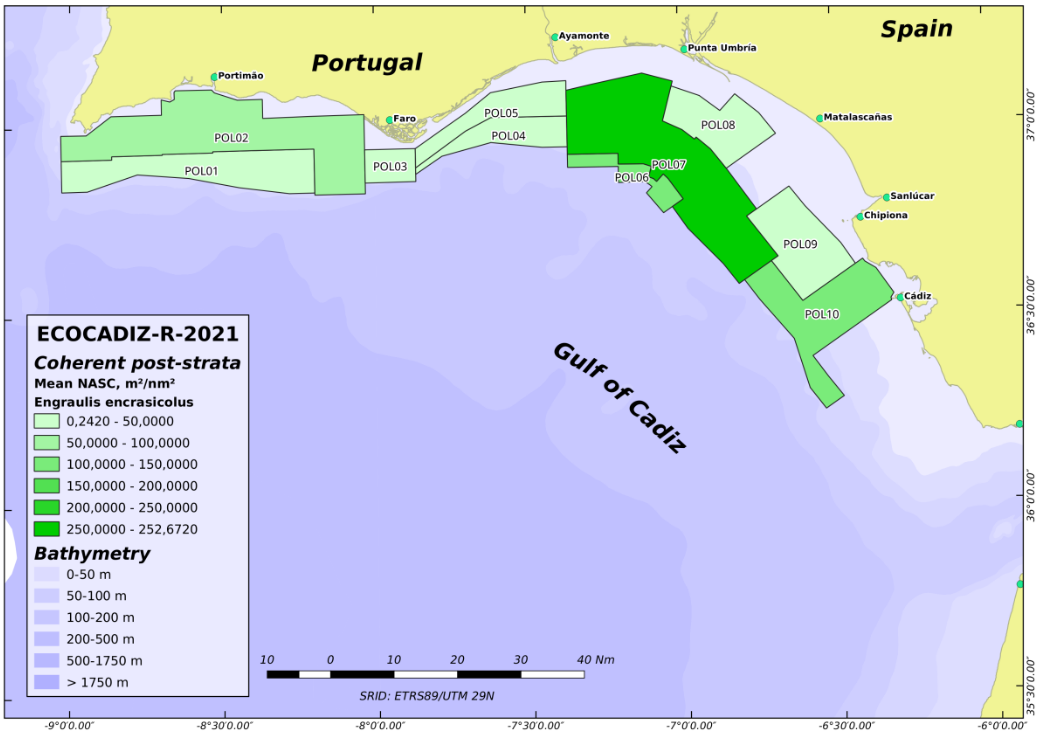


Figure 7. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*Engraulis encrasicolus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

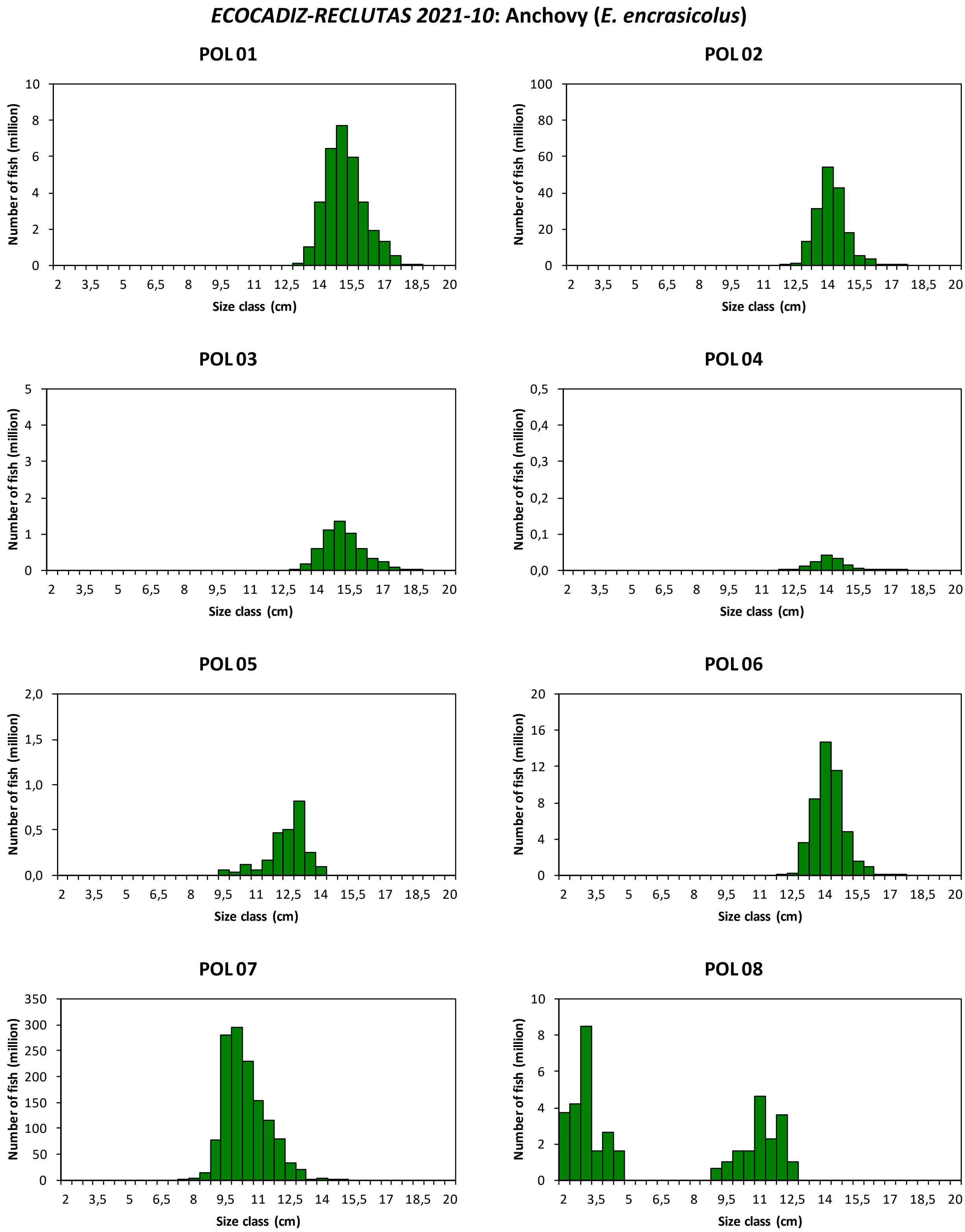


Figure 8. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*Engraulis encrasicolus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 7**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

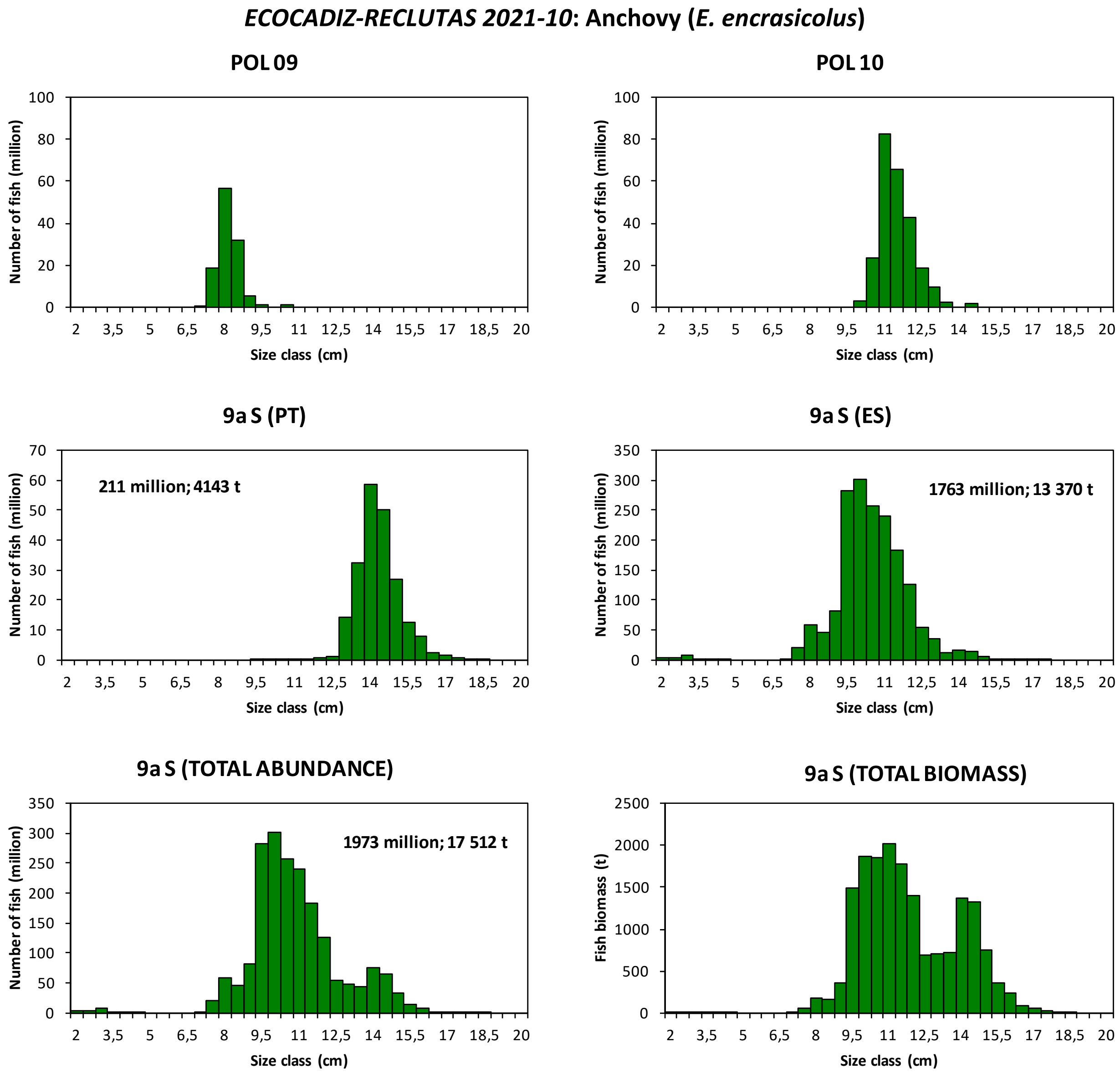


Figure 8. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*Engraulis encrasicolus*). Cont'd.

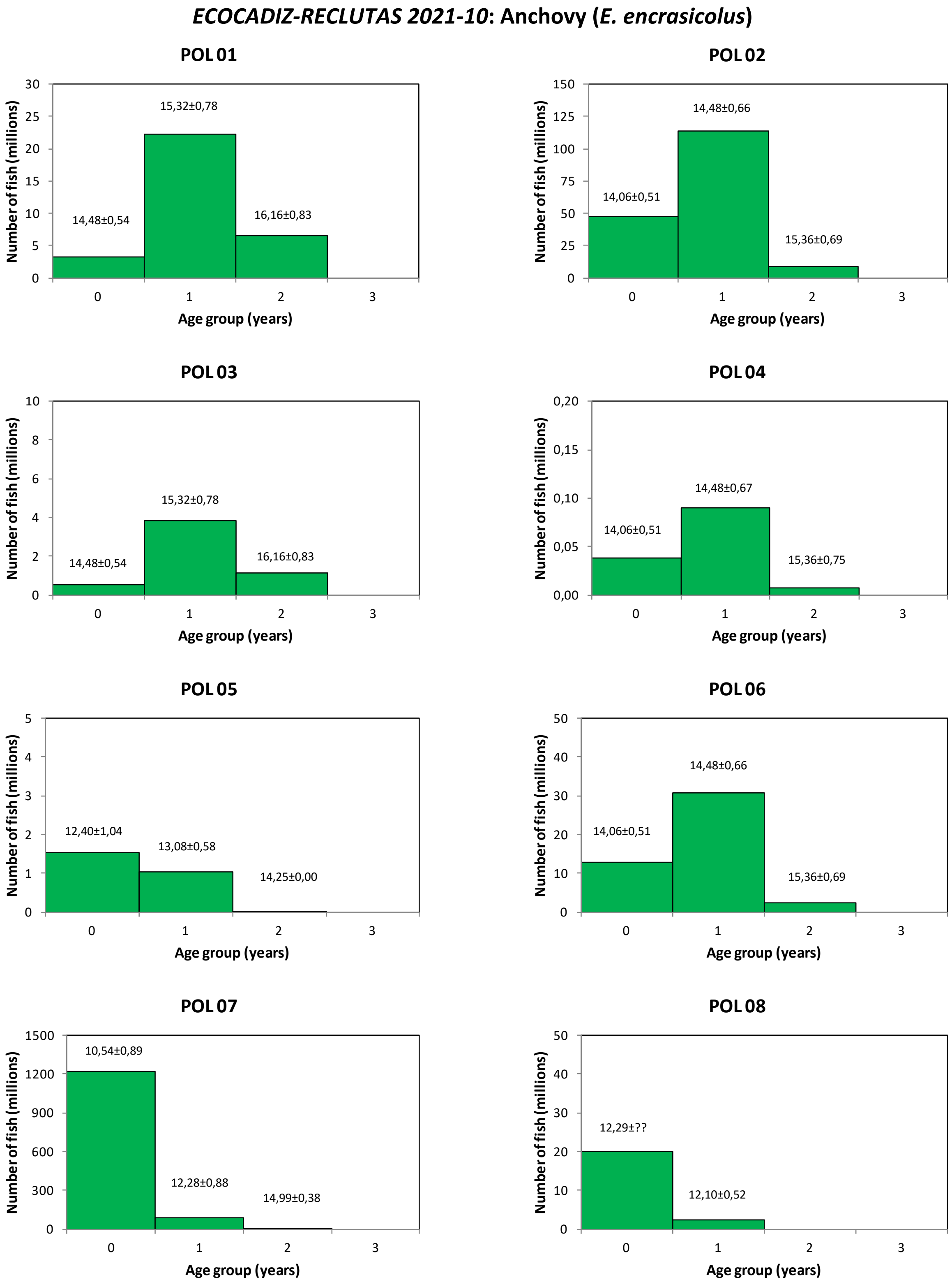


Figure 9. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*Engraulis encrasicolus*). Estimated abundances (number of fish in millions) by age group (years) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 7**) and total sampled area. Post-strata ordered in the W-E direction. Mean (±SD) sizes of age groups are also shown. The estimated biomass (t) by age group for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

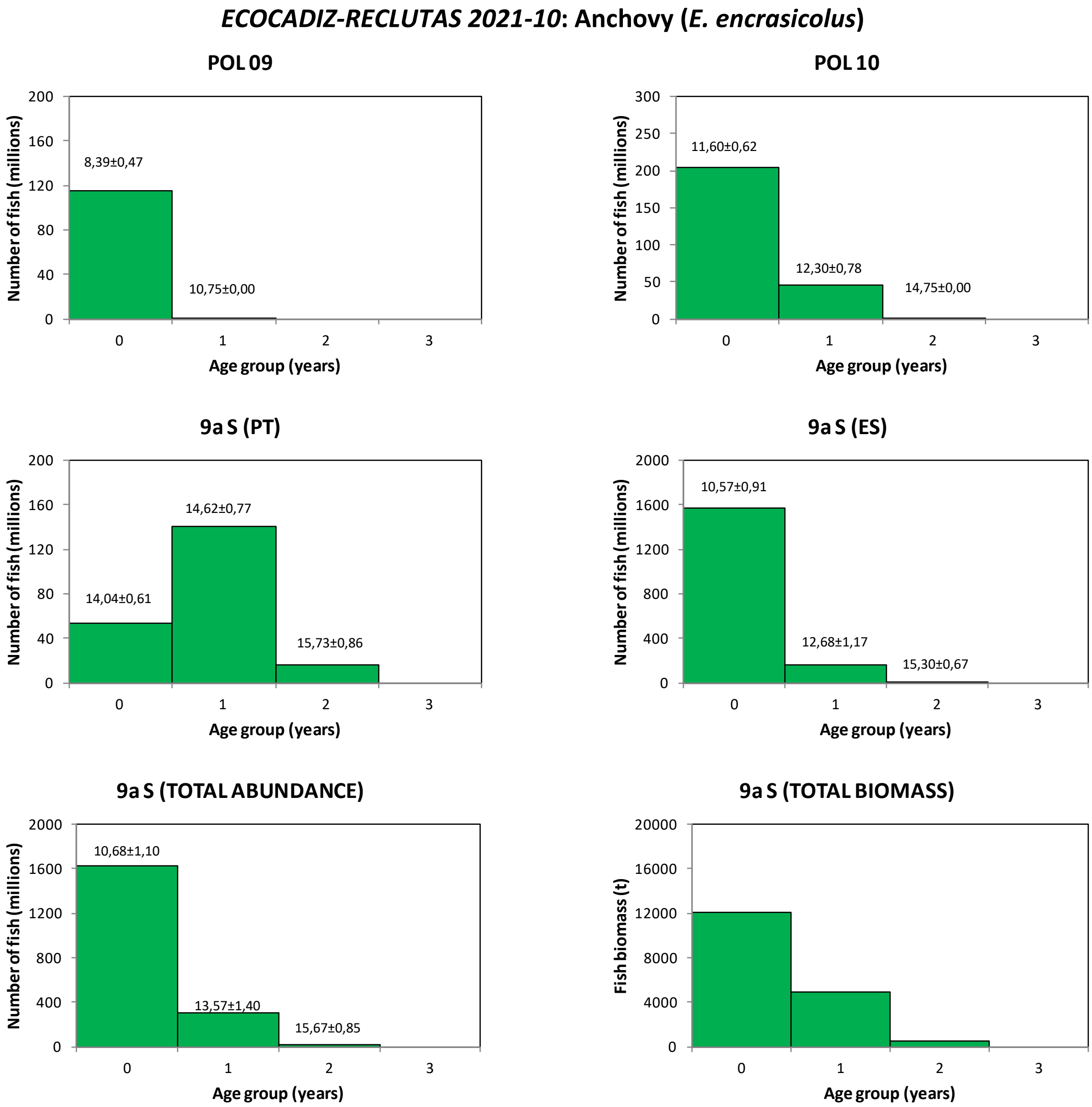


Figure 9. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*Engraulis encrasicolus*). Cont'd.

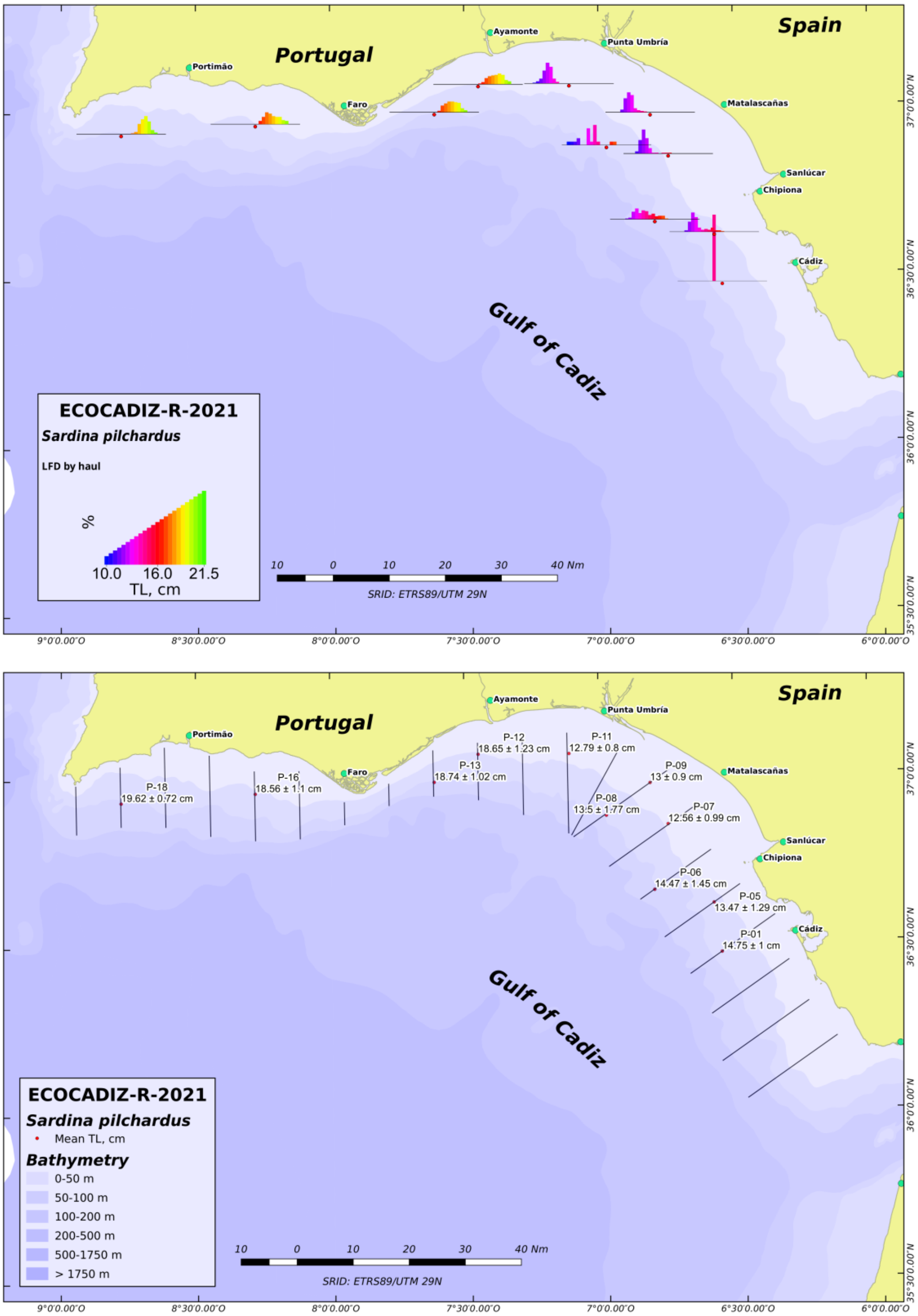
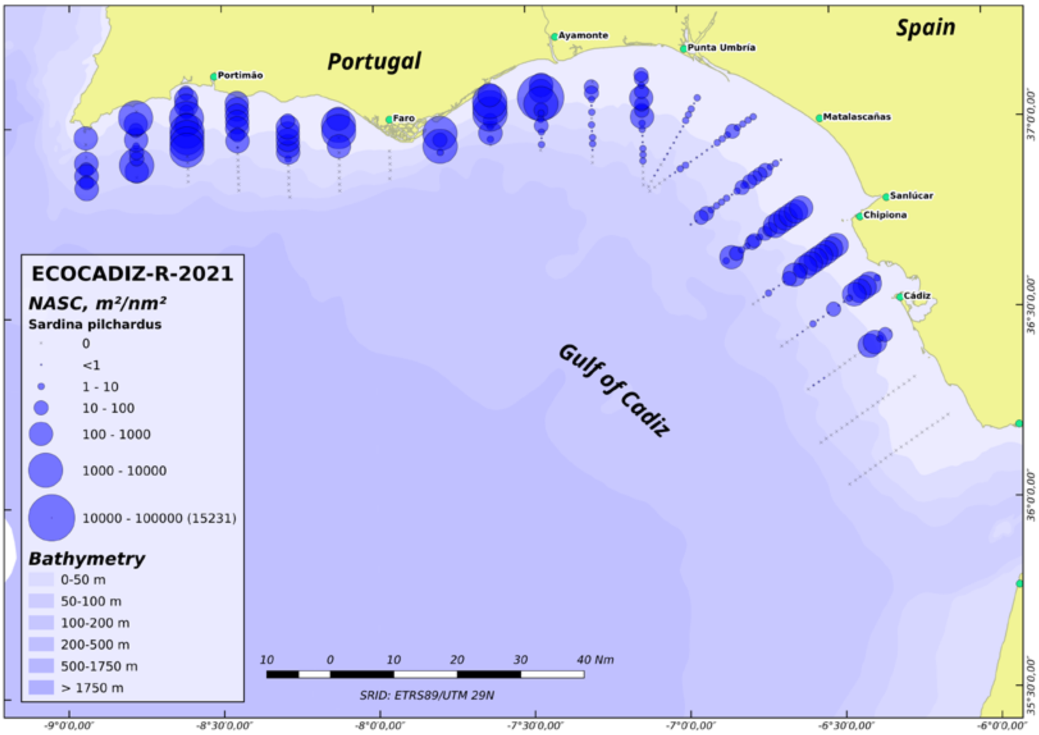


Figure 10. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina pilchardus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.



