ICES Survey Protocols – Manual for Acoustic Surveys Coordinated under ICES Working Group on Acoustic and Egg Surveys for Small Pelagic Fish (WGACEGG)

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