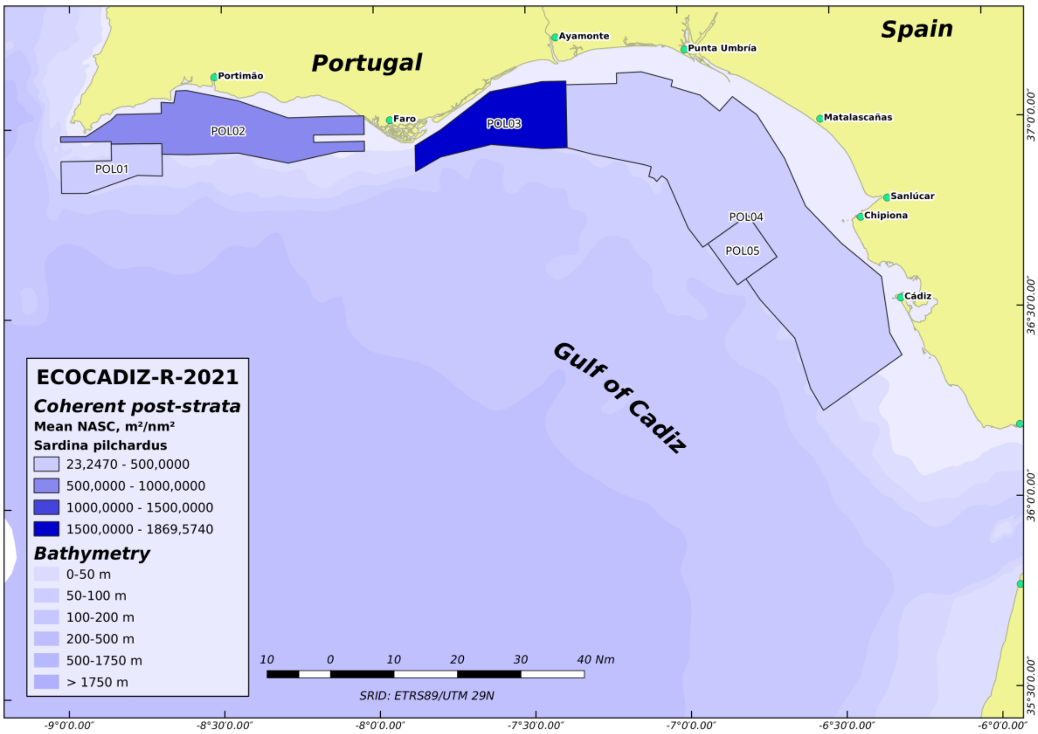


Figure 11. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina pilchardus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

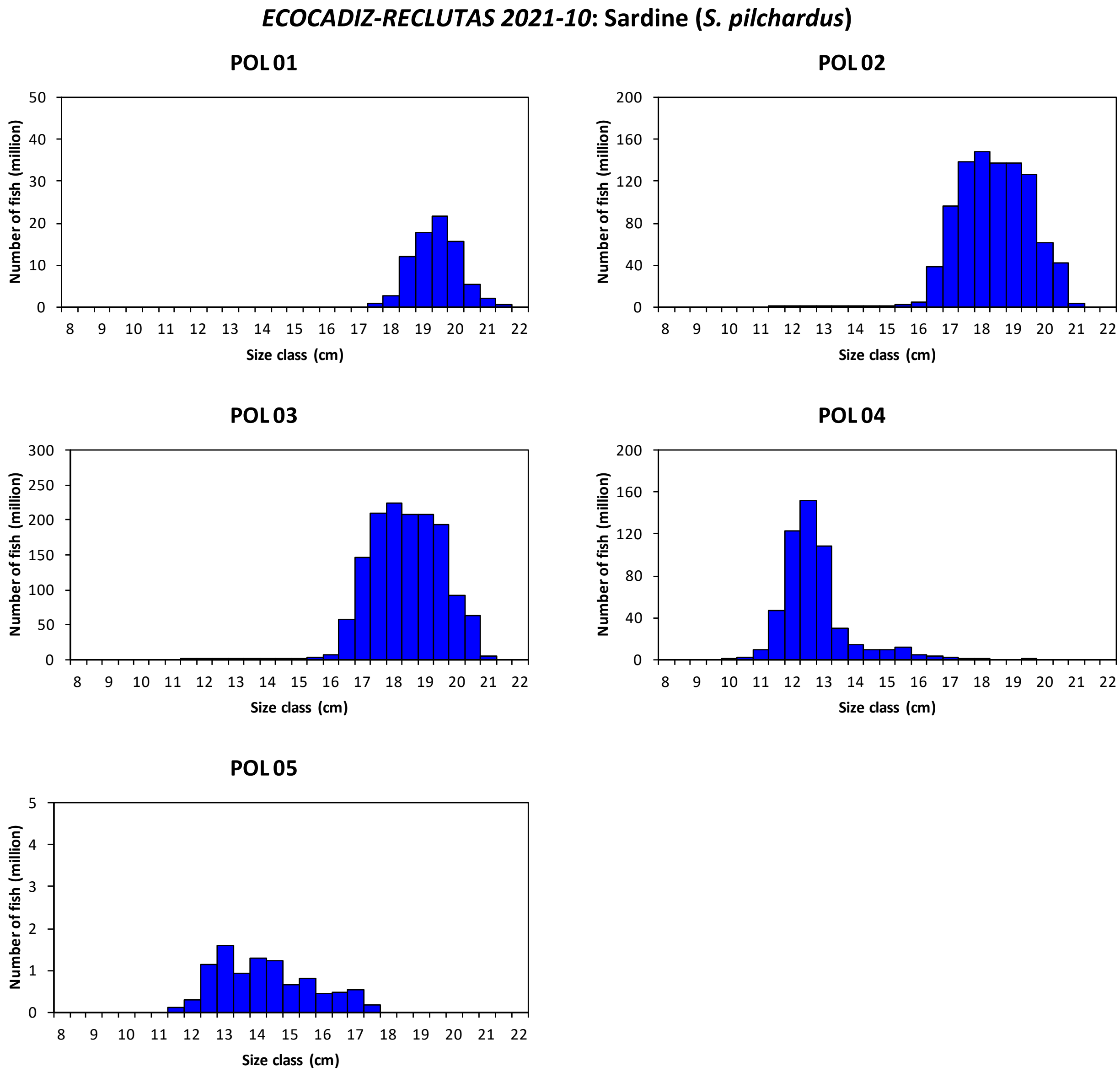


Figure 12. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina pilchardus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 11**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

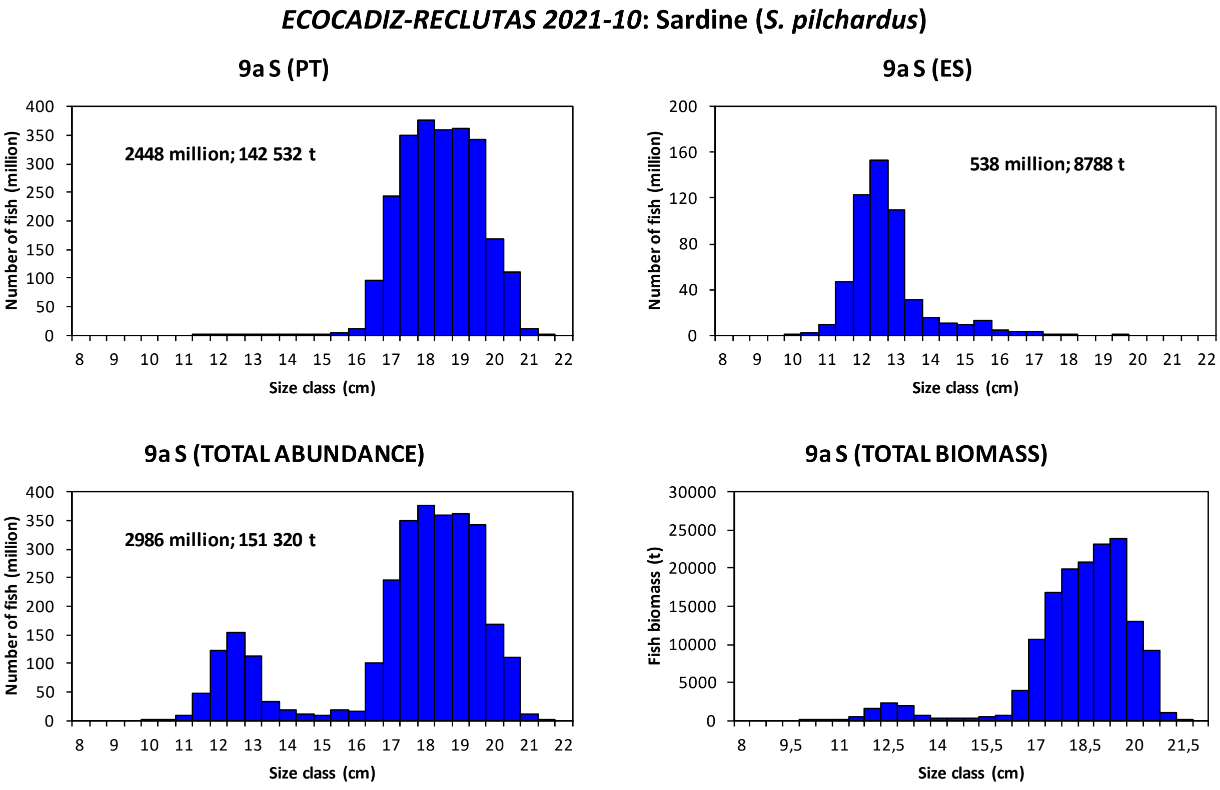


Figure 12. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina pilchardus*). Cont'd.

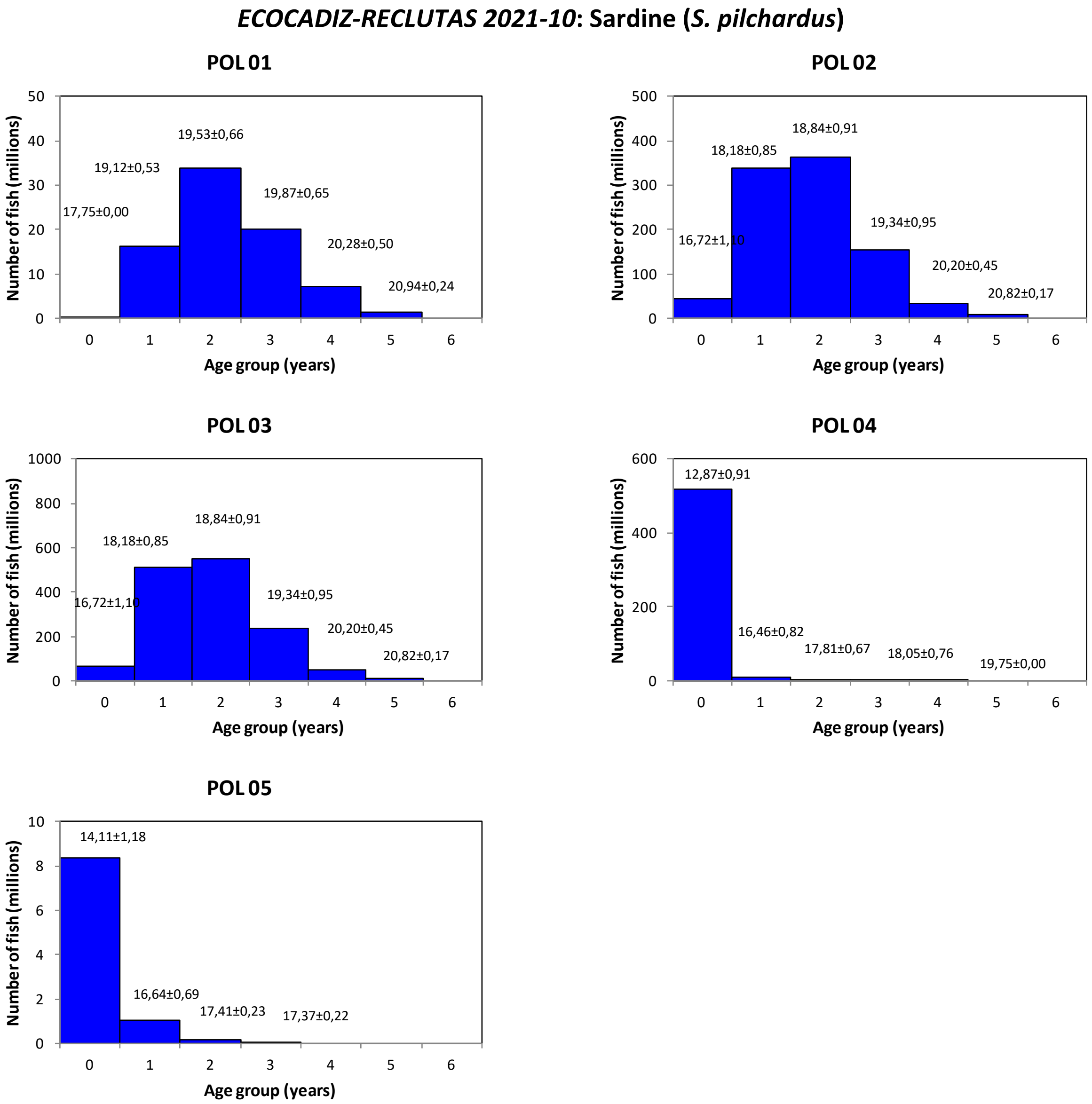


Figure 13. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina pilchardus*). Estimated abundances (number of fish in millions) by age group (years) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 11**) and total sampled area. Post-strata ordered in the W-E direction. Mean (±SD) sizes of age groups are also shown. The estimated biomass (t) by age group for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

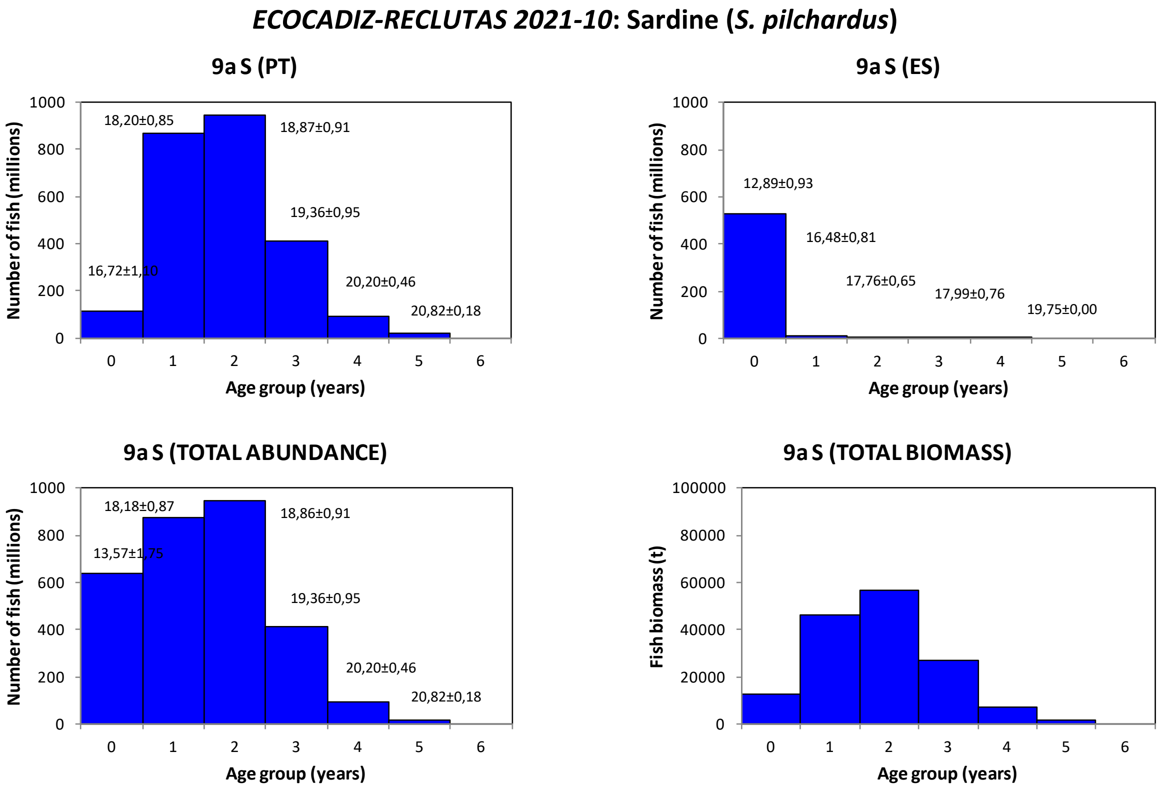
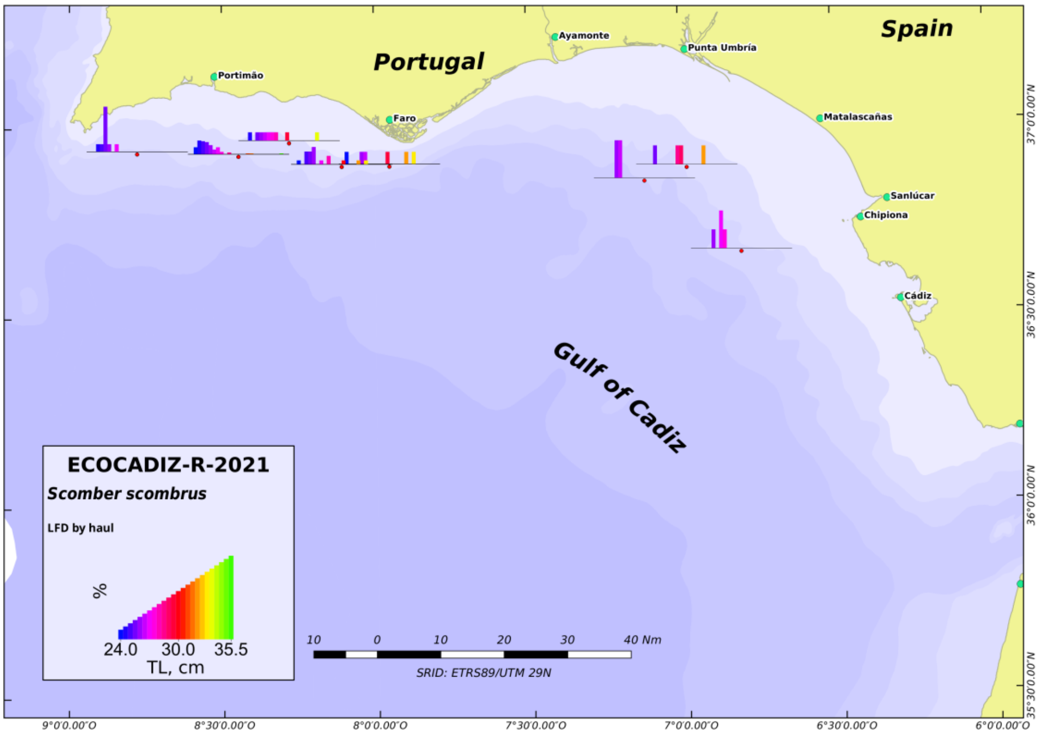


Figure 13. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina pilchardus*). Cont'd.



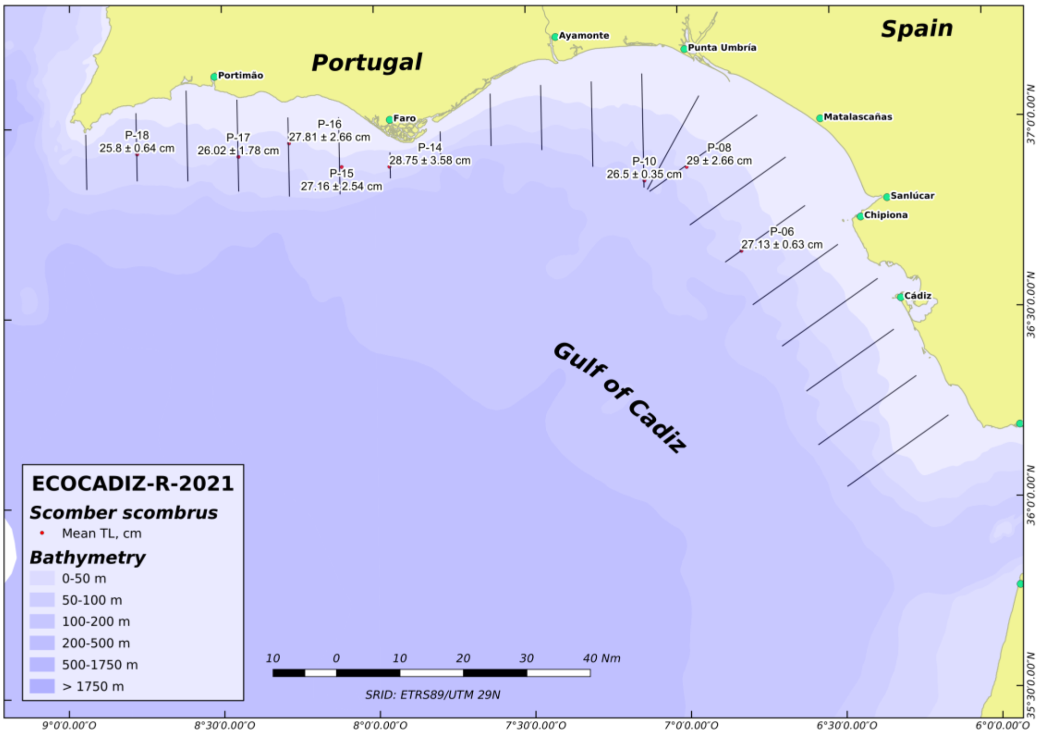


Figure 14. *ECOCADIZ-RECLUTAS 2021-10* survey. Atlantic mackerel (*Scomber scombrus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

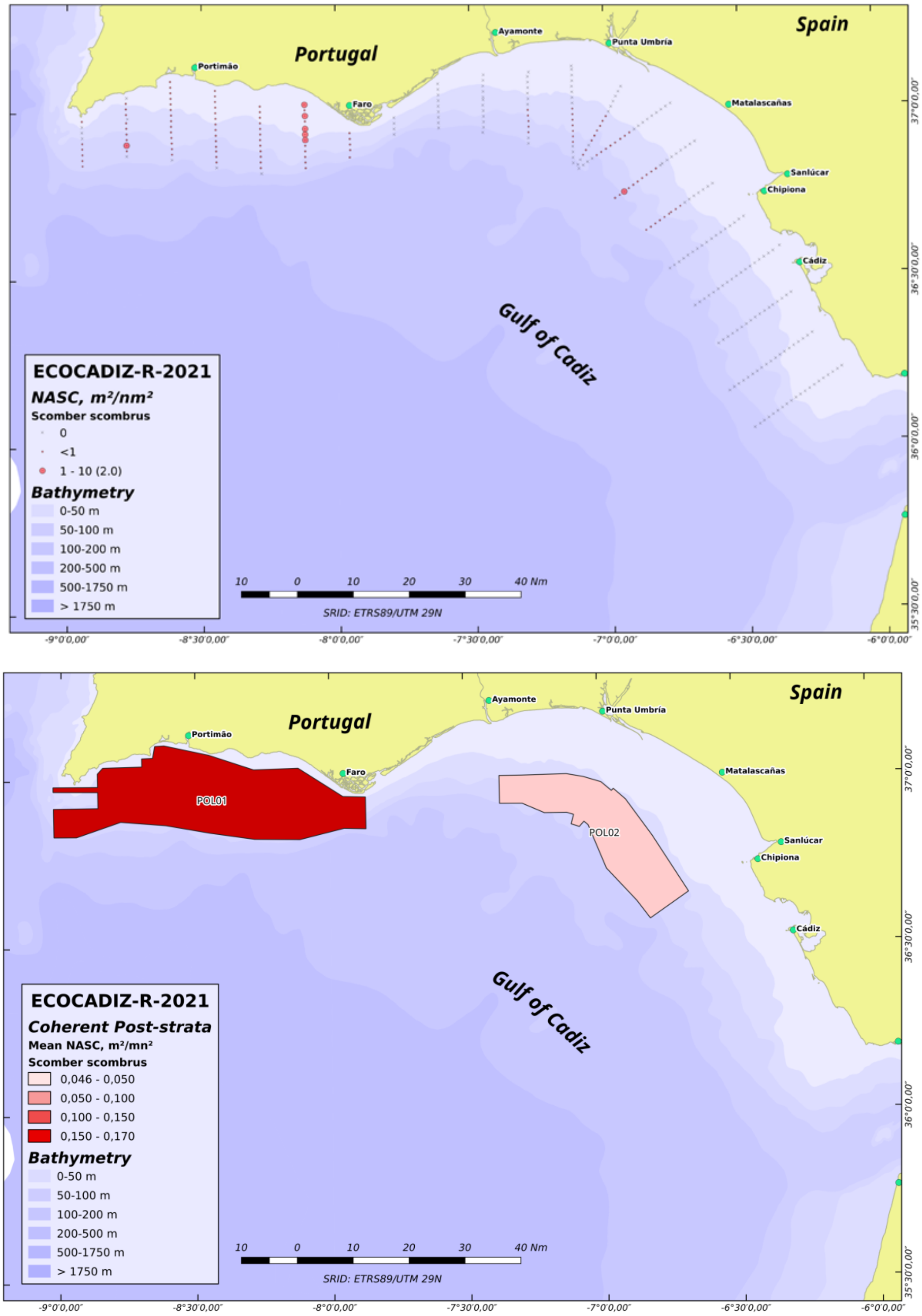


Figure 15. *ECOCADIZ-RECLUTAS 2021-10* survey. Atlantic mackerel (*Scomber scombrus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

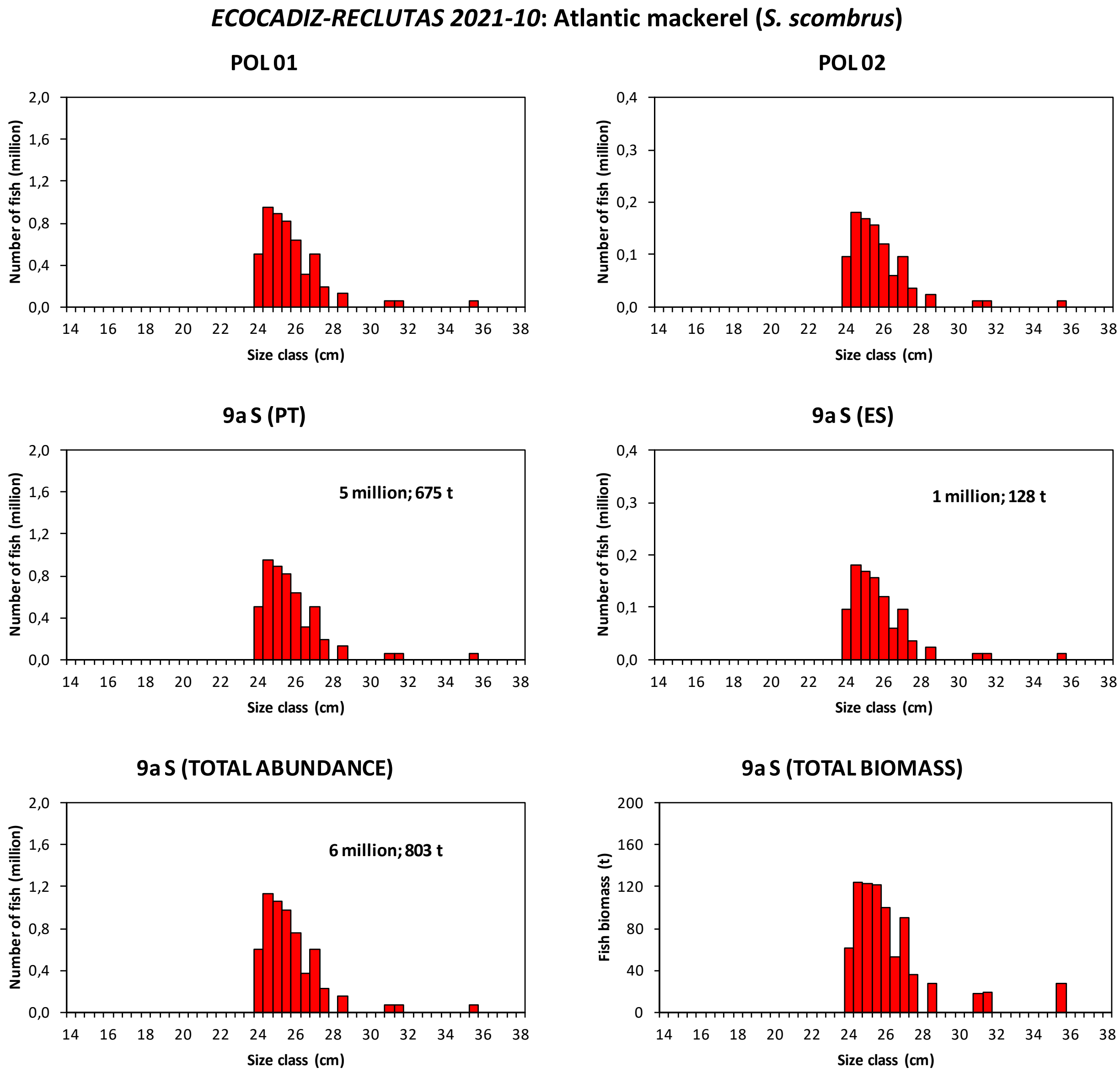


Figure 16. *ECOCADIZ-RECLUTAS 2021-10* survey. Atlantic mackerel (*Scomber scombrus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 15**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

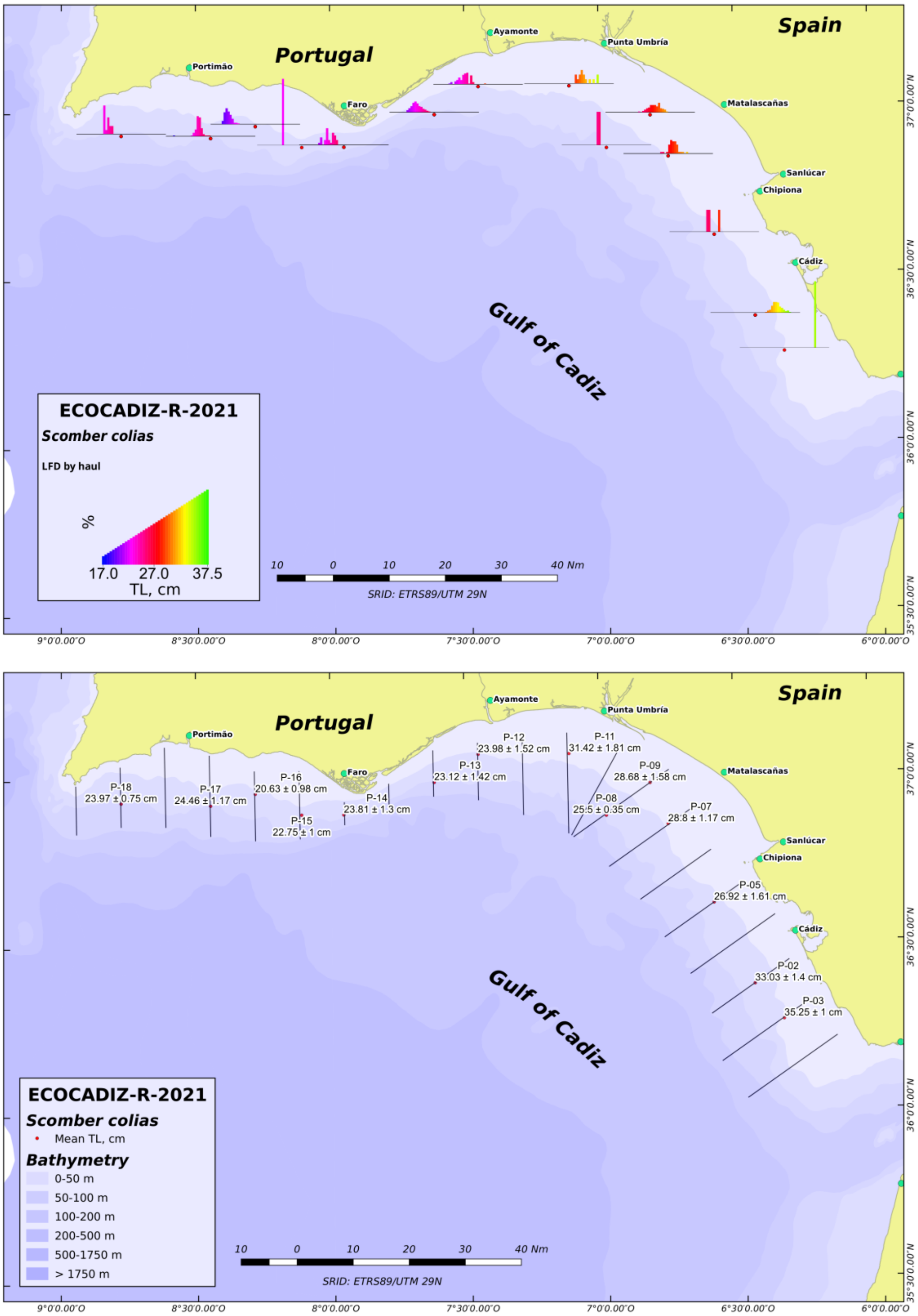


Figure 17. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber colias*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

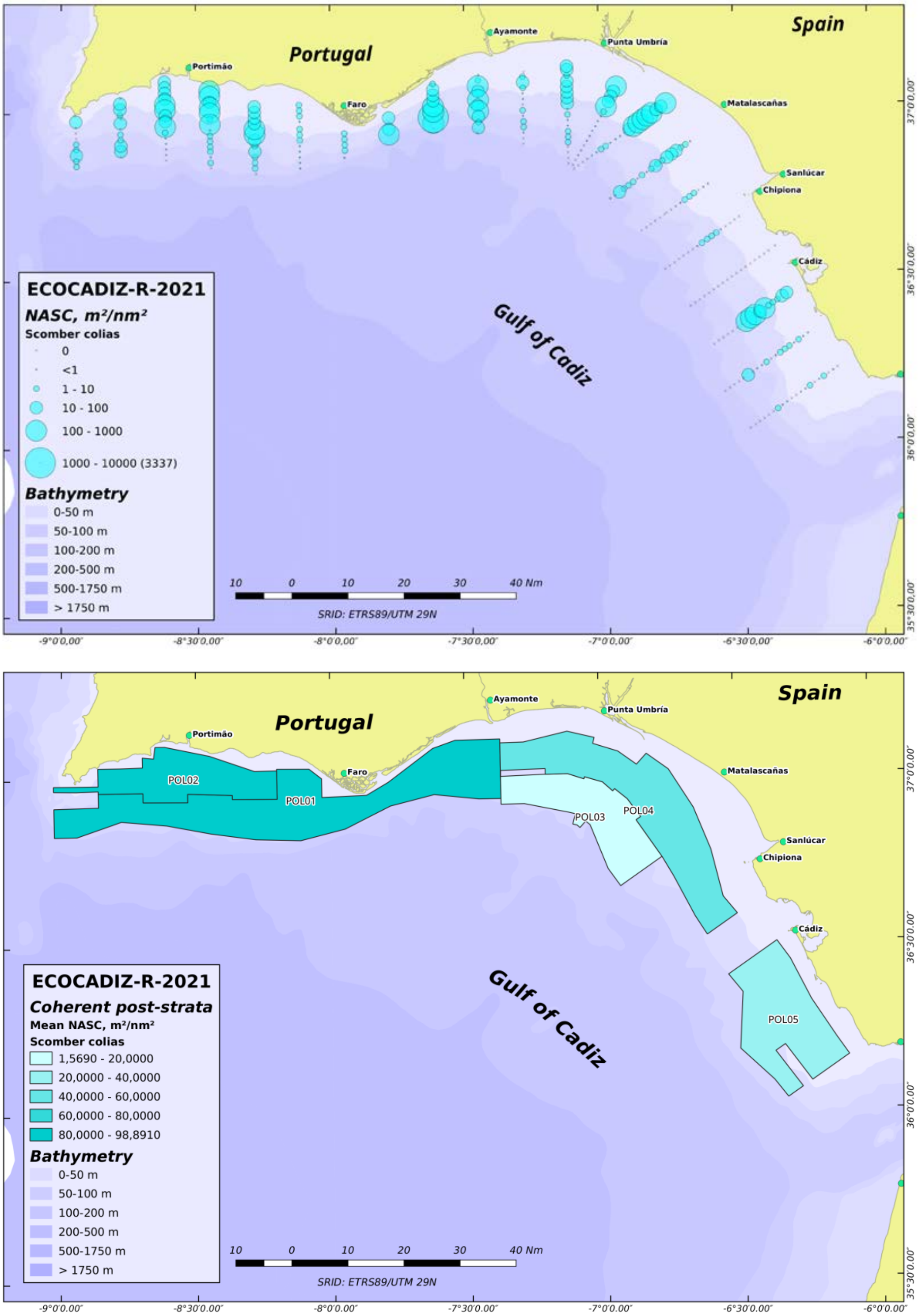


Figure 18. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber colias*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

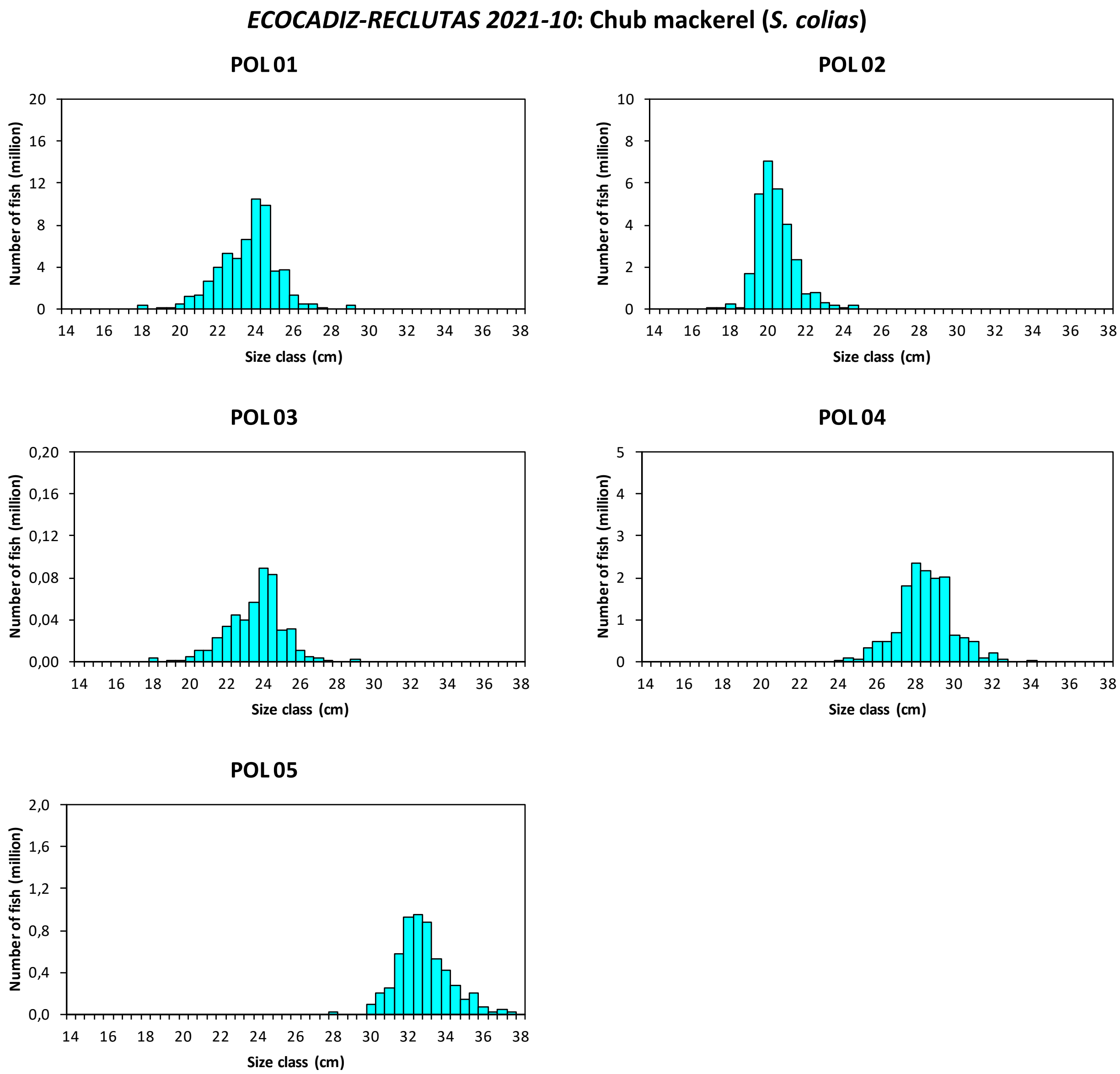


Figure 19. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber colias*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 18**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

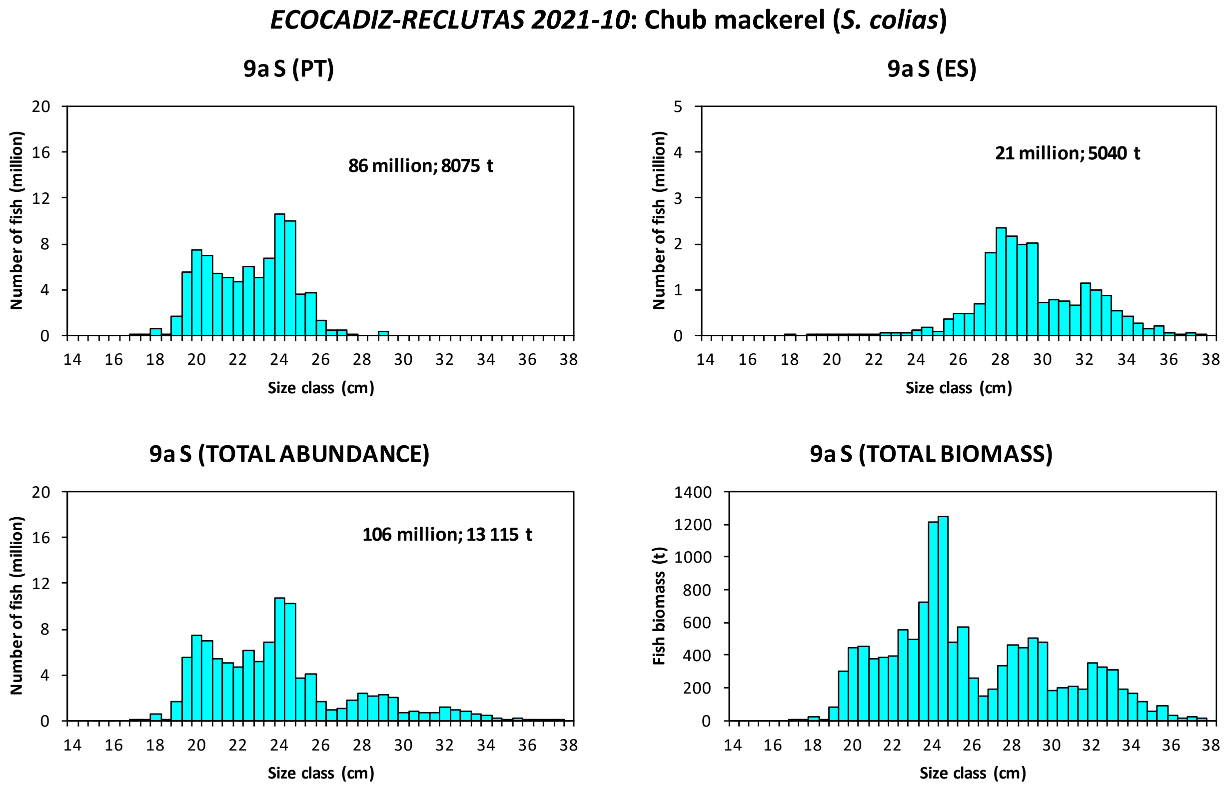


Figure 19. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber colias*). Cont'd.

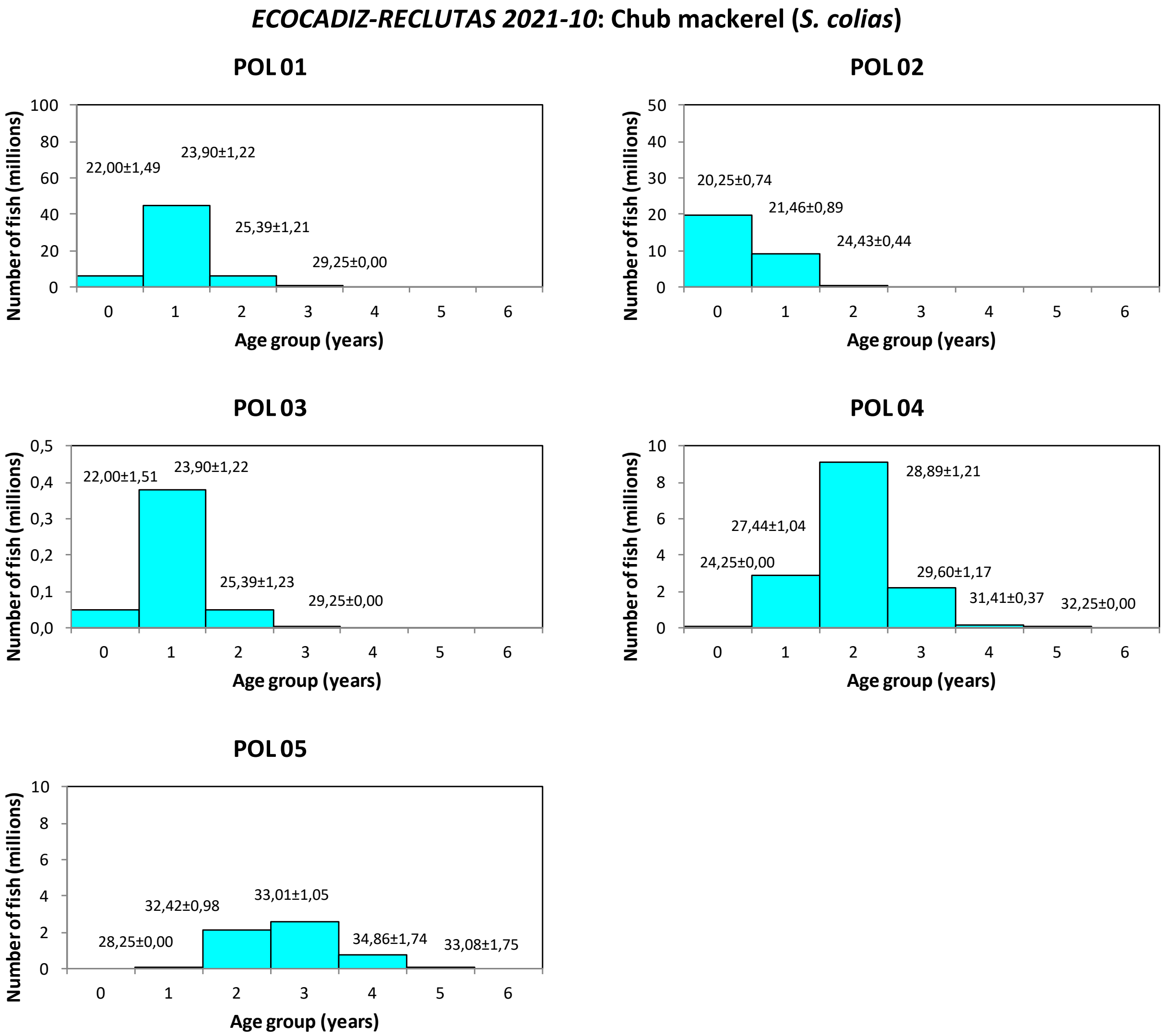


Figure 20. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber colias*). Estimated abundances (number of fish in millions) by age group (years) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 18**) and total sampled area. Post-strata ordered in the W-E direction. Mean (±SD) sizes of age groups are also shown. The estimated biomass (t) by age group for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

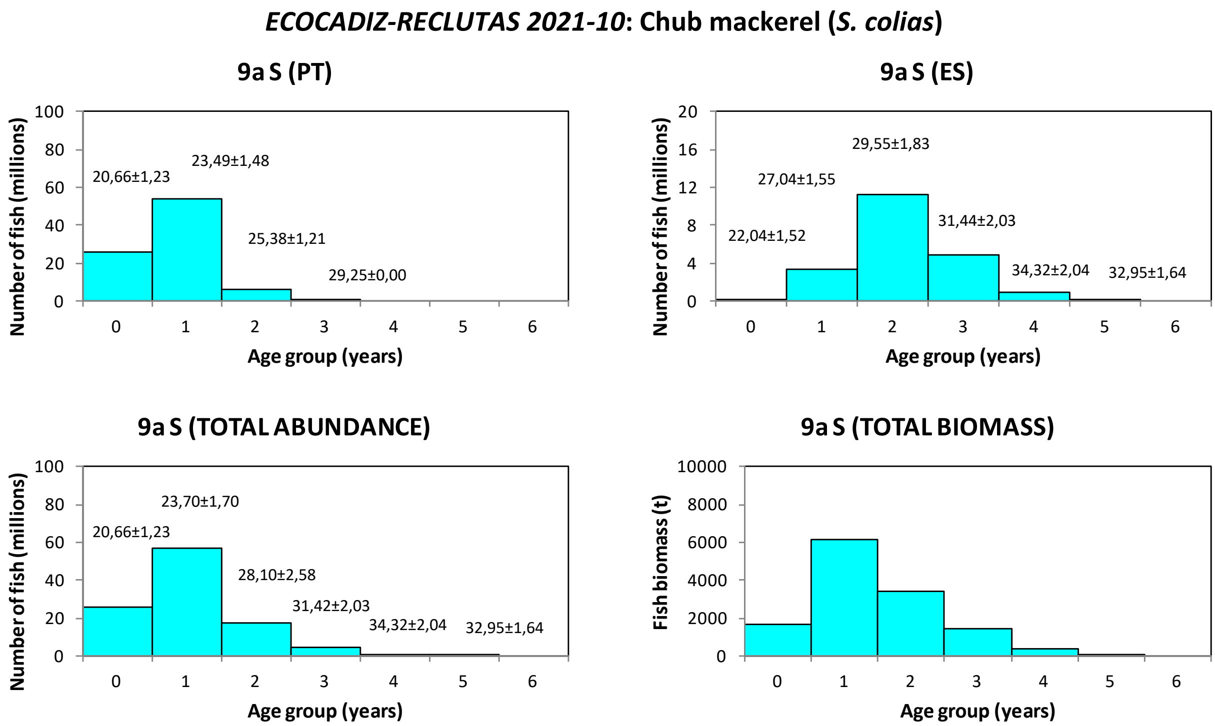


Figure 20. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber colias*). Cont'd.

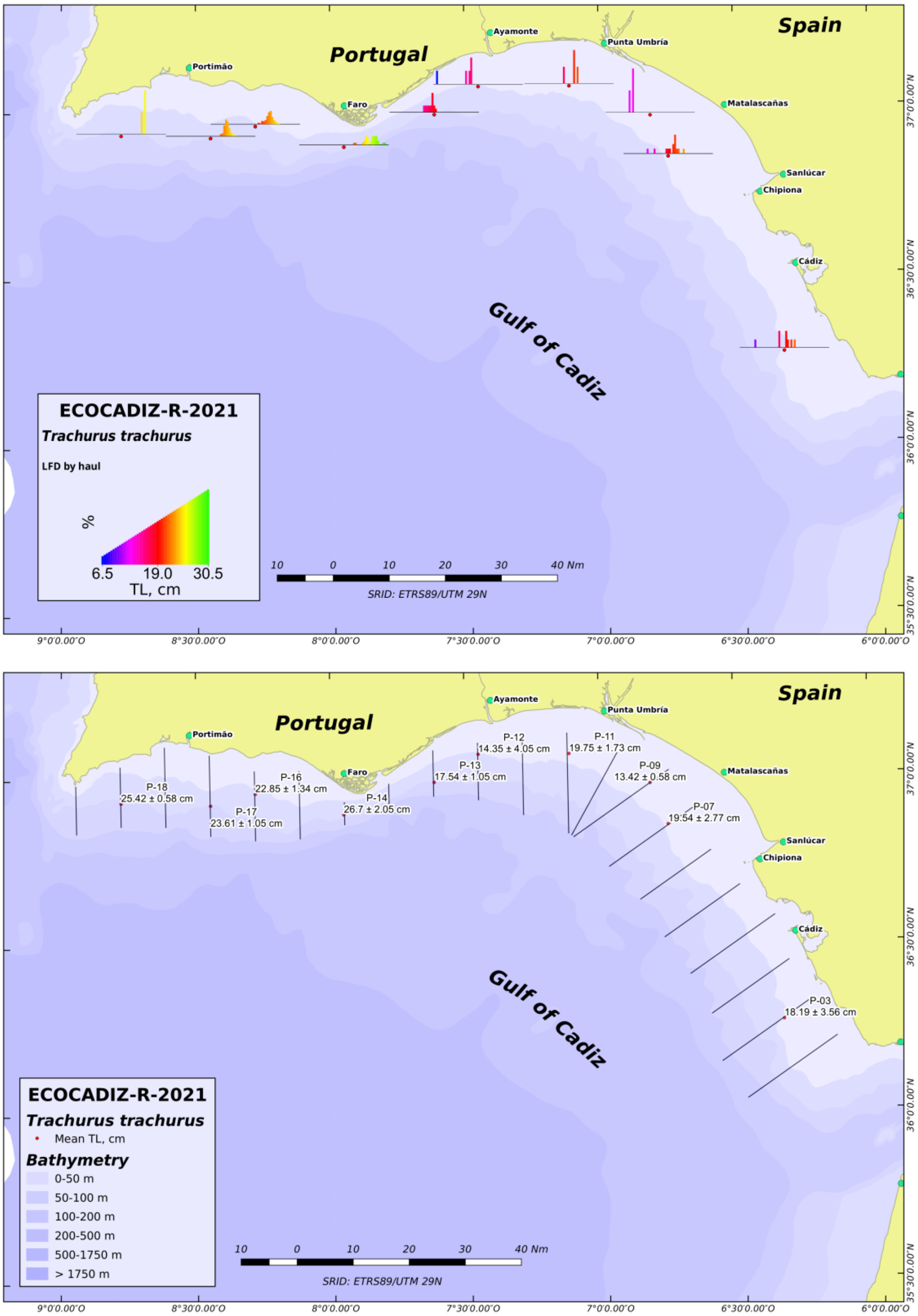


Figure 21. *ECOCADIZ-RECLUTAS 2021-10* survey. Horse mackerel (*Trachurus trachurus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

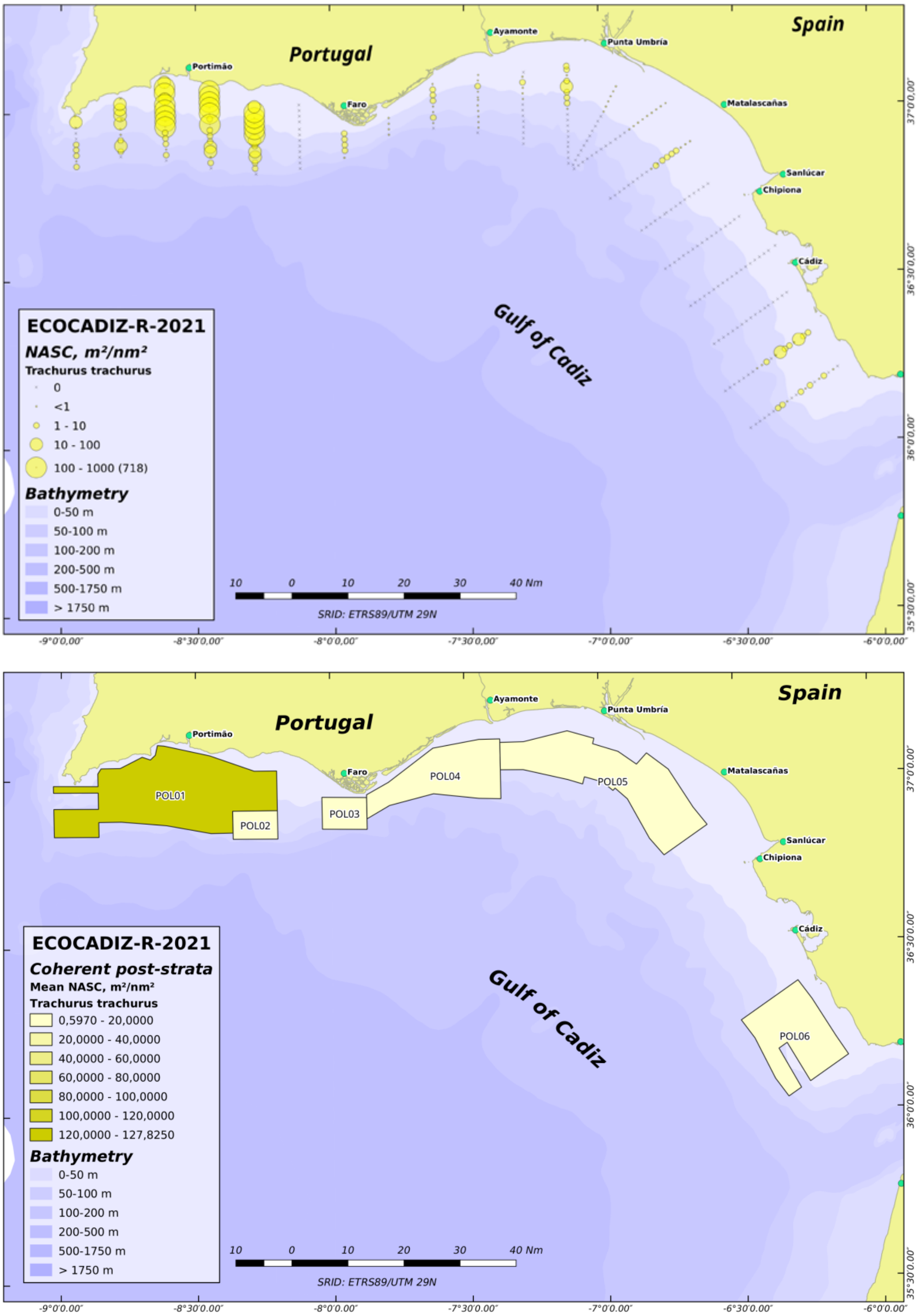


Figure 22. *ECOCADIZ-RECLUTAS 2021-10* survey. Horse mackerel (*Trachurus trachurus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

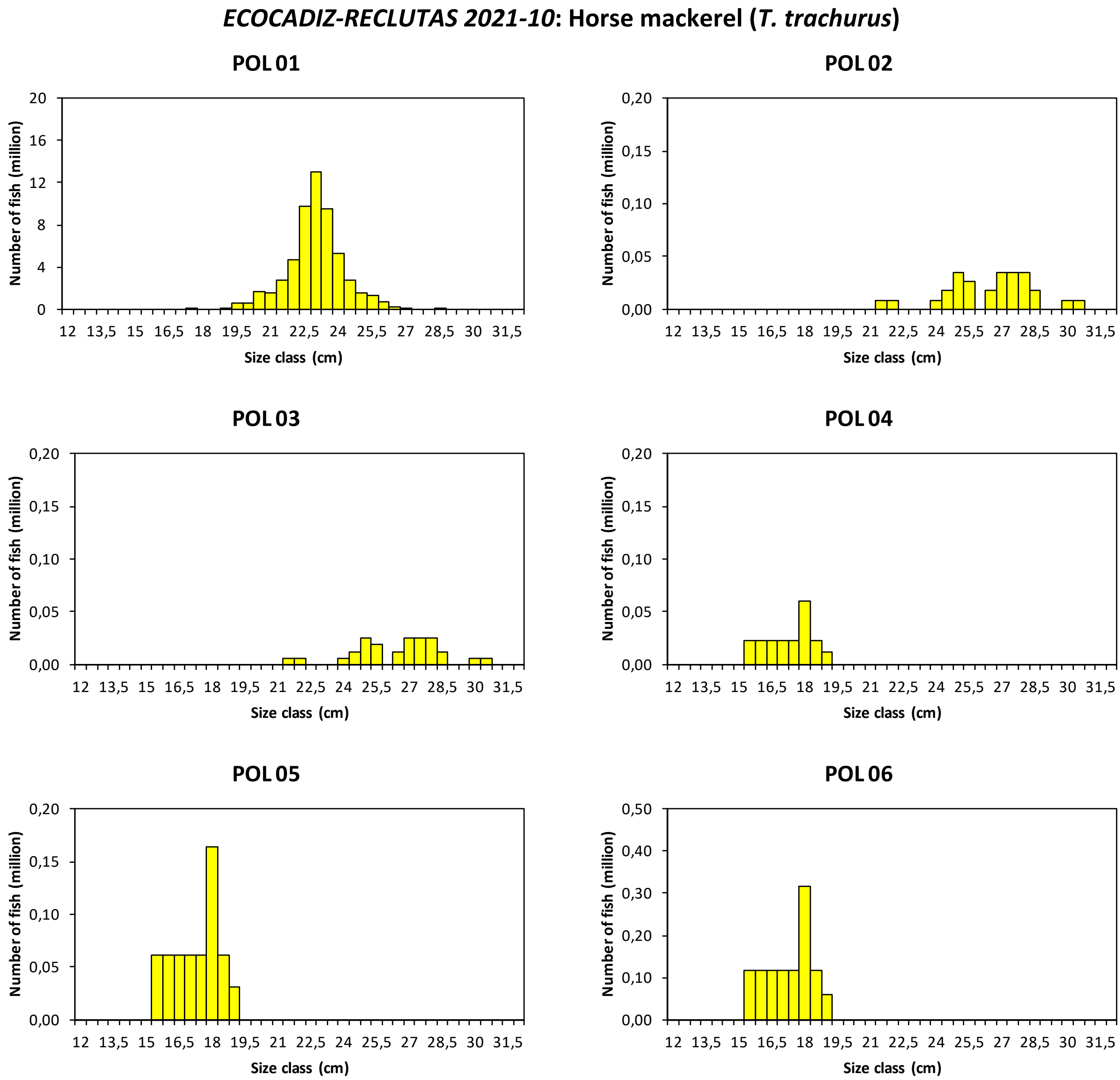


Figure 23. *ECOCADIZ-RECLUTAS 2021-10* survey. Horse mackerel (*Trachurus trachurus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 22**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

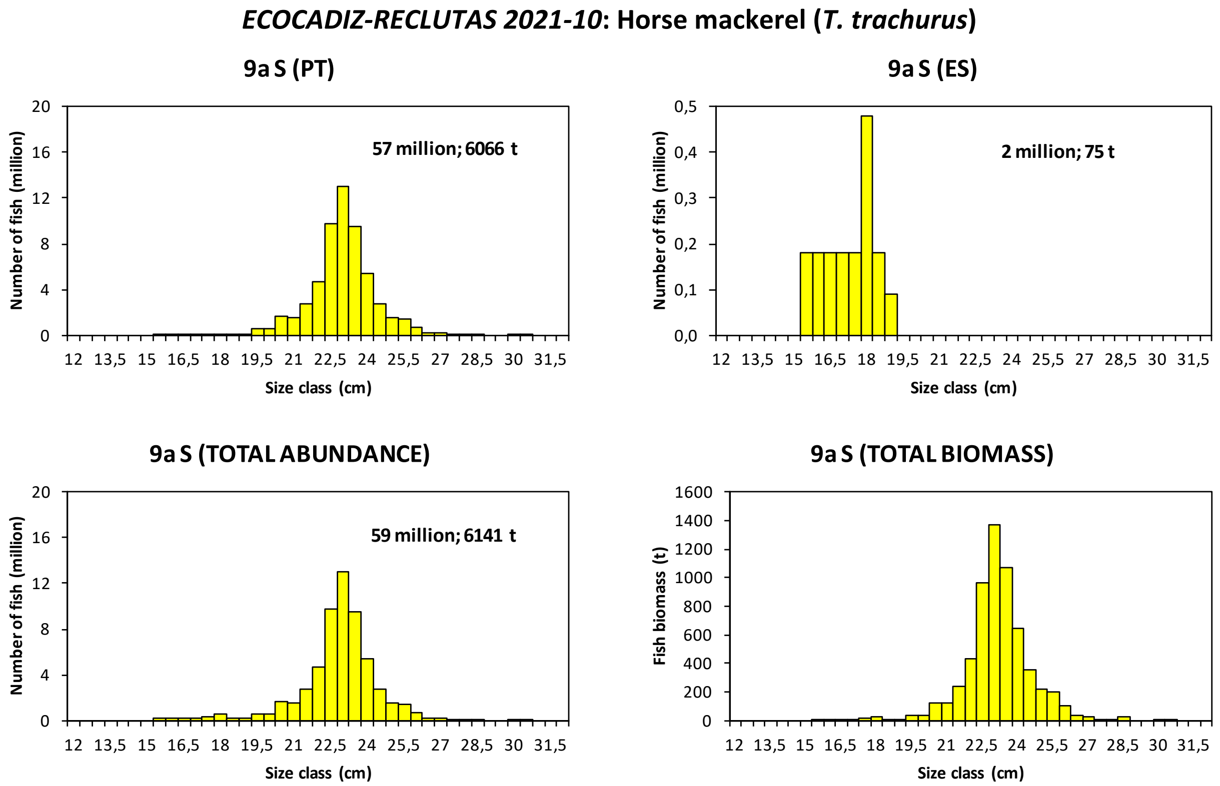


Figure 23. *ECOCADIZ-RECLUTAS 2021-10* survey. Horse mackerel (*Trachurus trachurus*). Cont'd.

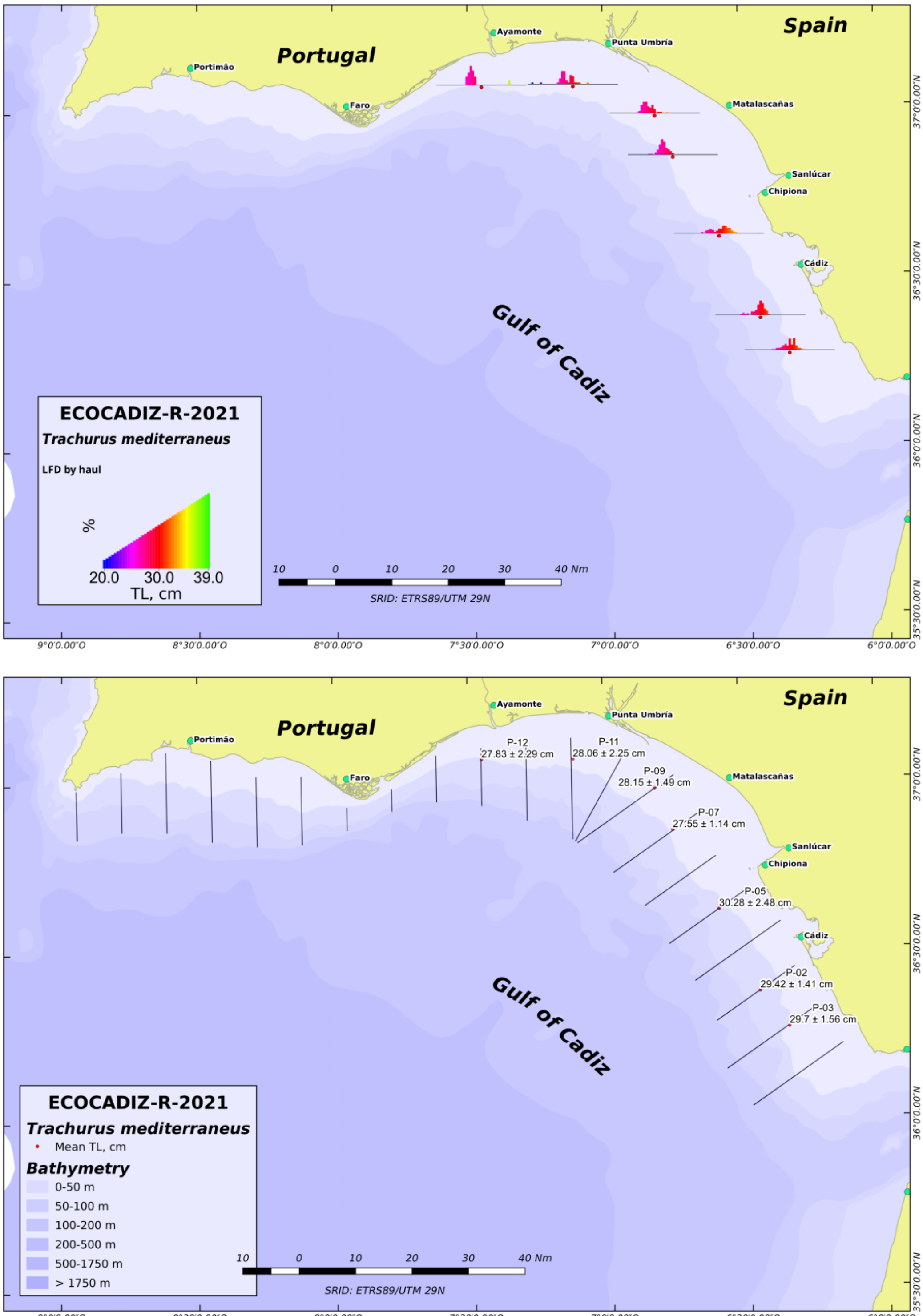


Figure 24. *ECOCADIZ-RECLUTAS 2021-10* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

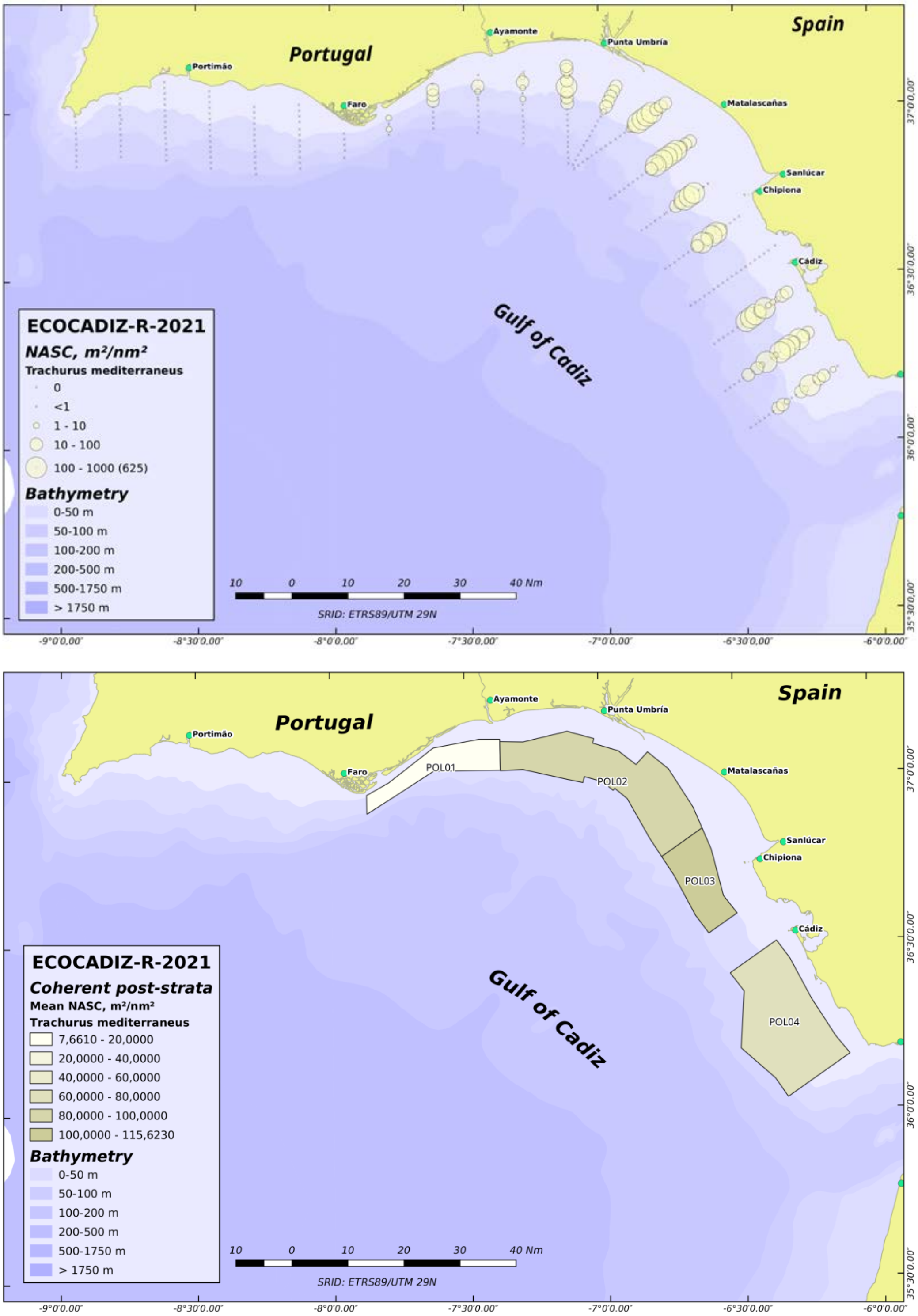


Figure 25. *ECOCADIZ-RECLUTAS 2021-10* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

***ECOCADIZ-RECLUTAS 2021-10*: Mediterranean horse mackerel (*T. mediterraneus*)**

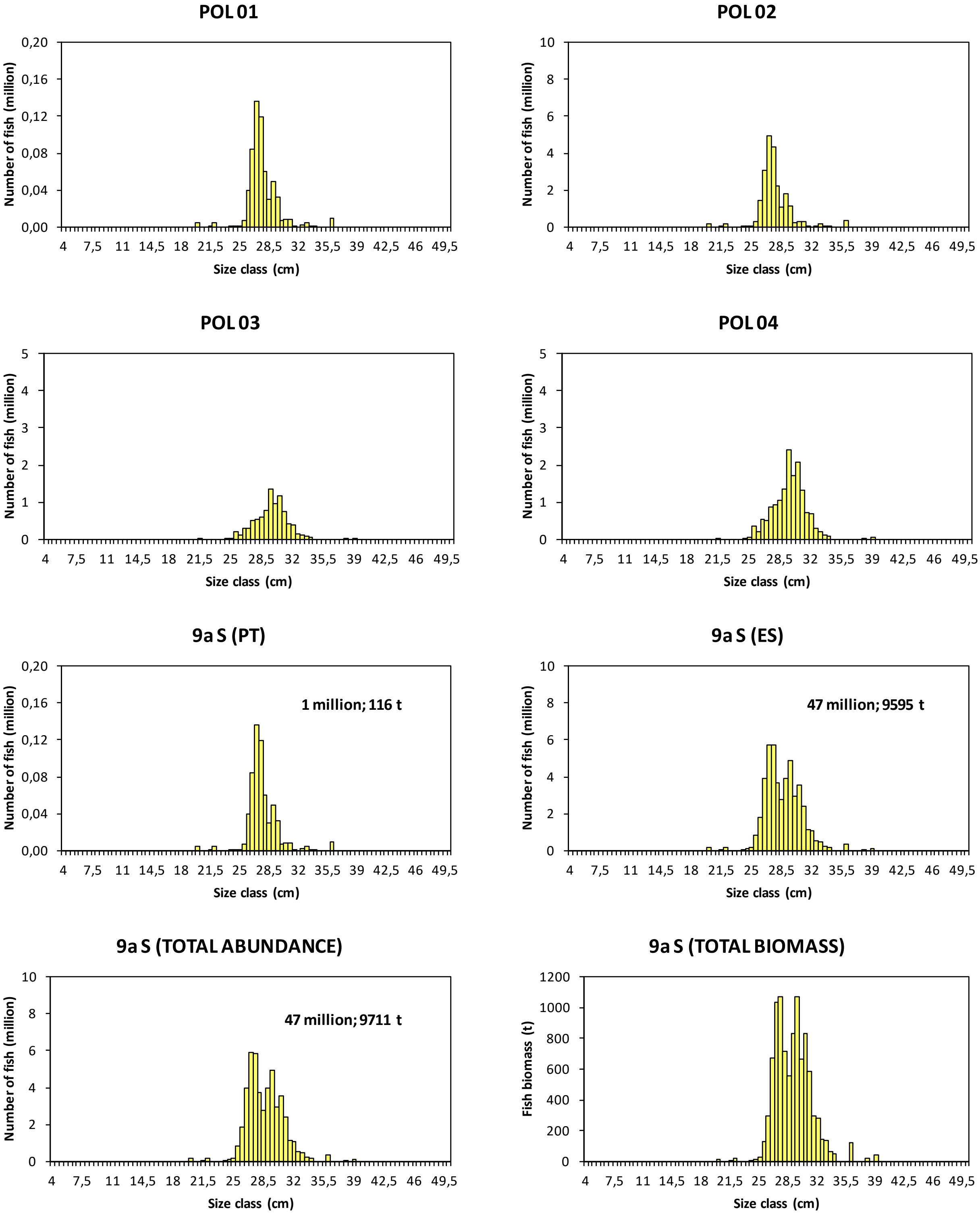


Figure 26. *ECOCADIZ-RECLUTAS 2021-10* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 25**) and total sampled area. Post-strata ordered in the W-E 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.

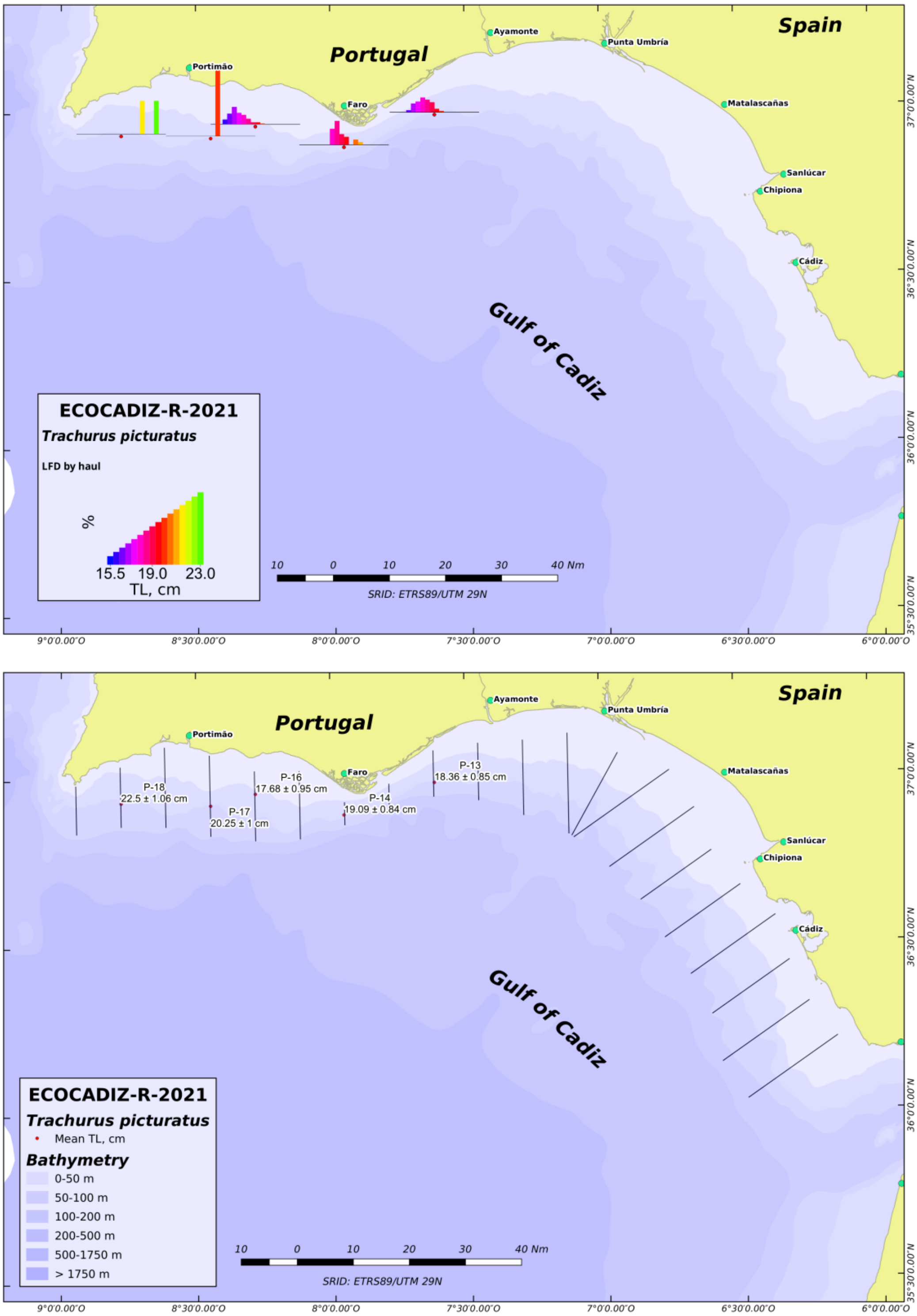


Figure 27. *ECOCADIZ-RECLUTAS 2021-10* survey. Blue jack mackerel (*Trachurus picturatus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

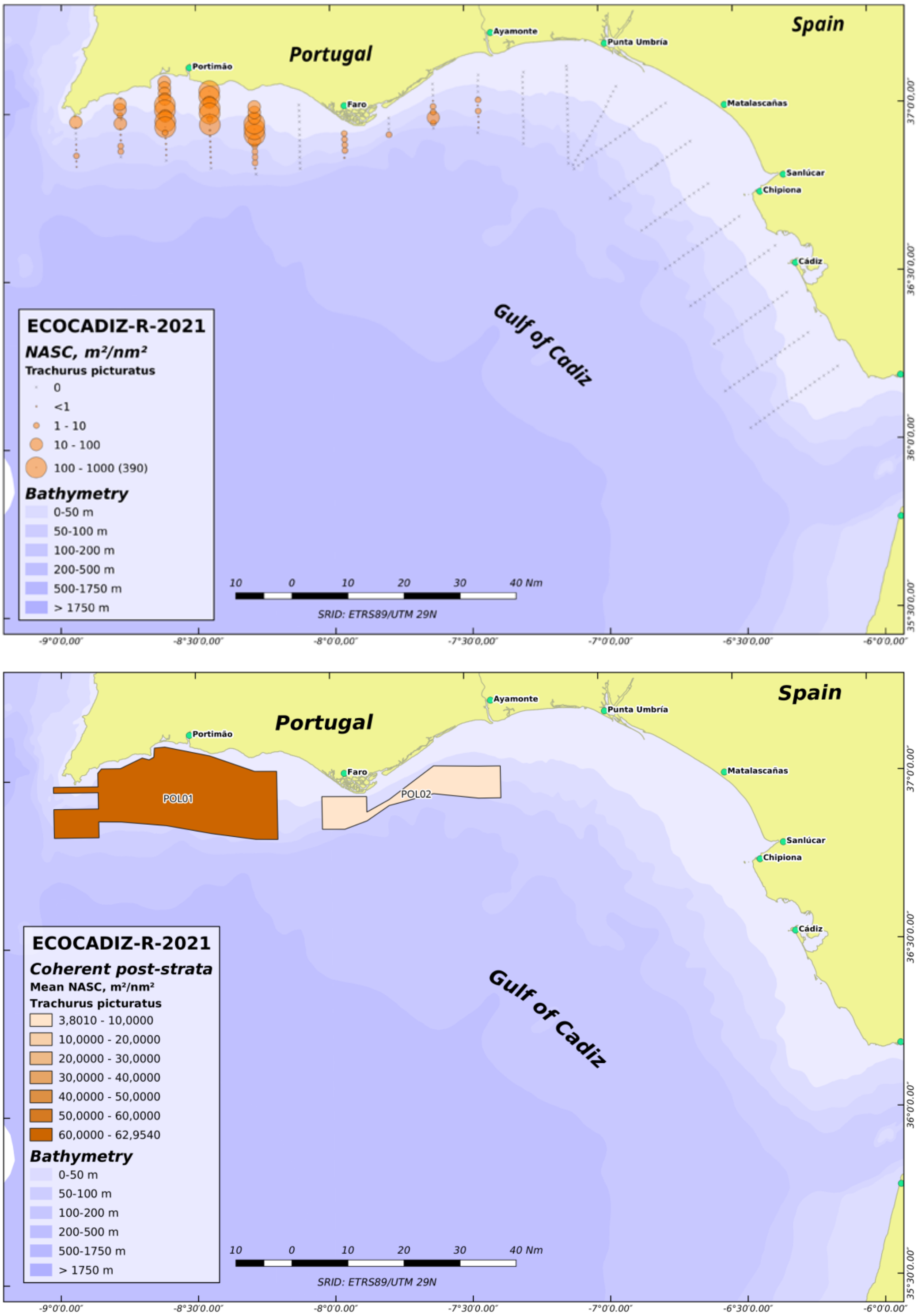


Figure 28. *ECOCADIZ-RECLUTAS 2021-10* survey. Blue jack mackerel (*Trachurus picturatus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

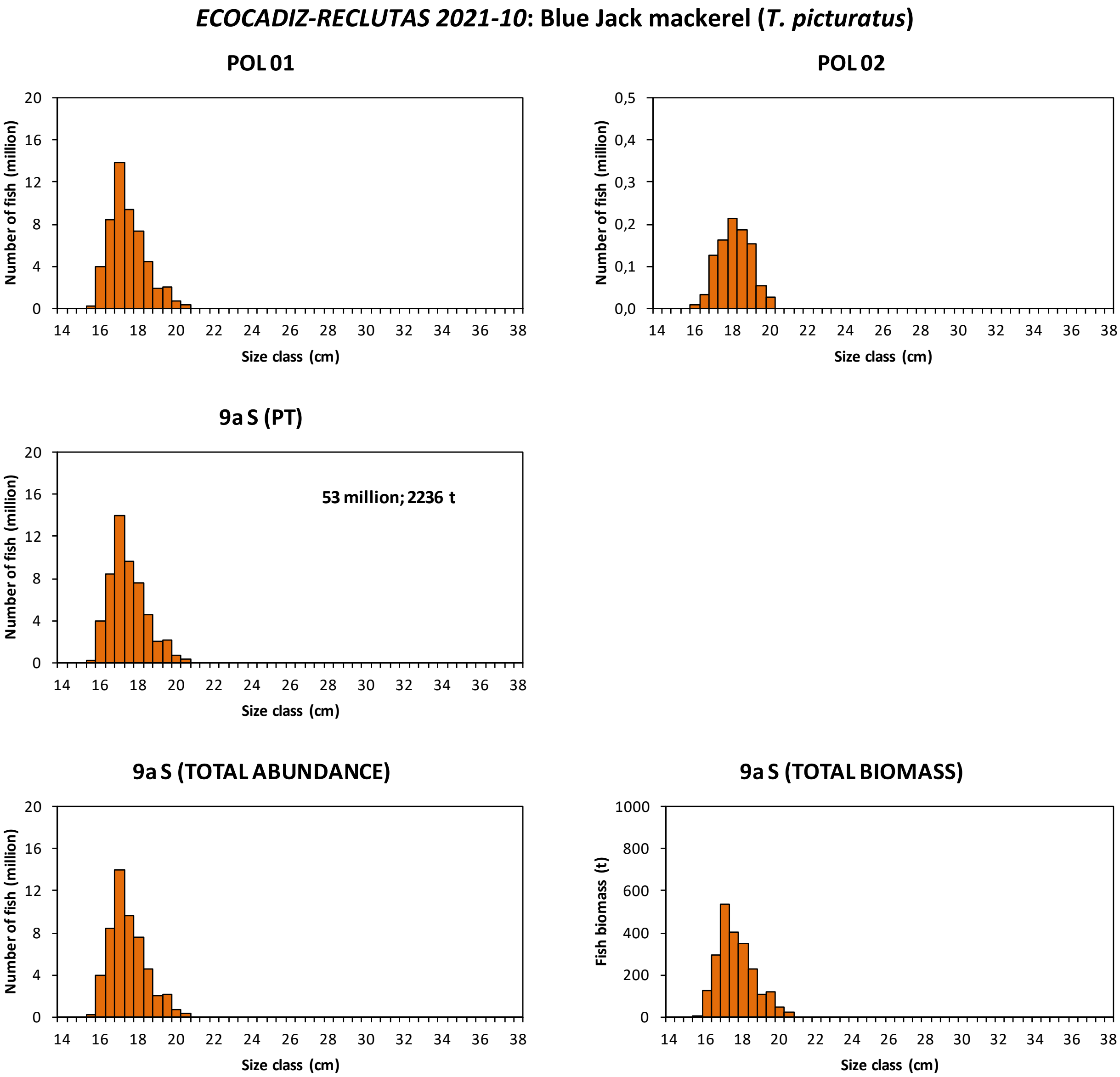


Figure 29. *ECOCADIZ-RECLUTAS 2021-10* survey. Blue jack mackerel (*Trachurus picturatus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 28**) and total sampled area. Post-strata ordered in the W-E direction. 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.

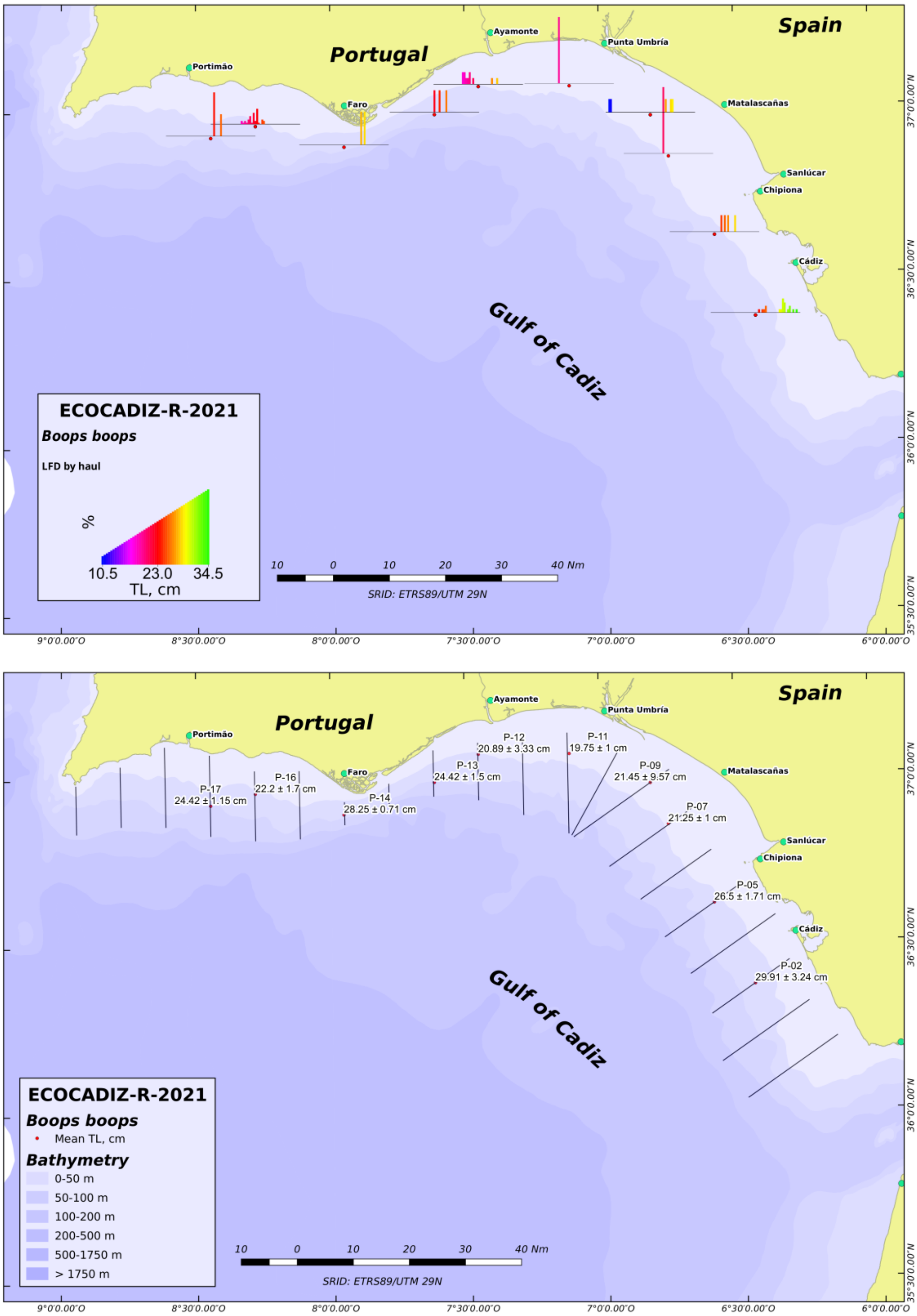


Figure 30. *ECOCADIZ-RECLUTAS 2021-10* survey. Bogue (*Boops boops*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

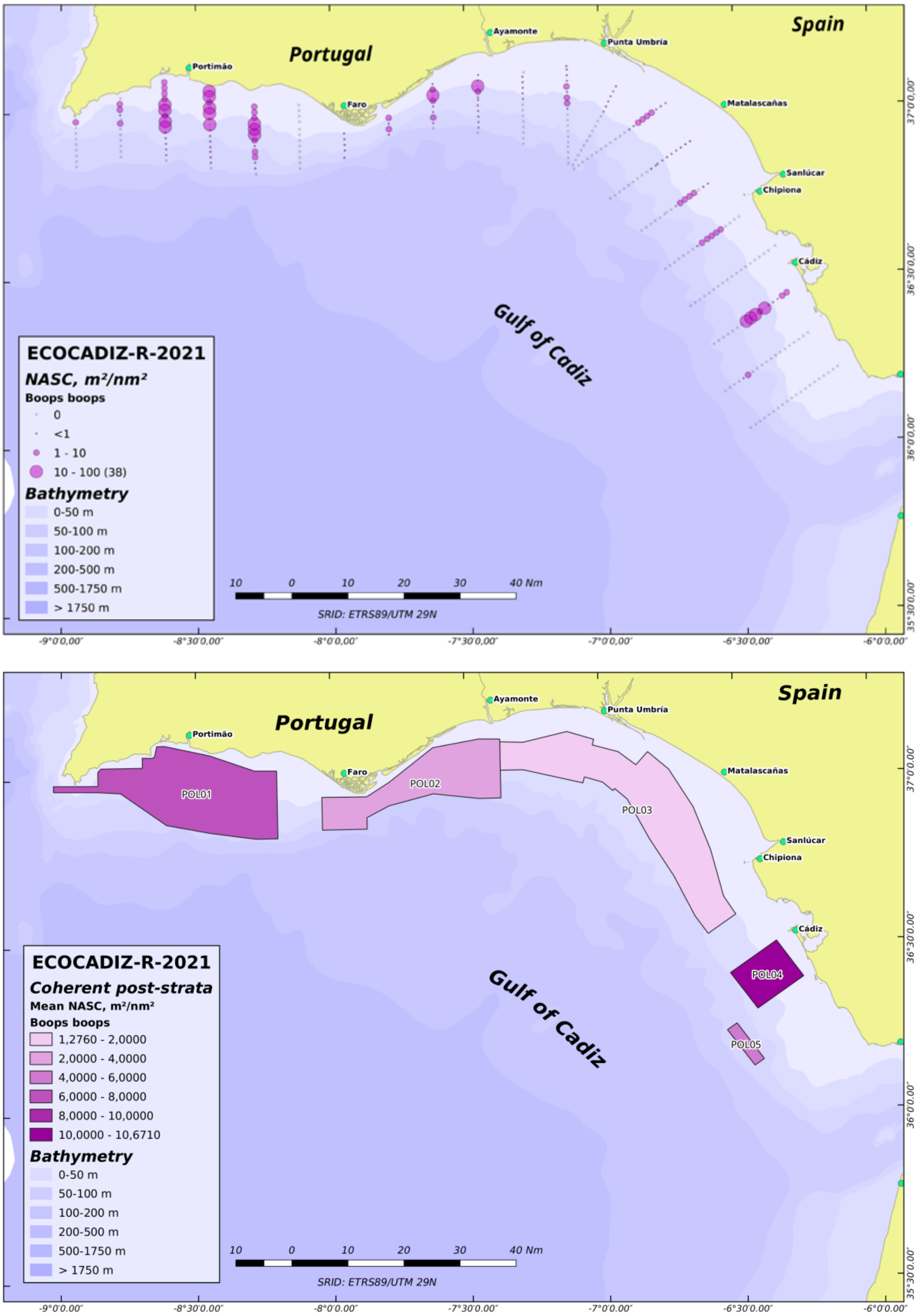


Figure 31. *ECOCADIZ-RECLUTAS 2021-10* survey. Bogue (*Boops boops*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

***ECOCADIZ-RECLUTAS 2021-10*: Bogue (*B. boops*)**

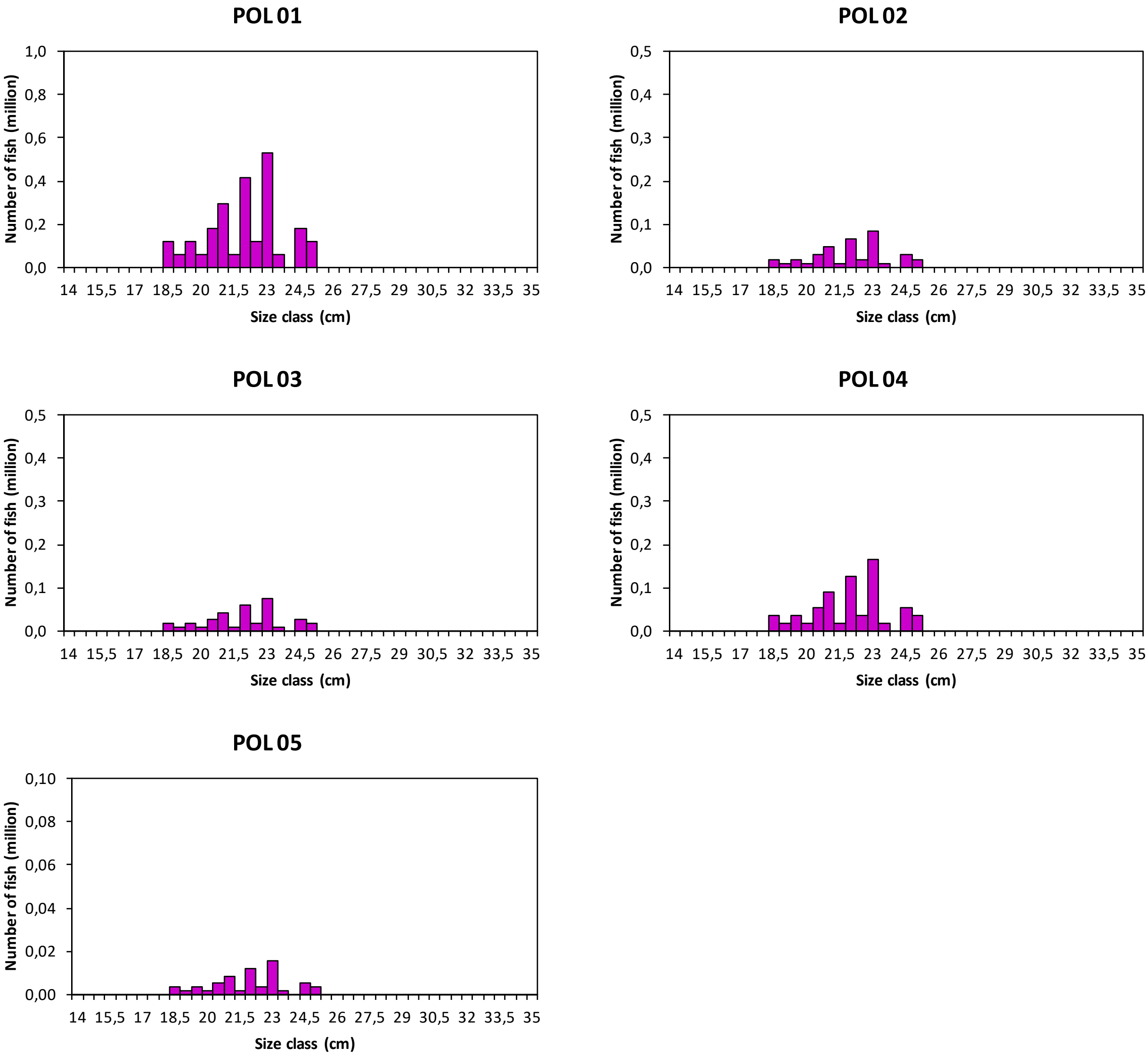


Figure 32. *ECOCADIZ-RECLUTAS 2021-10* survey. Bogue (*Boops boops*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 31**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

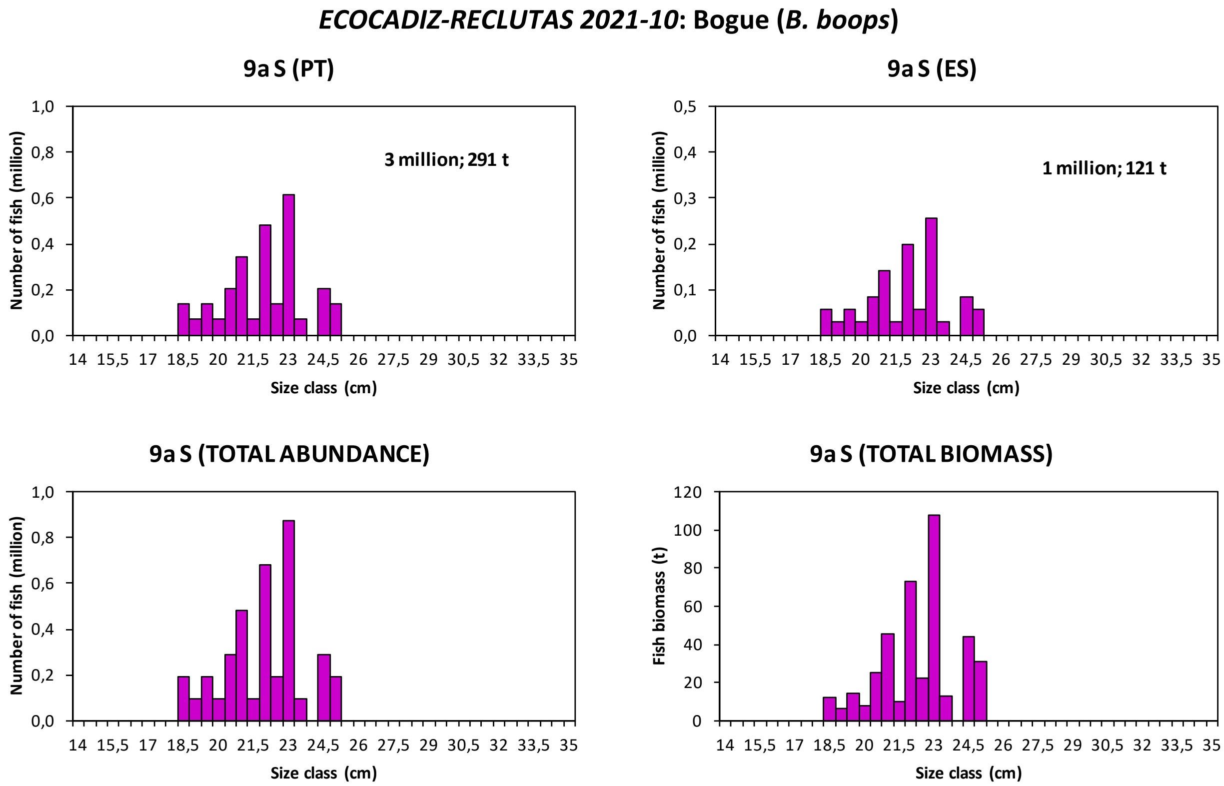


Figure 32. *ECOCADIZ-RECLUTAS 2021-10* survey. Bogue (*Boops boops*). Cont'd.

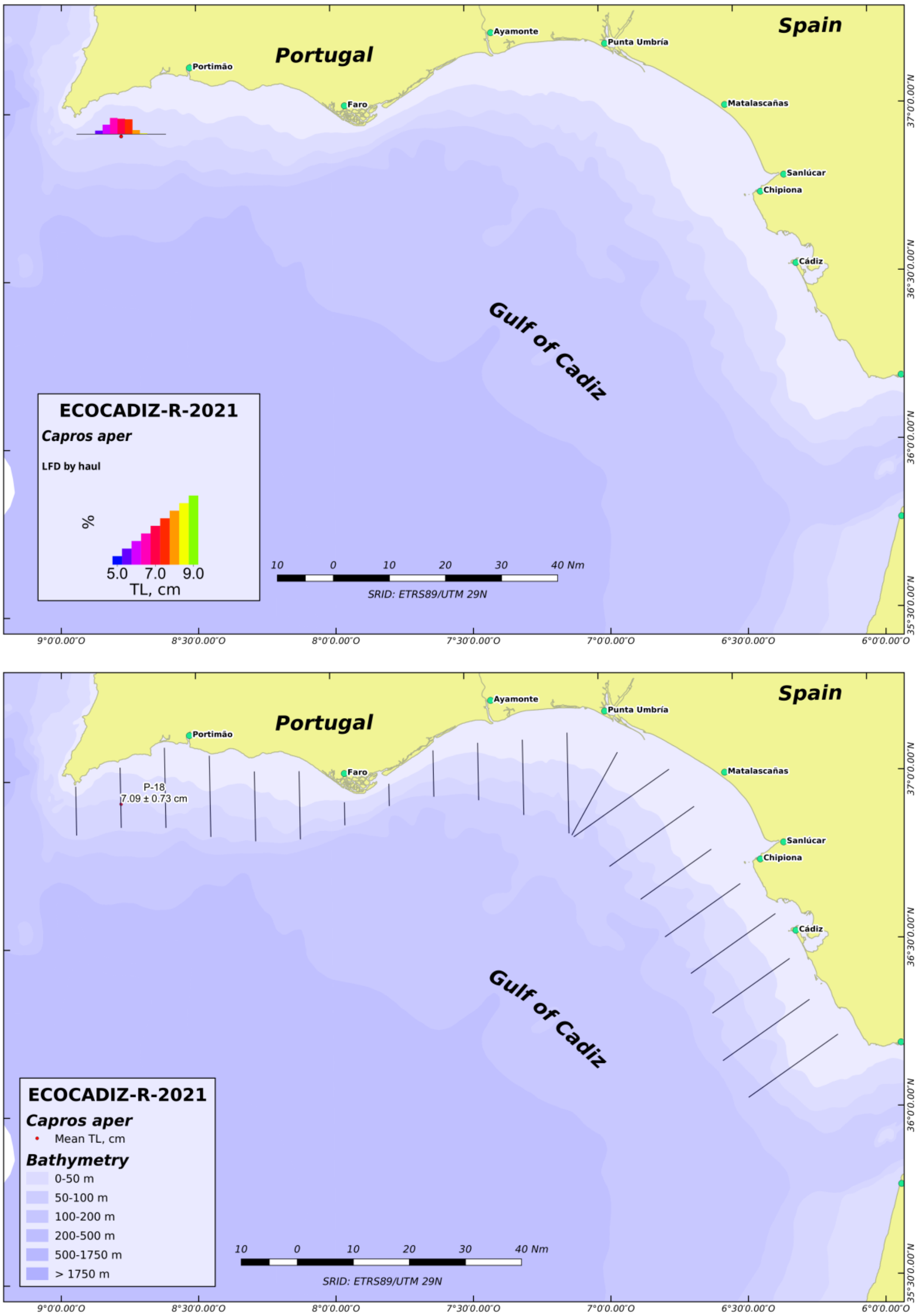


Figure 33. *ECOCADIZ-RECLUTAS 2021-10* survey. Boarfish (*Capros aper*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

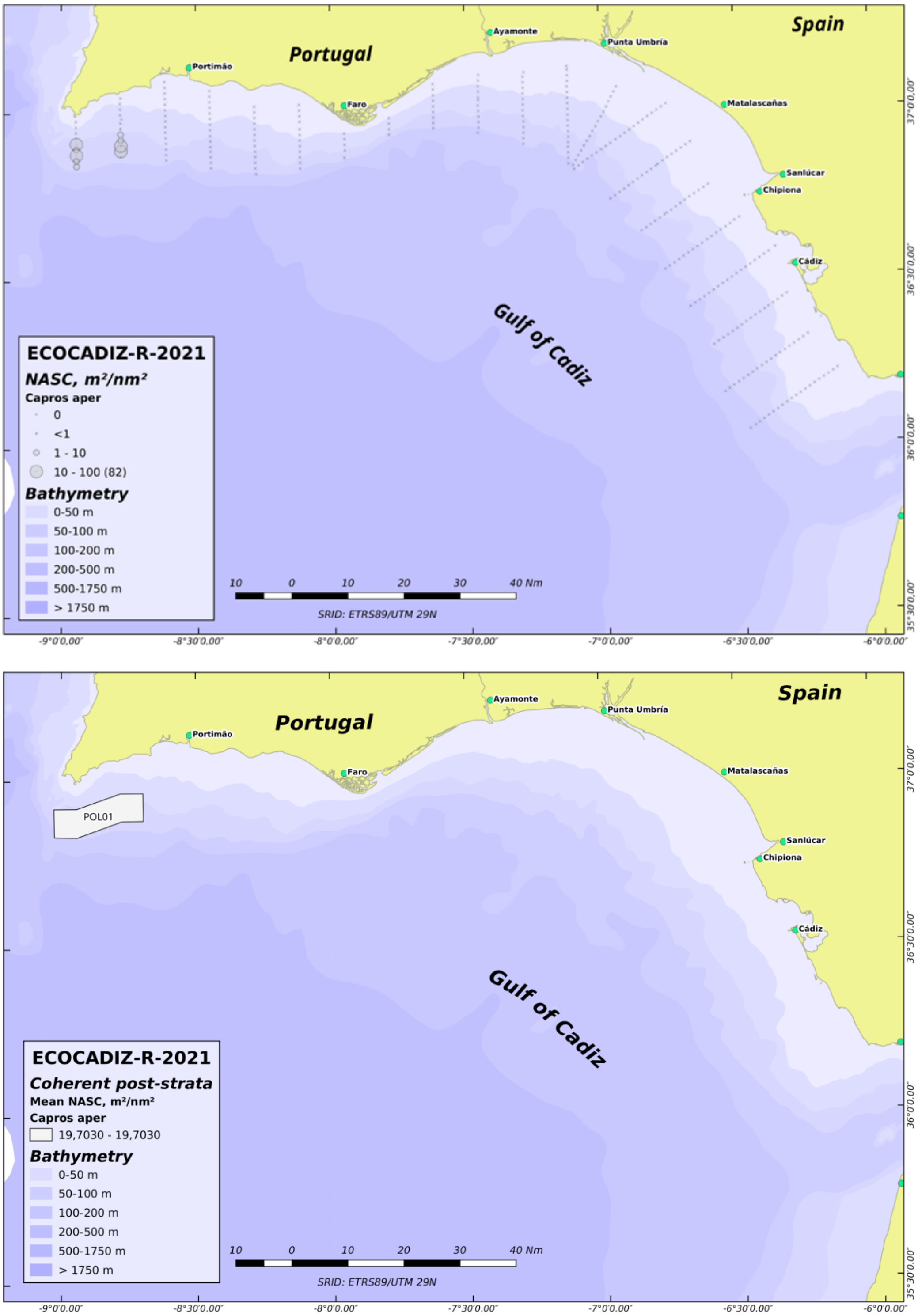


Figure 34. *ECOCADIZ-RECLUTAS 2021-10* survey. Boarfish (*Capros aper*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

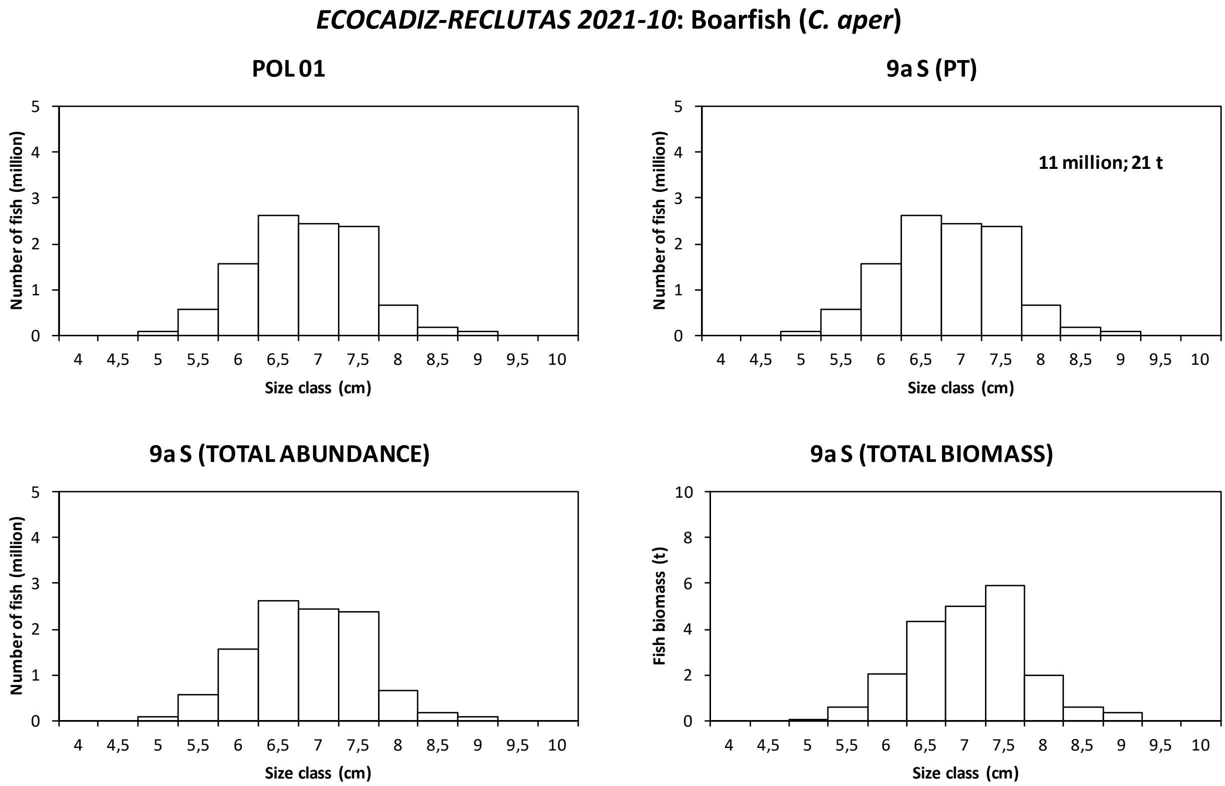


Figure 35. *ECOCADIZ-RECLUTAS 2021-10* survey. Boarfish (*Capros aper*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 34**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

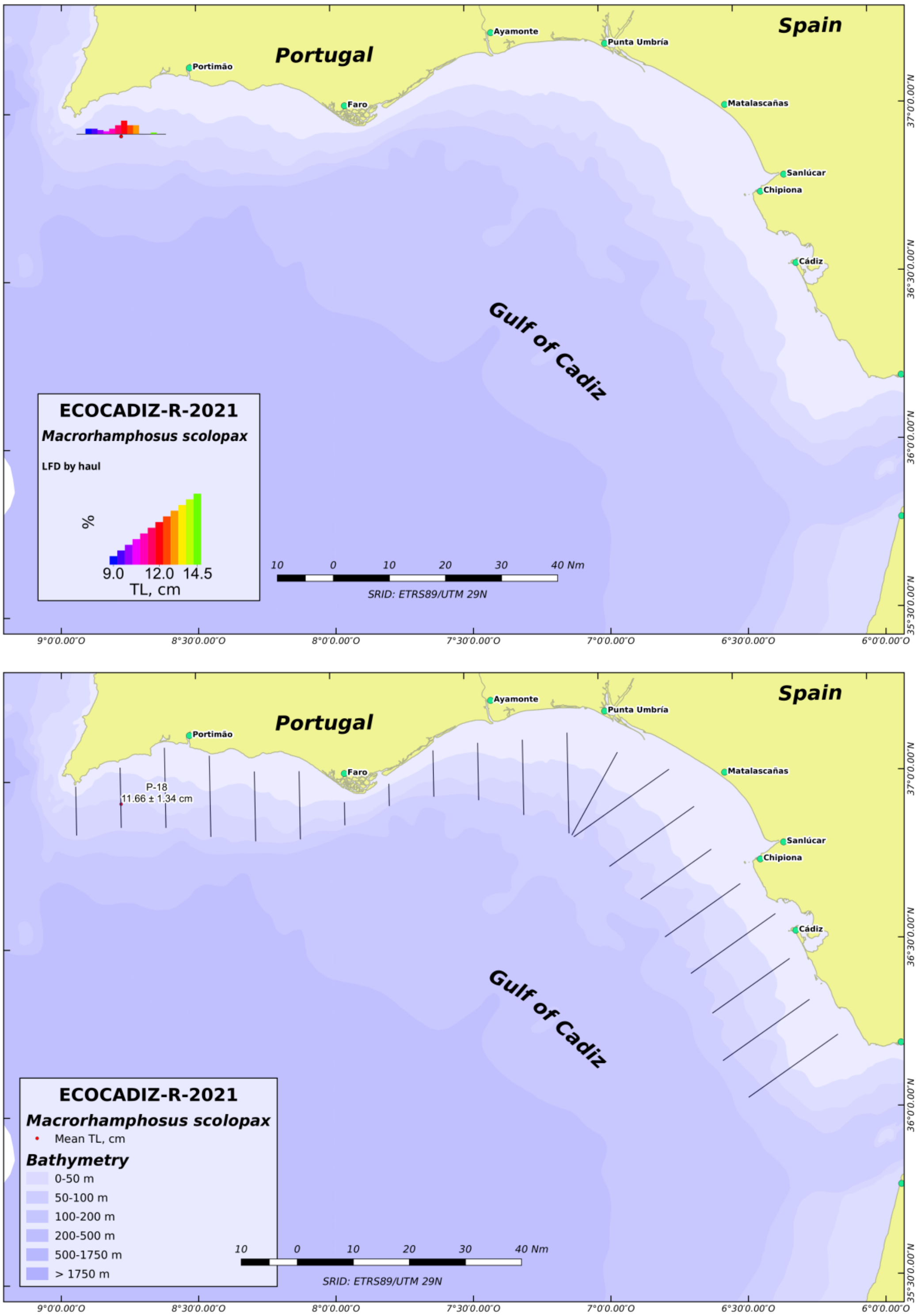


Figure 36. *ECOCADIZ-RECLUTAS 2021-10* survey. Longspine snipefish (*Macroramphosus scolopax*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

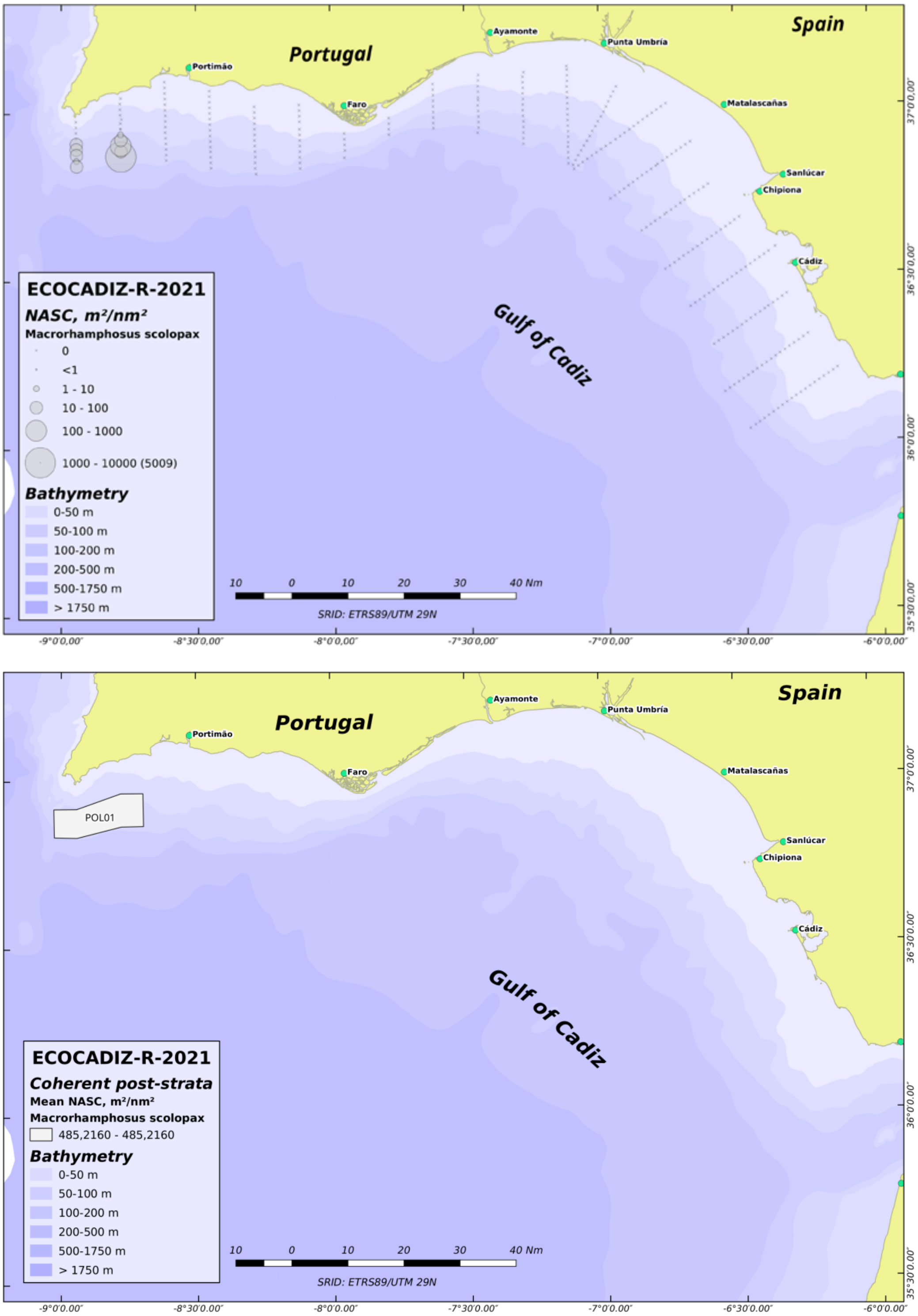


Figure 37. *ECOCADIZ-RECLUTAS 2021-10* survey. Longspine snipefish (*Macroramphosus scolopax*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

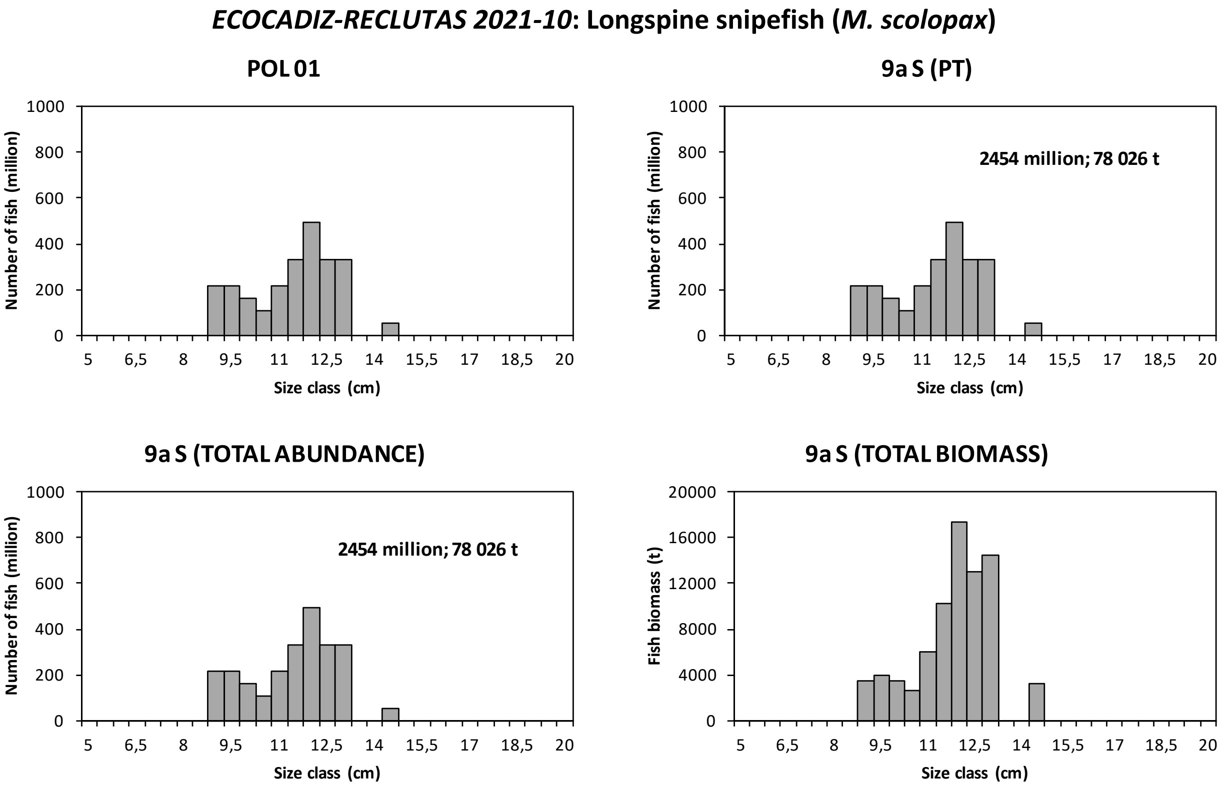


Figure 38. *ECOCADIZ-RECLUTAS 2021-10* survey. Longspine snipefish (*Macroramphosus scolopax*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 37**) and total sampled area. Post-strata ordered in the W-E direction. 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.

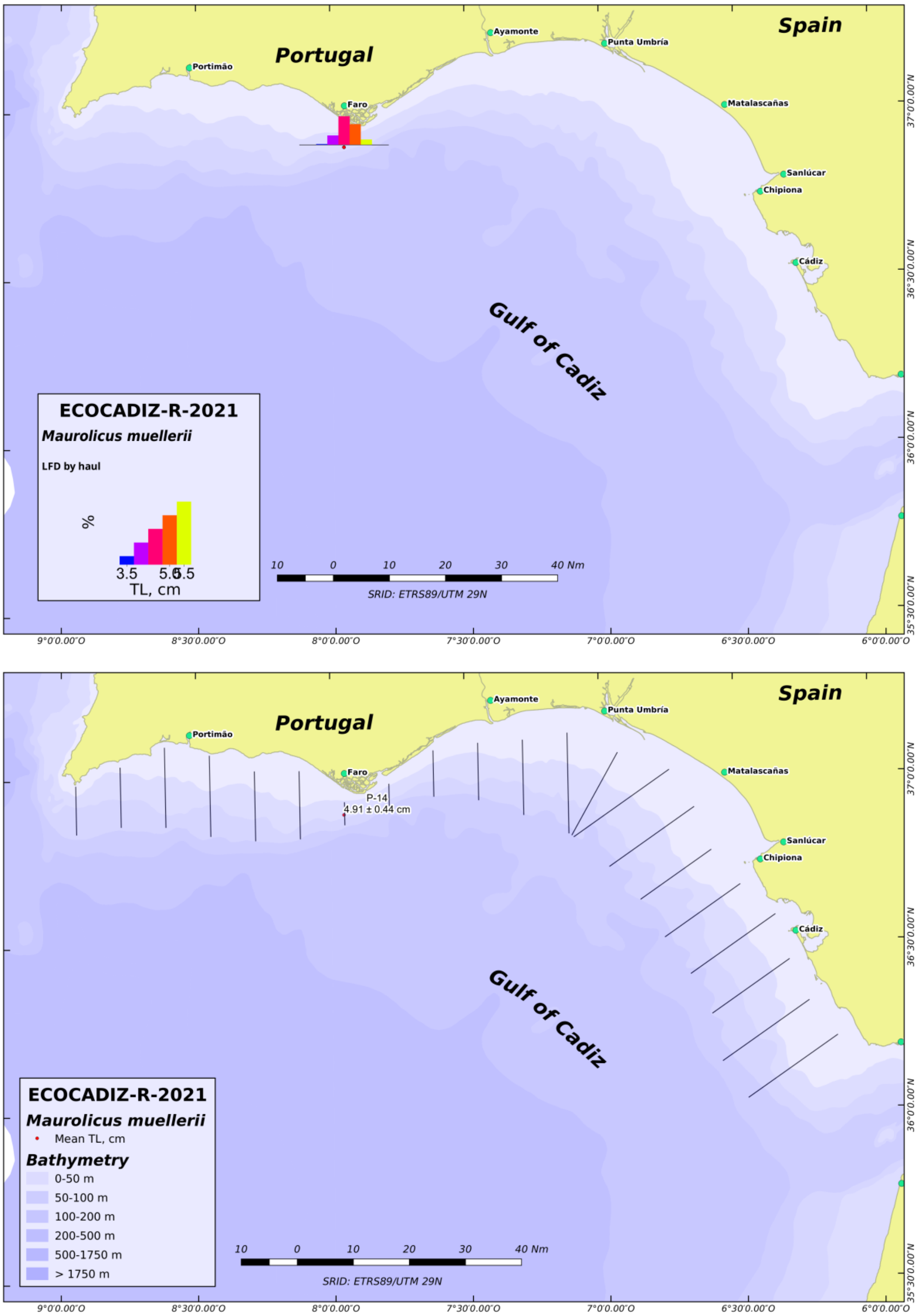


Figure 39. *ECOCADIZ-RECLUTAS 2021-10* survey. Pearlside (*Maurolicus muelleri*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

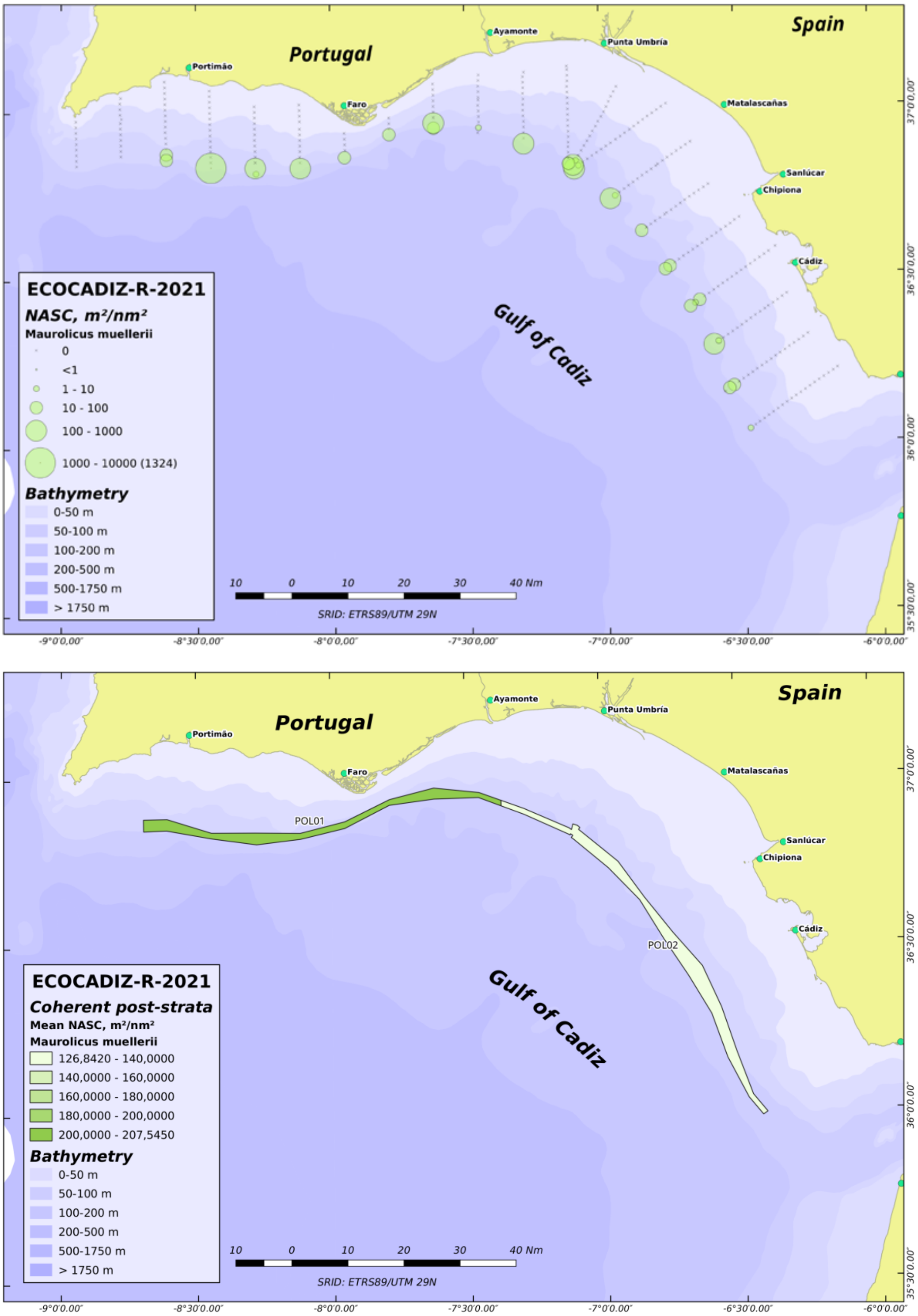


Figure 40. *ECOCADIZ-RECLUTAS 2021-10* survey. Pearlside (*Maurolicus muelleri*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

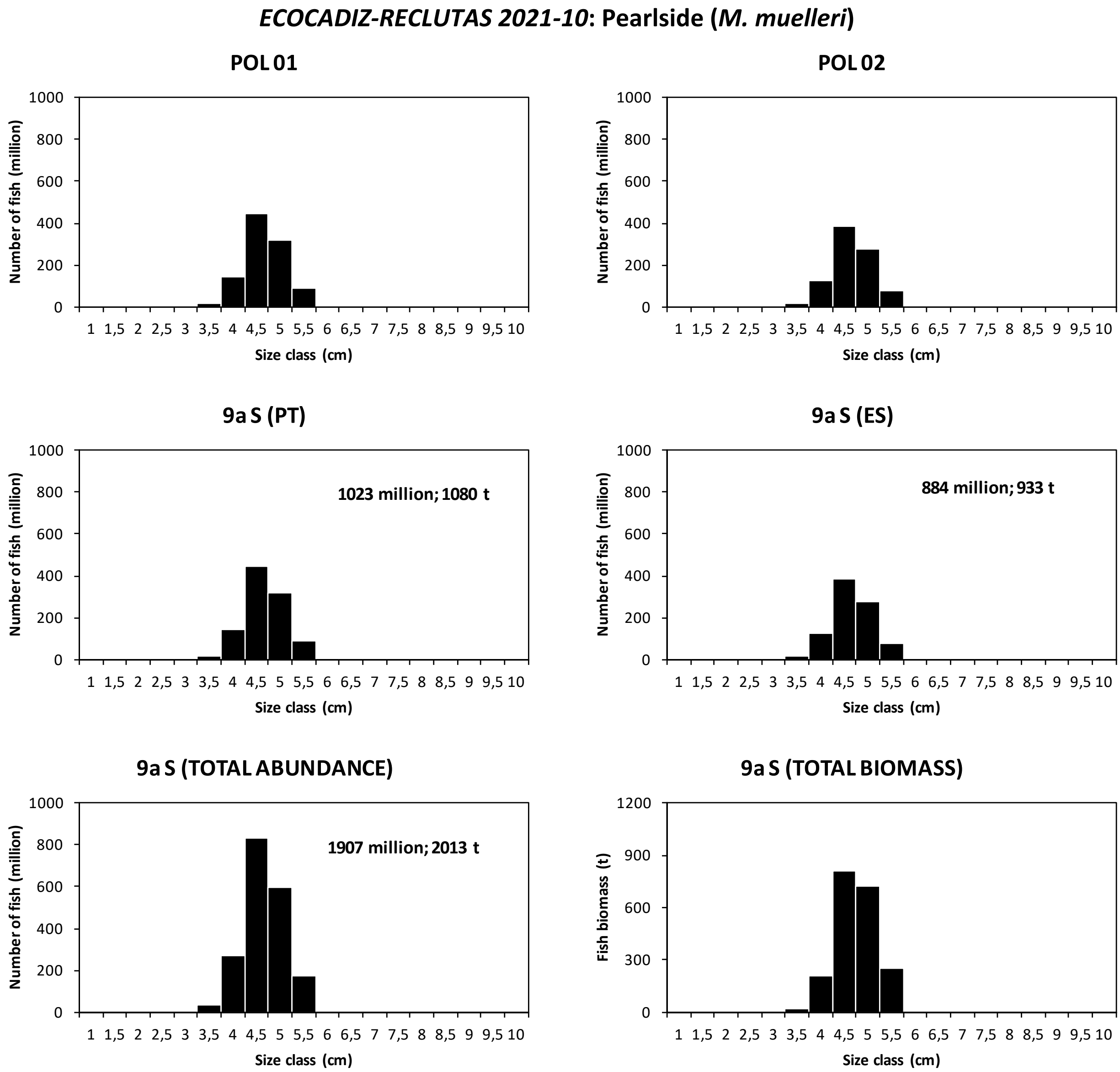


Figure 41. *ECOCADIZ-RECLUTAS 2021-10* survey. Pearlside (*Maurolicus muelleri*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous post-stratum (POL01-POLn, numeration as in **Figure 40**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

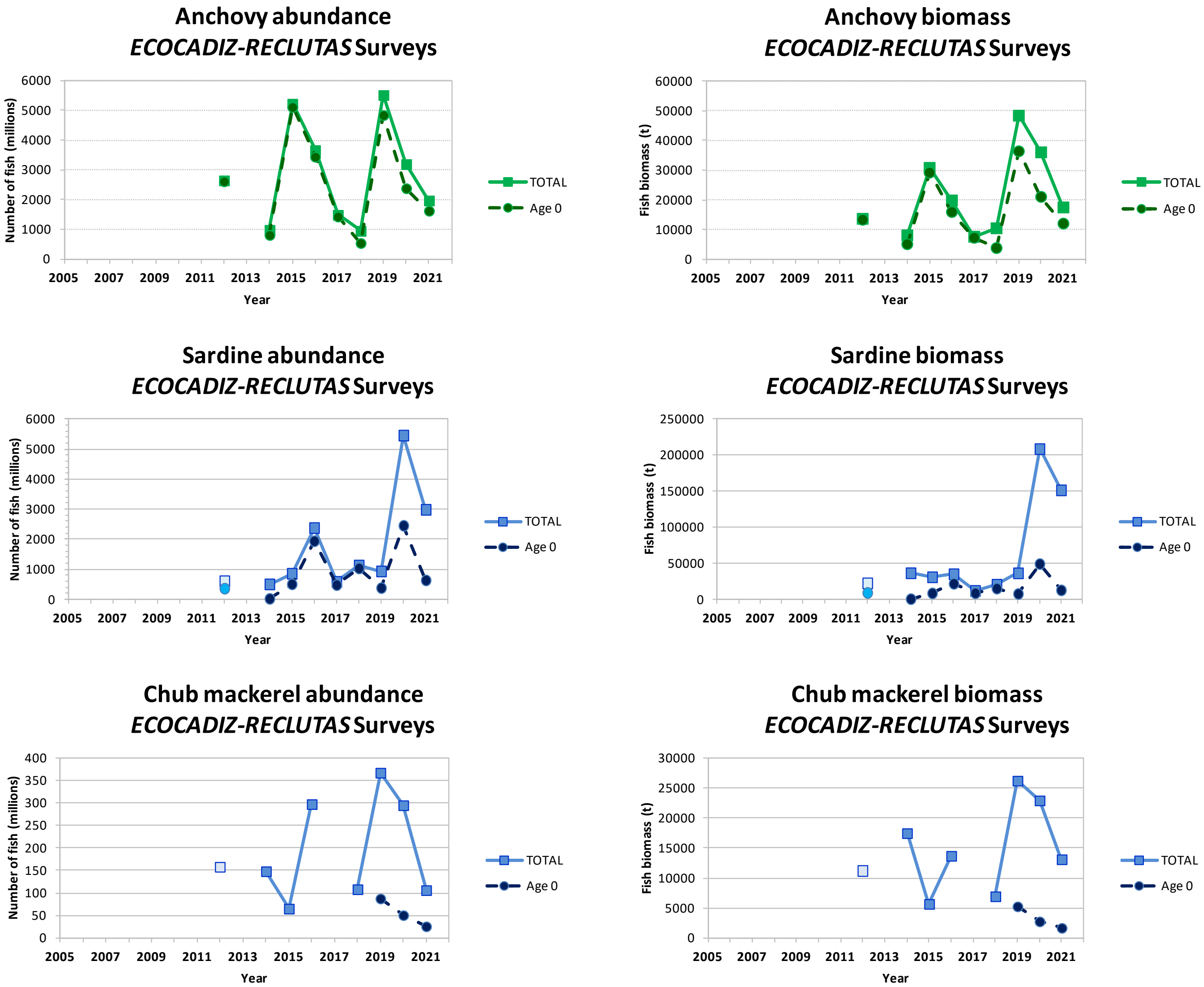


Figure 42. *ECOCADIZ-RECLUTAS* surveys series. Historical series of autumn acoustic estimates of anchovy, sardine and chub mackerel abundance (million) and biomass (t) in Sub-division 9.a South. The estimates correspond to the total population and age 0 fish. The 2012 survey only surveyed the Spanish waters. No survey was conducted in 2013. Although a survey was conducted in 2017, the survey was interrupted for a serious breakdown of the vessel's propulsion system and no estimates were computed. The 2018 estimates should be considered with caution because a possible under-estimation. Age data for chub mackerel started to be available since 2019 on.

Working Document to WGHANSA 2022 (23-27 May 2022)

Exploratory assessment of anchovy 27.9a-west using a surplus production model.

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Abstract

The aim of this WD was to explore surplus production models to assess the western component of the anchovy 27.9a stock. Models were fitted to catch per quarter or semester (1991 – 2021) and to one biomass index, the spring acoustic survey (1999 – 2021), or two biomass indices, the acoustic survey and the autumn groundfish survey (1991 – 2018) using SPiCT. Various assumptions regarding the shape of the production curve, the initial biomass depletion and the intrinsic growth rate of the population were combined such that models varied from nearly unconstrained (more complex) to increasingly constrained (less complex). Bi-annual catch data and two survey indices lead to a higher number of convergent models. Several models passed all ICES criteria to accept a SPiCT assessment, except for a higher level of uncertainty in F/F_{MSY} than the agreed one for long-lived stocks. A model assuming a Schaefer production curve, a prior on *r* from a meta-analysis and, an initial depletion rate of 80%, showed better retrospective analysis, survey hindcast cross-validation and convergence performance than other candidate models. The results indicated that F/F_{MSY} was below 1 across most of the period, B/B_{MSY} fluctuated well below 1 until 2010 and above 1 since 2016. The present results may be considered for further work in a benchmark workshop.

1. Introduction

The anchovy 27.9a stock spans the ICES Division 9a corresponding to the region between Cape Finisterre and the Strait of Gibraltar in the Gulf of Cadiz. Anchovy distributed off the western coast of the Iberian Peninsula, from Cape Finisterre to Cape Saint Vincent is the west component of the stock. The southern component ranges from Cape Saint Vincent to the Strait of Gibraltar, the southern waters of the Iberian Peninsula. ICES provides separate catch advice annually for each of the stock components using a common basis: the rule “one-over-two” constrained by an uncertainty cap of +/- 80% of the former catch advice (ICES 2018, 2020).

In the case of the southern component, the rule uses an SSB indicator estimated in a Gadget assessment model, using length-age based catches and, length-age based abundance indices from two acoustic surveys, ECOCADIZ and PELAGO. For the western component, the rule uses an indicator obtained by adding the biomasses estimated in the acoustic surveys PELAGO and PELACUS which together cover the area. The western component is data-poor. The limited data available before the 2000s is related to a near absence of the species in the area. Monitoring such small catches and very low abundance was practically impossible. Monitoring of the western component population started in the late 1990s as a “by-product” of acoustic surveys targeting sardines while catches started to be sampled systematically in the late 2010s (ICES, 2018).

The use of estimates from a stock assessment model may have advantages over the direct use of survey estimates in terms of catch advice. Models, as they integrate several sources of data and may take both observation and process error into account, become more robust to specific situations of bias or noise in the case of a single indicator, such as a research survey. The fact that anchovy is a short-lived species precludes the application of assessment and reference points methods developed by ICES for medium- and long-lived data-limited species, as they are often based on equilibrium assumptions (approximately constant recruitment over time) (ICES, 2018). This fact promoted the search for alternative methods, work that has been developed within the scope of the ICES WKDLSSLS. In 2021, the WKDLSSLS concluded that short-lived stocks that have sufficiently long time series (catch data and total biomass indicators) can be assessed with surplus production models (SPMs, also called biomass dynamic models) (ICES, 2021a), provided the data have enough contrast. Scientific advice can be formulated based on F_{MSY} and rules for achieving MSY should include biomass limits and uncertainty buffers (Mildenberger *et al*. 2021). The F_{MSY} rule will be most successful if applied to an assessment including an indicator of population biomass immediately before the management period and which includes most age classes of the exploitable population.

During the WKDLSSLS workshops, SPMs were applied to various short-lived stocks using SPiCT (SPiCT, Stochastic Surplus Production Model in Continuous Time; (Mildenberger *et al*. 2021; Pedersen & Berg, 2017), namely to the west and south components of the anchovy in division 9a, sprat on the west coast of Scotland and sardines in sub-area 7 (Celtic Sea). In the case of anchovy from the 9a south component, SPiCT showed a good performance and results comparable to those of the analytical model in use. Classical surplus production models were generally not applied to assess short/medium lived stocks, due to the high variability. The appearance of SPMs that allow observation and process error, such as SPiCT, increased the chances of good results with short-lived species (Zhou *et al*. 2009).

In this WD, we explored SPMs to assess the anchovy 9a-west stock component using SPiCT. Various combinations of catch data and survey indices and various model configurations were explored.

2. Material and methods

Data

- catch biomass, t, per quarter or semester from the beginning of the first quarter of 1991 to the end of the second quarter of 2021
- total biomass, t, in the spring acoustic surveys PELACUS+PELAGO 1999 – 2021 (gaps in 2000, 2004 and 2012) (Massé *et al.*, 2017; Doray *et al.*, 2021)
- mean biomass and corresponding standard deviation (SD), kg h^{-1}, in groundfish surveys October/December 1991 – 2018 (autumn, with gaps in 1994 and 2012). The computation of indices followed the methodology provided by Cochran (1977) for stratified random sampling and the survey methodology is described in ICES (2017).

Survey indices were corrected to reflect the exploitable biomass, assumed to correspond to the biomass of individuals > 10 cm total length, the minimum length present in the commercial catches. For both survey series, the differences between the corrected and uncorrected data were minor (see Figure 2.1 for the acoustic survey; in the groundfish survey, there were differences in 1997 and from 2014 to 2016, all below 3% except for 2015 where they were 23%).

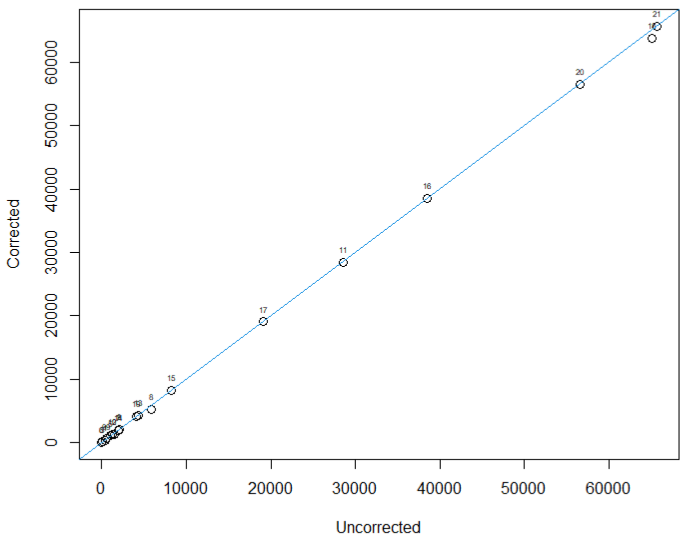

Figure 2.1 - Anchovy 9a-west: the relationship between uncorrected (all length classes) and corrected (biomass of length classes 10+) acoustic biomass.

Models were fitted to catch per quarter or semester and to one abundance index, the acoustic survey, or to both indices, with various assumptions regarding the shape of the production curve, the initial biomass depletion and the intrinsic growth rate of the population (see below). SPiCT fits surplus production models which incorporate dynamics in both biomass and fisheries and observation error of both catches and biomass indices. SPiCT uses a re-parametrization of the Pella and Tomlinson (1969) equation:

$$dB_t = r/(n-1) * B_t*(1-(B_t/K)^{n-1}) - F_tB_t$$

where B_t is the exploitable population biomass, F_t is the instantaneous fishing mortality rate, r is the intrinsic growth rate of the population, K is the carrying capacity and n is a unit-less parameter determining the shape of the production curve. The fraction B_1/K, where B_1 is the biomass in the first year of the assessment ($1-B_1/K$ is termed the initial depletion rate), is often difficult to estimate from the data. Data available on historical catches may be used to set priors for this parameter.

All models start in the middle of the calendar year (July 1st), following the ICES advice calendar for this stock. Assessment years go from 1 July of year *y* to 30 June of year *y+1*.

The time of catch (timeC) and survey (timeI) observations in the model is shown in Table 2.1.

Table 2.1 – Anchovy 9.a-west: Time of catch and survey observations. The forecast period is shown in bold.

Year	Time of catch observations				Time of survey observations	
	Quarterly data		Biannual data		Acoustic survey (spring)	Groundfish survey (autumn)
1991	1	1990.50	1	1990.5	1990.75	1991.25
1991	2	1990.75				
1991	3	1991.00	2	1991.0		
1991	4	1991.25				
1992	1	1991.50	1	1991.5	1991.75	1992.25
1992	2	1991.75				
1992	3	1992.00	2	1992.0		
1992	4	1992.25				
…	…	…	…	…	…	…
2021	1	2020.50	1	2020.5	2020.75	
2021	2	2020.75				
2021	**3**	**2021.00**	**2**	**2021.0**		
2021	**4**	**2021.25**				
2022	**1**	**2021.50**	**1**	**2021.5**		
2022	**2**	**2022.00**				

Coefficients of variation (CV) of groundfish indices were used as weighting factors of the data points to reflect differences in observation error. Acoustic surveys were given equal weight (=1) over time since estimates of observation error were not available. For better numerical stability all indices and weighing factors were scaled to have a mean = 1.

Priors for n, B_1/K, and r were combined such that models varied from nearly unconstrained (more complex) to increasingly constrained (less complex) (Table 2.2; Figure 2.2). The n.Thorson and r.Thorson priors were derived from n and r parameters for Clupeiforms and *Engraulis encrasicolus*, respectively, obtained in meta-analyses (Thorson *et al.* 2012; Thorson, 2020). Default priors (lognormal, mean = ln(1), SD = 2) were applied to the ratios of process error of fishing mortality/biomass to observation error in catches/abundance indices.

Table 2.2 – Anchovy 9.a-west: Prior means and standard deviations for n, B1/k and r parameters. In all cases prior probability distributions are lognormal. SD of n.Thorson and r.Thorson priors calculated as sqrt[mean(r)^2 /predictive error(r)^2].

	Prior		
Parameter	Name	exp(Mean)	Standard deviation
n	Default	2.00	2.00
	Schaefer	2.00	1.00E-03
	Fox	1.00	1.00E-03
	n.Thorson	0.60	0.57
B_1/K	20	0.20	0.50
	50	0.50	0.50
	80	0.80	0.80
r	r.Thorson	1.98	0.28

Figure 2.2 – Anchovy 9.a-west: Diagram of all possible prior combinations.

n		B_1/K		r
n.none		BKnone		r.none
Default	**X**	BK20	**X**	r.Thorson
Schaefer		BK50		
Fox		BK80		
n.Thorson				

To find one or a few final models, standard criteria of convergence, goodness-of-fit and consistency were checked according to ICES guidelines for the acceptance of a SPiCT assessment (2021b) and to recommendations of Pedersen and Berg (2017) and Carvalho *et al.* (2021). The following checklist was applied:

1) Convergence: successful completion of the fit, finite and reasonable confidence intervals; all absolute values of parameter correlations below 0.95; low sensitivity to initial values;
2) Goodness-of-fit: residuals normal (Shapiro-Wilk test; q-q plot), unbiased (t-test comparing the mean to zero; scatterplot of standardized residuals) and independent (Ljung and Box (1978) test on four lags; empirical auto-correlation plot);
3) Consistency: 5-year retrospective Mohn's Rho of B/BMSY and F/FMSY between -0.22 and 0.30; consistent retrospective trajectories across the historical period;
4) Prediction skill: mean absolute scaled error (MASE) of each abundance index of 7-year hindcast cross-validation, below 1 and, as low as possible.

The checklist was applied sequentially, apart from the sensitivity test to initial values, a time-consuming procedure, which was therefore applied only to models that passed the checklist. The sensitivity test consists of perturbing initial parameter values by random proportions between -2 and +2 and re-fitting the model. The recommended number of trials is 30. A vector of the distance between the estimates of the main model parameters of each trial and those of the base model is provided. The closest the distances are to zero the better although quantitative thresholds to accept a model have not been defined yet. Here, we calculated the 50th and the 90th percentiles of the distance vector and the proportion of vectors which failed to converge as ad-hoc indices to compare models.

3. Results

3.1. Overview of anchovy catches and abundance

The historical series of anchovy catches in Portugal from 1943 to 2020 showed fluctuations around a mean of 722 t (SD = 1075 t) apart from a period of consistently higher catches since 2017 (mean ± SD = 6944 ± 1705 t) and a single high value in 1943 (7476 t) (Figure 3.1). Although there were no data from Spanish catches far back in time, assuming Portuguese catches made the bulk of the catches of the stock component as seen in recent years, there were no signs of overexploitation of the resource at the beginning of the assessment period (1991). In the late 2010s the abundance "took off" reaching unprecedented levels in recent years (Figure 3.2). The index of abundance in the autumn groundfish survey in a given year *y* is significantly positively correlated with the index of abundance in the acoustic survey the following year, *y+1* ($r = 0.91$, $p<0.001$). Both indices presented marked fluctuations since 2015; the groundfish survey showed an increase to very high abundance in 2017, which resulted mainly from a single haul with a catch of 600 Kg of adult anchovy; abundance drops markedly the following autumn (2018). A similar, although less dramatic, variation was observed in the acoustic survey from 2017 to 2018.

Total catches showed a strong seasonal component, being the highest in the 3rd quarter of the year and decreasing from the 3rd quarter of a year to the second quarter of the next year (Figure 3.3). On average, 36% of the catches were obtained in the first semester.

Length frequency distributions (LFDs) of catches and surveys by semester available from the period 2015 – 2020 indicate that surveys observe smaller sized anchovy than caught in the fisheries (Figure 3.4). The difference is more pronounced in the second semester, with the autumn groundfish survey showing large proportions of individuals around 11 cm (possibly recruits) in some years.

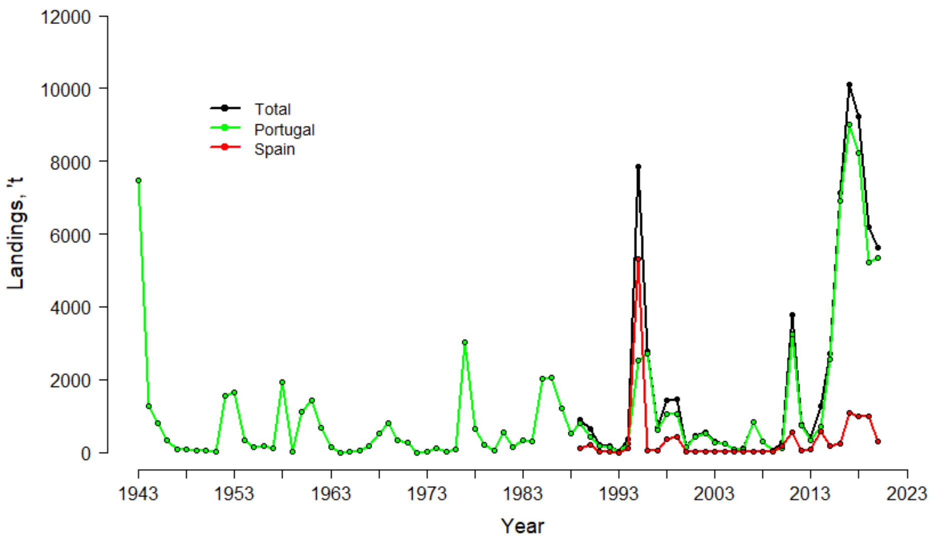

Figure 3.1 – Anchovy 9a-west: annual catch 1943 – 2021 by country and in total.

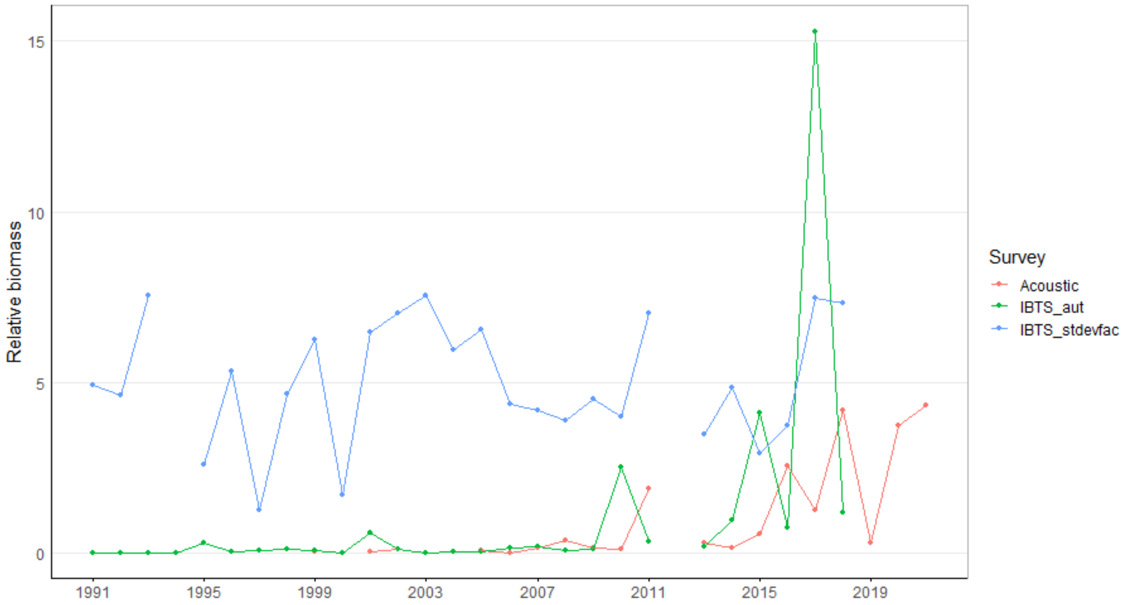

Figure 3.2 – Anchovy 9a-west: Index of the abundance of the spring acoustic survey 1999 – 2021 and index of abundance and coefficient of variation of the Portuguese autumn groundfish survey 1991 – 2018. Each survey and CV observation was divided by the mean of the corresponding series, therefore each series has a mean = 1 (the CV series was multiplied by 5 to improve the readability of the figure).

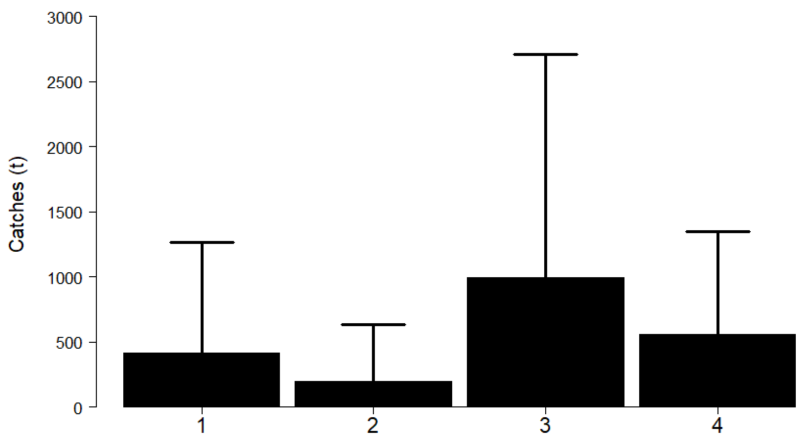

Figura 3.3 - Anchovy 9a-west: Mean catches by quarter in the period 1991 – 2021. Bars represent 1 standard deviation.

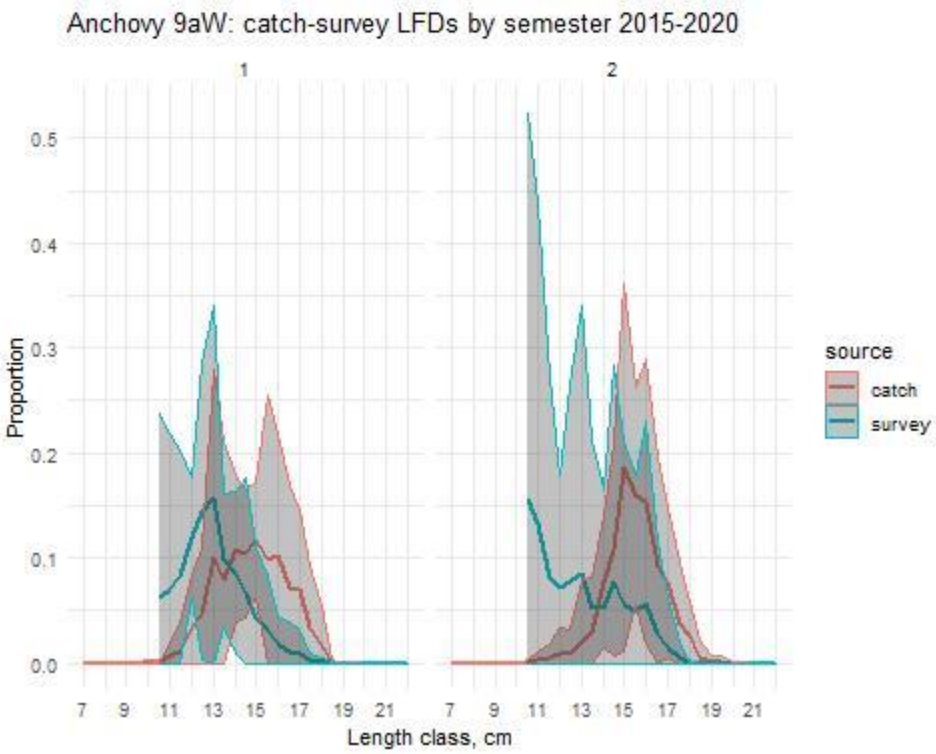

Figure 3.4 – Anchovy 9a-west: Mean proportion of individuals per ½ cm length class in the catches and the surveys by semester in the period 2015 – 2020.

3.2. Model diagnostics and results

Table 3.1 presents a summary of the main model diagnostics, parameters and derived quantities with corresponding estimates of uncertainty, for models which converged, had random, unbiased and independent residuals and, showed a minimum of four converged retrospective runs with consistent trajectories over time. Out of the initial 160 models, fourteen were retained on this step, 10 based on bi-annual catch data of which 4 used the acoustic survey and 6 used both the acoustic and the groundfish survey. All 14 models had, at least, one parameter with a prior from Table 2.2.

None of the models complied with the ICES guideline about the magnitude of B/B_{MSY} and F/F_{MSY} confidence intervals. Considering that larger uncertainty is expected for small pelagic fish due to their highly variable dynamics, this criterion was relaxed to admit models which estimated B/B_{MSY} and F/F_{MSY} confidence intervals spanning 2 orders of magnitude of the point estimates (T. Mildenberger, personal communication).

Models 11 to 14 showed the best performance in hindcast cross-validation of survey indices and overall good resistance to jittering of initial parameters (Table 3.1). Except for model 11, all showed MSY-K correlations above + 0.95; on the other hand, model 11 showed high sensitivity to the perturbation of initial values in a few trials. The four models had a similar performance regarding the checklist criteria and comparable point and uncertainty estimates of parameters (Table 3.1). The second retrospective trajectory, corresponding to the run with the 2019 acoustic survey and the 2018 groundfish survey as the last survey data points indicated considerably higher F/F_{MSY} and lower B/B_{MSY} in 2019 (with some backward effect) than the remaining retrospective runs (Figure 3.1). These surveys showed a 90% drop in biomass from the previous year's surveys and were followed by an increase of biomass of more than 1000%.

While any of the four models could be considered for further analysis, model 12, assuming a Schaefer production curve (n = 2), a Thorson prior on r (lognormal, mean=0.68, SD=0.30) and a lognormal prior on B1/K with mean = 0.20 (CV=0.50), corresponding to an initial depletion of 80%, seemed to have a slightly better retrospective, hindcast and convergence performance than the other 3 models (Table 3.1; Figures 3.1 and 3.2). Residuals complied with the assumptions of normality, no bias and independence (Figure 3.3). The retrospective pattern of the period 2016 – 2021 was positive for both B/B_{MSY} and F/F_{MSY} and, according to Mohn's Rho, substantially stronger for the latter while still below the threshold for short-lived species of 0.30. MASE scores were <1 for both surveys indicating the model had a superior prediction skill than the naïve baseline forecast (MASE=0.5 means twice as accurate as of the naïve forecast, i.e.; assuming the same abundance next year; Carvalho *et al.* 2021). The groundfish survey appears to have a better prediction skill than the acoustic survey; however, it is unclear if the fewer number of years used to calculate the MASE of the groundfish survey, 5 instead of 7 years, may have affected the result and prevented a fair comparison. Posterior distributions indicated that there is not much information on the data to estimate the intrinsic growth rate (Figure 3.4). Estimates of alpha ratios indicated that biomass process error was around double the observation error for both surveys (Table 3.1). On the other hand, the fishing mortality process error was about half the catch observation error. The estimate of B_{1991}/K (mean=0.11, CV=0.52) pointed to a depleted stock at the beginning of the assessment period.

Historical variations of B/B_{MSY} and F/F_{MSY} are shown in Figure 3.5. Point estimates of F/F_{MSY} were below 1 across most of the period. However, the huge confidence interval until the mid-2000s prevents any conclusion about the state of the stock. B/B_{MSY} fluctuated well below 1 until 2010. Since 2016, the stock has fluctuated slightly above B_{MSY}. On the 30 of June 2021, the end of the assessment period, the relative fishing mortality was estimated to be 0.06 and the relative total exploitable stock biomass was estimated to be 1.15, suggesting that the stock was healthy.

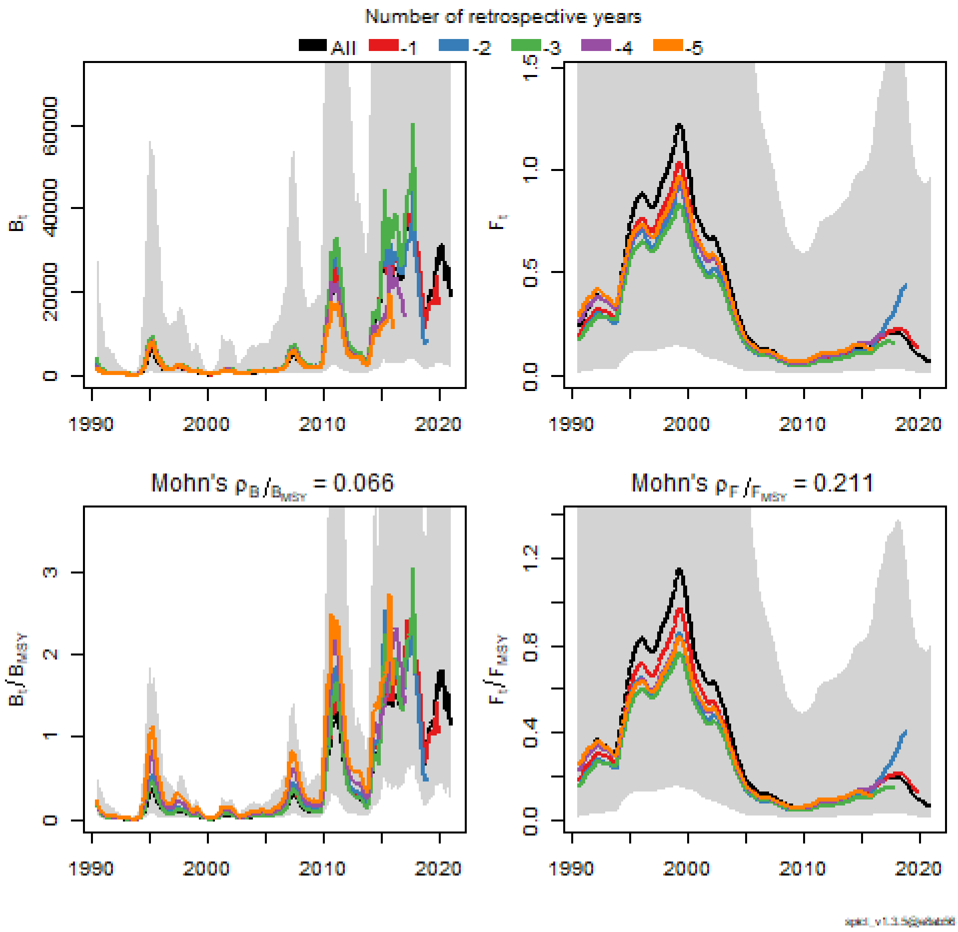

Figure 3.1 – Anchovy 9a-west: Retrospective error of B_{MSY} and F_{MSY} (top panel) and B/B_{MSY} and F/F_{MSY} (bottom panel) of model 12.

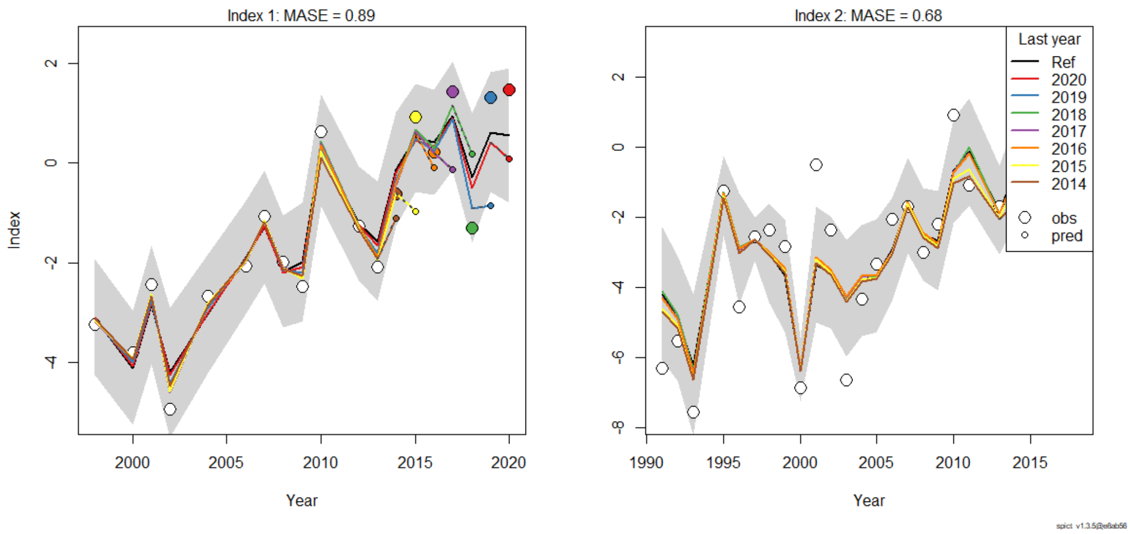

Figure 3.2 – Anchovy 9a-west: Hind-cast cross-validation results for the acoustic (left) and groundfish survey indices (right). The reference result corresponds to the result of Model 12; seven and five hindcast runs were carried out for the acoustic and the groundfish surveys, respectively (the last groundfish survey was in 2018).

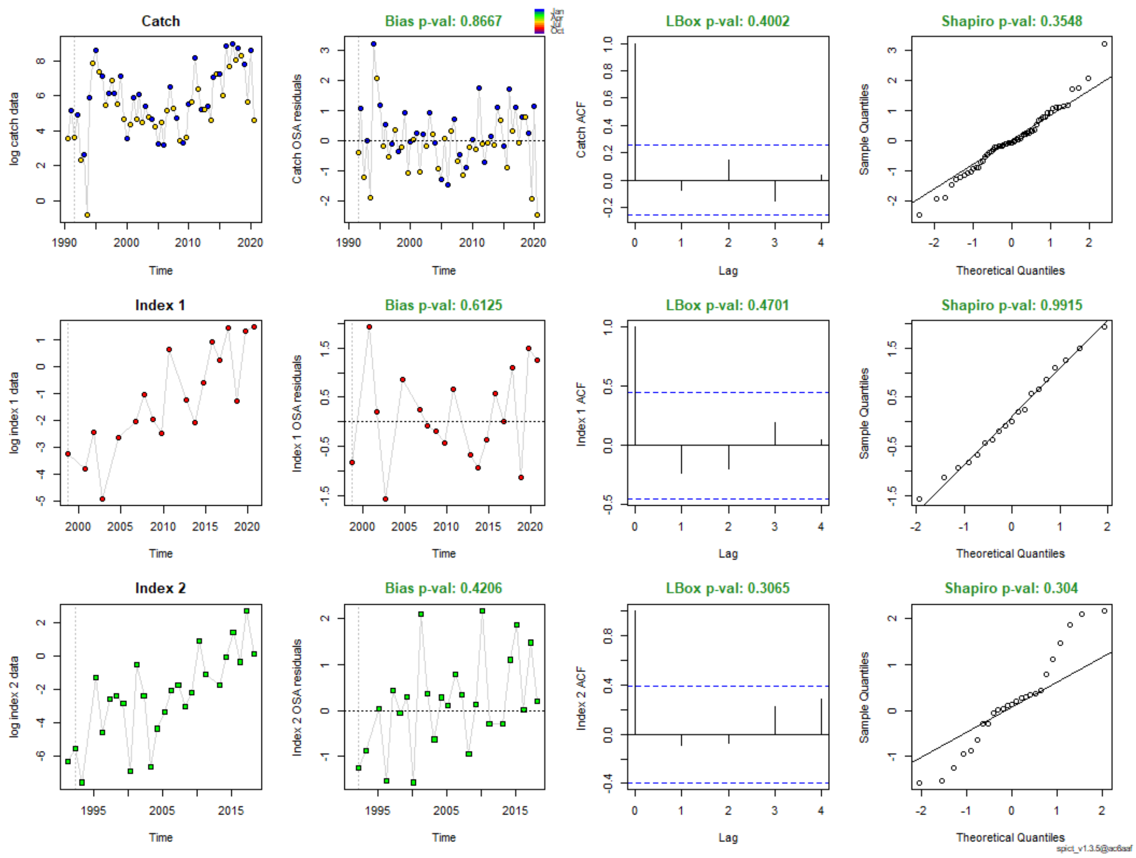

Figure 3.3 – Anchovy 9a-west: Plots of catch and survey residuals of Model 12.

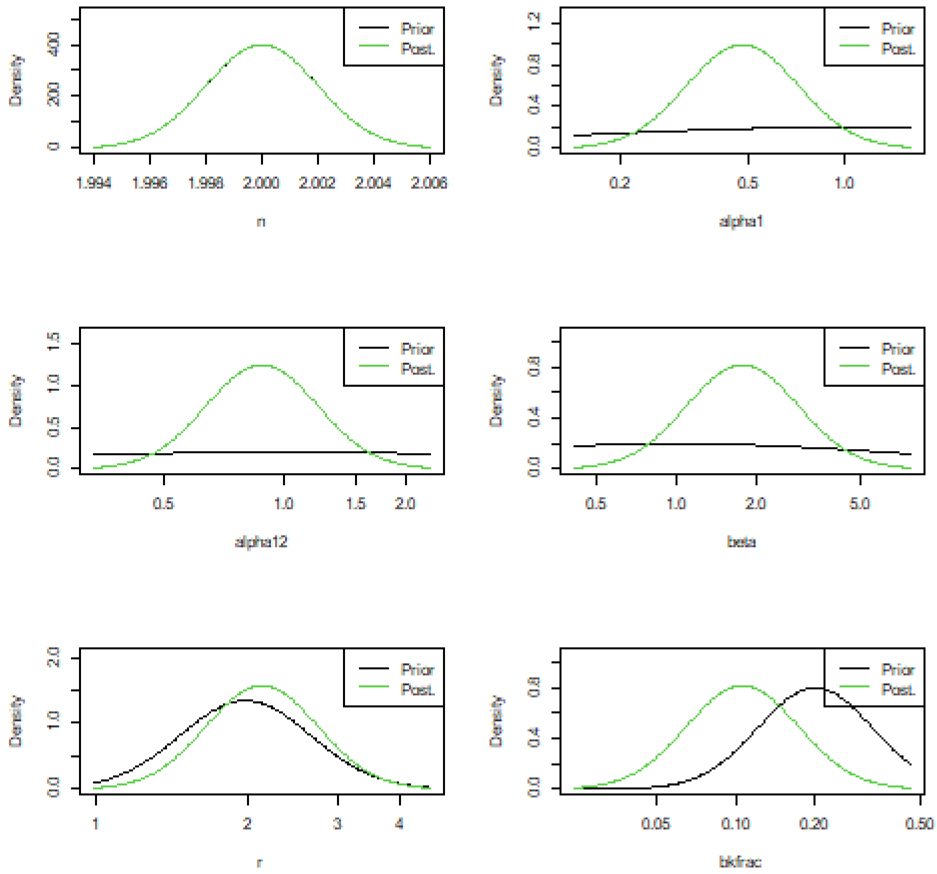

Figure 3.4 - Anchovy 9a-west: Prior and posterior distributions of n, alphas, beta, r and bk fraction of Model 12.

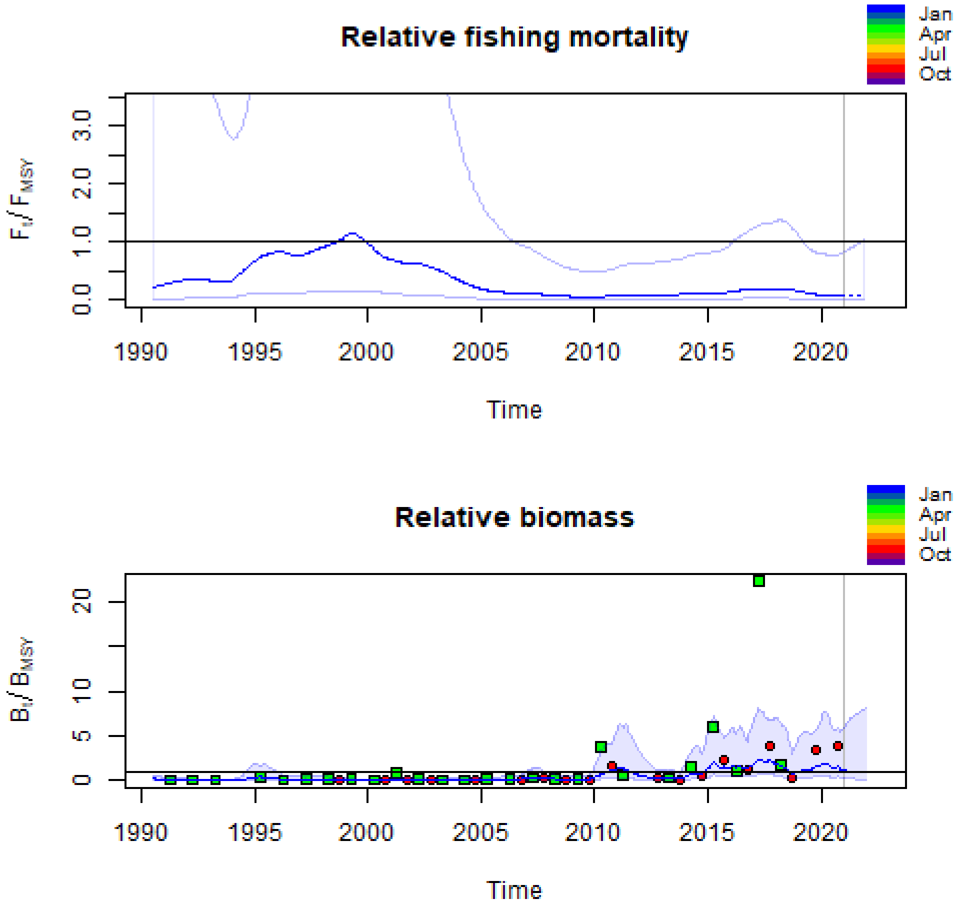

Figure 3.5 – Anchovy 9a-west: Historical F/F_{MSY} and B/B_{MSY} trajectories over the period 1991 – 2021. 95% CIs of relative biomass and fishing mortality are shown using shaded blue regions. The end of the data range is shown using a vertical grey line. Data are shown using points coloured by season.

3.3. Sensitivity of Model 12 to potentially biased survey data points

Three sensitivity tests of model 12 to down-weighting the following survey data points were carried out:

1) 2019 acoustic survey
2) 2019 acoustic survey and 2018 groundfish survey
3) 2017 groundfish survey

In all cases, the standard deviation of the data point was increased by a factor of 3, meaning an increase from 1 to 3 in the case of acoustic surveys and an increase from 1.44, to 4.32 in the case of 2018 groundfish survey.

Compared to Model 12, both models 1) and 2) showed a small decrease in the CV of B/B_{MSY} and the MASE of the acoustic survey (both around 8%) (Table 3.2). Changes in the CVs of the remaining parameters were negligible. The divergence of the second peel of the retrospective analysis decreased substantially in both runs compared with model 12 (Figures 3.1 and 3.6). Graphically, the fit of the model to the biomass in the two most recent years 2 improved (Figure 3.7). However, the Mohn's Rho of B/B_{MSY} and F/F_{MSY} increased 124% and 9% in comparison to model 12, respectively, something that was contrary to the expectation given the graphical pattern

Regarding test 3), down-weighting the 2017 groundfish data point decreased substantially the Mohn's Rho of F/F_{MSY} (67%) at the cost of cancelling the predictive power of the survey (MASE=1.1) (Table 3.2).

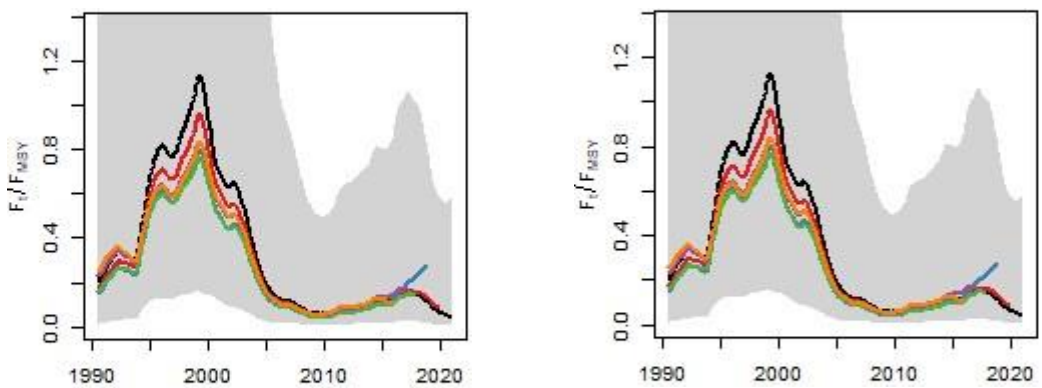

Figure 3.6 – Anchovy 9a-west: F/FMSY retrospective runs of models with down-weighted 2019 acoustic survey (left) and both the latter and the 2018 groundfish survey (right).

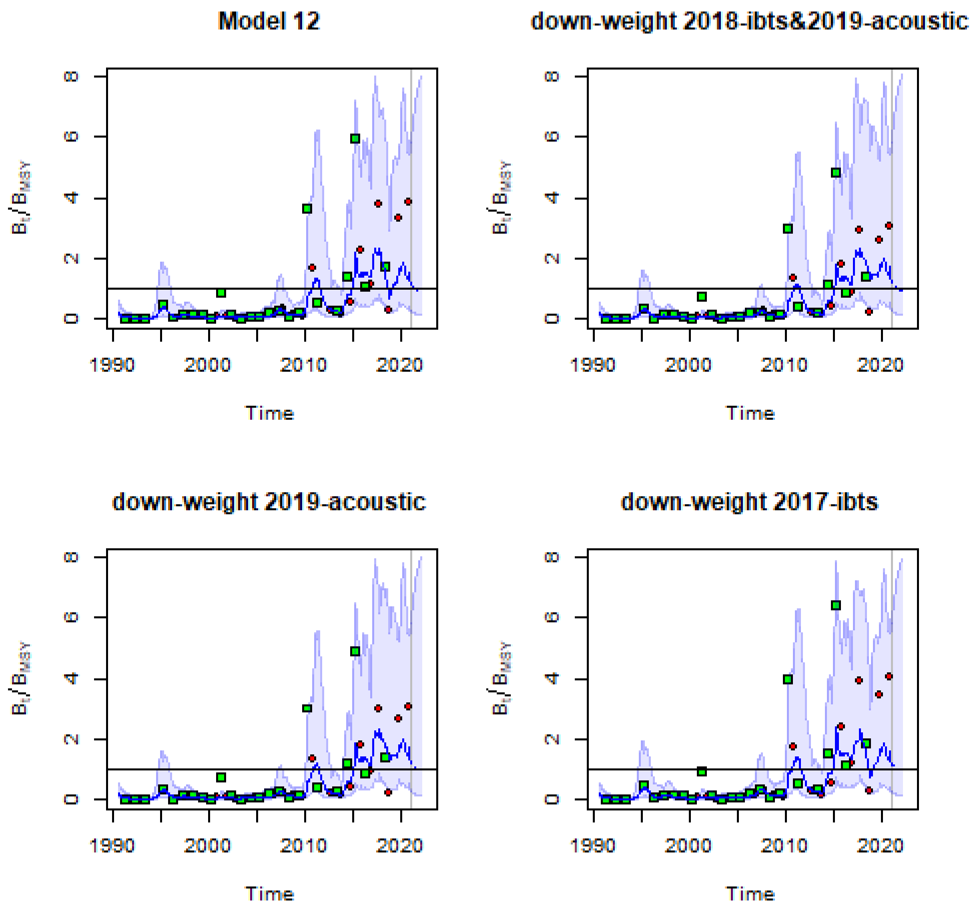

Figure 3.7 – Anchovy 9a-west: Plots of B/BMSY estimates of Model 12 and the models with down-weighted 2018 groundfish and 2019 acoustic surveys observations, down-weighted 2019 acoustic survey observation and down-weighted 2017 groundfish survey observation. The y-axis is truncated at 8 therefore the 2017 groundfish survey observation is not visible.

3.4.Sensitivity of Model 12 to the default prior assumptions on alpha and beta

Three additional sensitivity tests were:

4) Excluding the beta default prior
5) Excluding the alfa default prior
6) Excluding beta and alfa default priors

All tests had small effects on the CVs of parameters and derived quantities (Table 3.2). The main improvement when estimating alpha and beta parameters without priors was a decrease of 25-30% on F/F_{MSY} Mohn's Rho. Although at the same time the Mohn's Rho of B/B_{MSY} increased about 10%, the values were still well below the limits. Therefore, the free estimation of both alpha and beta parameters might be an option to consider in the final model.

4. Discussion

The following bullet points summarise the discussion in the group plenary:

- Surveys may not always represent the exploitable biomass, as they observe larger proportions of small individuals in years of good recruitment; small individuals may also be under-represented in the catches if there is slipping in those years; the fact that surveys are point observations in time may contribute to the differences observed in the LFDs; it may be sufficient that surveys cover the general length range caught in the fisheries; in future work, it may be worth to test the influence of a larger cut-off length (e.g. >13 cm) or corrected LFDs following Pedersen *et al.* (2017);
- The index of biomass of the autumn groundfish survey appears to be an acceptable index of abundance of anchovy since it showed a significantly positive correlation with that of the spring acoustic survey in the following year; both indices should continue to be explored for assessment purposes;
- PELACUS estimates are available since 2007 therefore this is the first year in the ICES assessment. In the present WD, the acoustic survey index starts in 1999, the first year with PELAGO survey estimates. Total abundance was assumed to be equal to the PELAGO estimates from 1999 to 2005 since abundance estimates of PELACUS in that period was assumed to be zero. The group considered this assumption to be acceptable since it was based on statements that PELACUS surveys were carried out although the estimation of anchovy was not possible due to its low abundance:
  "*Spanish acoustic surveys aimed at sardine have been conducted in Sub-division IXa North and Division VIIIc since 1983. Results from these surveys for the Sub-division IXa North have shown the scarce presence or even the absence of anchovy in this area (Carrera et al., 1999; Carrera, 1999, 2001). This situation still continues in the most recent years (surveys in the 2003-2007 period, see Porteiro et al., 2005; WD Iglesias et al., 2007)*". ICES, 2007, page 598).

- The possibility of using PELACUS and PELAGO separately was not considered an option because PELACUS coverage is not representative of the stock since it is just a small part of the western component distribution area.
- The decision to down-weight the 2018/2019 survey data points should be discussed with survey experts;
- The group noted that in the best model (model 12), F/F_{MSY} was estimated to be near the lowest historical harvest rate level calculated in the ICES assessment and well below the average of the historical series (Figure 4.1); the wide confidence intervals, namely in the past, may partly result from some very high harvest rates in combination with gaps in the acoustic survey series;
- Finally, the seasonal F parameter was inadvertently fixed equal to 1 in the bi-annual models but should have been estimated; the correction of this issue (running: `inp$phases$logphi=1)` was found just before the meeting, there was no time to re-run the models. It is noted that correcting this issue may introduce changes to the results presented so far.
- The WG considered that the present approach may be considered for further work in a benchmark workshop.

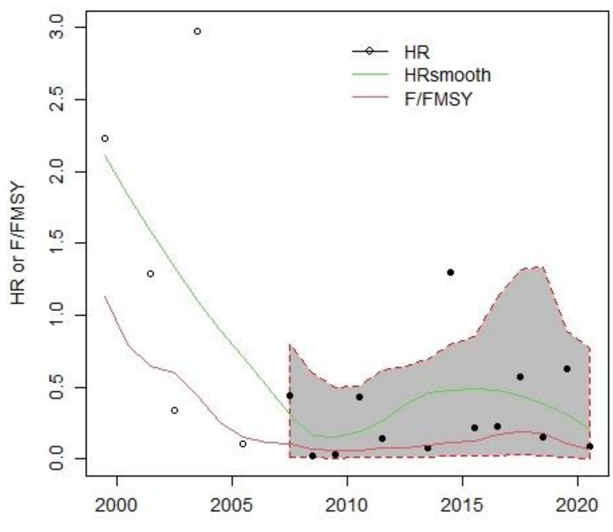

Figure 4.1 - Anchovy 9a-west: Estimates of F/F_{MSY} from the best SPiCT model (model 12) and harvest rates (ratio between annual catch and the PELAGO+PELACUS biomass) used in the ICES assessment (dots). The white dots show harvest rates before 2007 which are not used in the advice.

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Table 3.1 - Anchovy 9a-west: Summary of data, assumptions, diagnostics and results of the models fitted to anchovy data which converged, had random, unbiased and independent residuals and, showed a minimum of four converged retrospective runs with consistent trajectories over time (14 out of 40 initial models).

						Model parameters and coefficient of variation																		Absolute reference points			Relative reference points		Coefficient of variation			Mohn's Rho			Sensitivity to initial values			Hindcast crossvalidation (MASE)			
Model number	Catch aggregation	Indices of abundance	n prior	r prior	B1/K prior	n	n.cv	bkfrac	bkfrac.cv	r	r.cv	K	K.cv	alpha$_{ac}$.est	alpha$_{ac}$.cv	alpha$_{IBTS}$.est	alpha$_{IBTS}$.cv	beta	beta.cv	q_{ac}.est	q_{ac}.cv	q_{IBTS}.est	q.cv	BMSY	FMSY	MSY	B/BMSY	F/FMSY	B/BMSY	F/FMSY	Abs(param correlations) > 0.95	B/BMSY	F/FMSY	Comments on retro	P50 dist.	P90 dist.	Prop. fail	Acoustic survey (5 runs)	Groundfish survey (3 runs)	Number not converged (order)	other comments
1	quarter	1-acoustic	Schaefer	None	BK50	2	0	0.42	0.56	1.26	0.71	45837	1.20	0.79	0.55			1.17	0.36	4.4E-05	1.35			NaN	0.37	NaN	1.52	0.02	0.82	2.35		0.06	0.13	retro-2 contrasts with the others; retrospective -5 not converged	0.47	193286.45	0.19	0.96	-	3 (5, 6, 7)	
2	quarter	1-acoustic and 2-groundfish	Thorson	None	BK20	1.05	0.26	0.13	0.54	0.68	0.88	24611	1.08	0.49	0.90	0.47	0.44	1.81	0.53	7.2E-05	4.8E-05	1.08	0.99	NaN	0.62	NaN	1.88	0.04	1.58	1.91		-0.08	0.26	retrospective -5 not converged	0.12	0.49	0.16	1.00	0.47	2 (6, 7)	Odd shape of the production curve
3	quarter	1-acoustic and 2-groundfish	Thorson	None	BK50	0.92	0.39	0.33	0.54	0.52	1.15	20525	0.98	0.53	1.10	0.53	0.52	1.48	0.49	7.4E-05	4.3E-05	0.83	0.78	7240	0.57	4113	2.59	0.04	2.01	1.98		-0.11	0.09		0.15	11327.14	0.26	1.13	0.68		
4	quarter	1-acoustic and 2-groundfish	Thorson	None	BK80	0.87	0.36	0.53	0.53	0.48	0.99	18658	0.98	0.54	1.18	0.52	0.46	1.39	0.4	7.4E-05	4.2E-05	0.84	0.78	6401	0.56	3555	2.98	0.03	1.98	2.04		-0.16	0.15		0.13	11469.48	0.23	1.16	0.72		
5	semester	1-acoustic	Schaefer	None	BK50	2	0	0.42	0.55	1.24	0.85	50828	1.35	0.79	0.63			1.07	0.46	3.9E-05	1.50			NaN	0.36	NaN	1.4	0.04	0.86	3.11		0.11	0.18		0.13	72941.05	0.06	1.07	-	1 (7)	
6	semester	1-acoustic	Schaefer	Thorson	BK50	2	0	0.42	0.55	1.79	0.26	40789	1.19	0.61	0.41			1.07	0.47	5.5E-05	1.19			NaN	0.74	NaN	1.28	0.04	0.89	3.01	MSY-K	0.18	0.24	retro-2 contrasts with	0.08	0.31	0.16	1.05	-	1 (7)	
7	semester	1-acoustic	Schaefer	None	BK80	2	0	0.68	0.55	1.24	0.73	47786	1.23	0.81	0.59			1.00	0.44	4.1E-05	1.37			NaN	0.37	NaN	1.44	0.04	0.83	2.94		0.12	0.17	the others	0.29	136430.71	0.00	0.91	-	2 (6, 7)	
8	semester	1-acoustic	Schaefer	Thorson	BK80	2	0	0.69	0.55	1.78	0.26	38238	1.15	0.62	0.42			1.02	0.46	5.8E-05	1.14			NaN	0.73	NaN	1.31	0.04	0.87	2.86	MSY-K	0.19	0.19		0.14	0.44	0.16	1.07	-	1 (7)	
9	semester	1-acoustic and 2-groundfish	Schaefer	None	None	2.0	0.0	0.00	2.20	2.53	0.36	67843	1.82	0.43	0.67	0.48	0.36	1.70	0.49	4.7E-05	3.8E-05	1.56	1.41	NaN	2.64	NaN	0.96	0.03	1.03	2.16	MSY-K	0.08	0.12	Trajectories diverge to	0.25	16322.83	0.06	0.74	0.66		
10	semester	1-acoustic and 2-groundfish	Schaefer	Thorson	None	2.0	0.0	0.00	2.20	2.18	0.24	86715	1.99	0.47	0.73	0.44	0.33	1.72	0.5	3.7E-05	3.0E-05	1.65	1.51	NaN	1.37	NaN	0.97	0.03	1.03	2.39	MSY-K; q_{ac}-q_{IBTS}	0.08	-0.11	the past	0.45	1.06	0.10	0.75	0.67		
11	semester	1-acoustic and 2-groundfish	Schaefer	None	BK20	2.0	0.0	0.10	0.53	2.58	0.48	25387	1.56	0.44	0.78	0.48	0.40	1.86	0.53	9.2E-05	5.7E-05	1.62	1.66	NaN	2.94	NaN	1.11	0.07	0.96	2.16		0.05	0.24		2.72	108623.70	0.13	0.89	0.66		
12	semester	1-acoustic and 2-groundfish	Schaefer	Thorson	BK20	2.0	0.0	0.11	0.52	2.13	0.26	34166	1.31	0.48	0.88	0.42	0.33	1.78	0.52	6.5E-05	4.0E-05	1.26	1.25	NaN	1.25	NaN	1.15	0.06	0.95	2.18	MSY-K	0.07	0.21	retro-2 contrasts with the others	0.09	0.35	0.03	0.89	0.68		
13	semester	1-acoustic and 2-groundfish	Schaefer	Thorson	BK50	2.0	0.0	0.26	0.54	2.09	0.26	37817	1.34	0.47	0.93	0.43	0.34	1.63	0.51	5.7E-05	3.2E-05	1.30	1.29	NaN	1.16	NaN	1.18	0.05	0.96	2.33	MSY-K	0.07	0.25		0.12	0.49	0.03	0.93	0.71		
14	semester	1-acoustic and 2-groundfish	Schaefer	Thorson	BK80	2.0	0.0	0.42	0.55	2.07	0.26	38702	1.33	0.48	0.98	0.43	0.34	1.53	0.5	5.4E-05	2.9E-05	1.29	1.28	NaN	1.14	NaN	1.20	0.05	0.96	2.36	MSY-K	0.07	0.27		0.12	0.53	0.10	0.94	0.73		

Table 3.2 – Anchovy 9a-west: Percentage of change of point estimates and coefficients of variation between Model 12 and each of the sensitivity test models.

Sensitivity test	Model	BBMSY	BBMSY.CV	FFMSY	FFMSY.CV	B.MoR	F.MoR	bkfrac	bkfrac.cv	r	r.cv	K	K.cv	$alpha_{ac}$.est	$alpha_{ac}$.cv	$alpha_{IBTS}$.est	$alpha_{IBTS}$.cv	beta	beta.cv	q_{ac}.est	q_{ac}.cv	q_{IBTS}.est	q.cv	P50 dist.	P90 dist.	Prop. fail	MASE Acoustic survey (5 runs)	MASE Groundfish survey (3 runs)
13	Down-weight acoustic 2019	9.6	-8.4	-33.3	-1.8	123.9	19.3	-9.1	0.0	-1.4	0.0	22.9	0.8	-25.0	-1.1	11.9	-3.0	1.1	-1.9	3.4	-1.0	-0.8	-0.6	-52.9	1.4	400.0	-7.7	0.000
14	Down-weight groundfish 2018 & acoustic 2019	8.7	-7.4	-33.3	-1.4	127.0	28.4	-9.1	0.0	-0.9	0.0	24.7	2.3	-27.1	-2.3	11.9	0.0	1.7	-1.9	2.6	-0.7	-0.1	0.0	-52.9	-1.4	300.0	-7.7	0.000
15	Down-weight groundfish 2017	0.9	-1.1	0.0	-1.8	118.6	-67.1	-9.1	0.0	2.3	0.0	-8.5	-1.5	0.0	-8.0	0.0	6.1	0.0	0.0	4.9	1.5	-0.7	-0.2	17.6	71.6	0.0	0.3	1.1
16	No beta prior	0.0	0.0	0.0	0.5	-5.7	-4.3	0.0	0.0	0.5	0.0	-1.6	0.8	0.0	0.0	0.0	0.0	3.4	3.8	1.7	1.7	1.3	1.4	100.0	80.3	200.0	-0.1	-0.2
17	No alpha prior	0.9	-1.1	0.0	0.9	10.0	-25.7	0.0	0.0	0.9	0.0	1.6	0.8	-4.2	-1.1	7.1	0.0	0.0	0.0	-0.8	-0.5	0.9	0.9	41.2	84.1	300.0	-0.8	-0.2
18	No alpha&beta priors	0.9	0.0	0.0	1.4	11.4	-30.5	0.0	0.0	0.9	0.0	0.0	2.3	-4.2	-2.3	7.1	0.0	3.9	3.8	0.9	1.2	2.3	2.3	105.9	71.0	200.0	-0.9	-0.3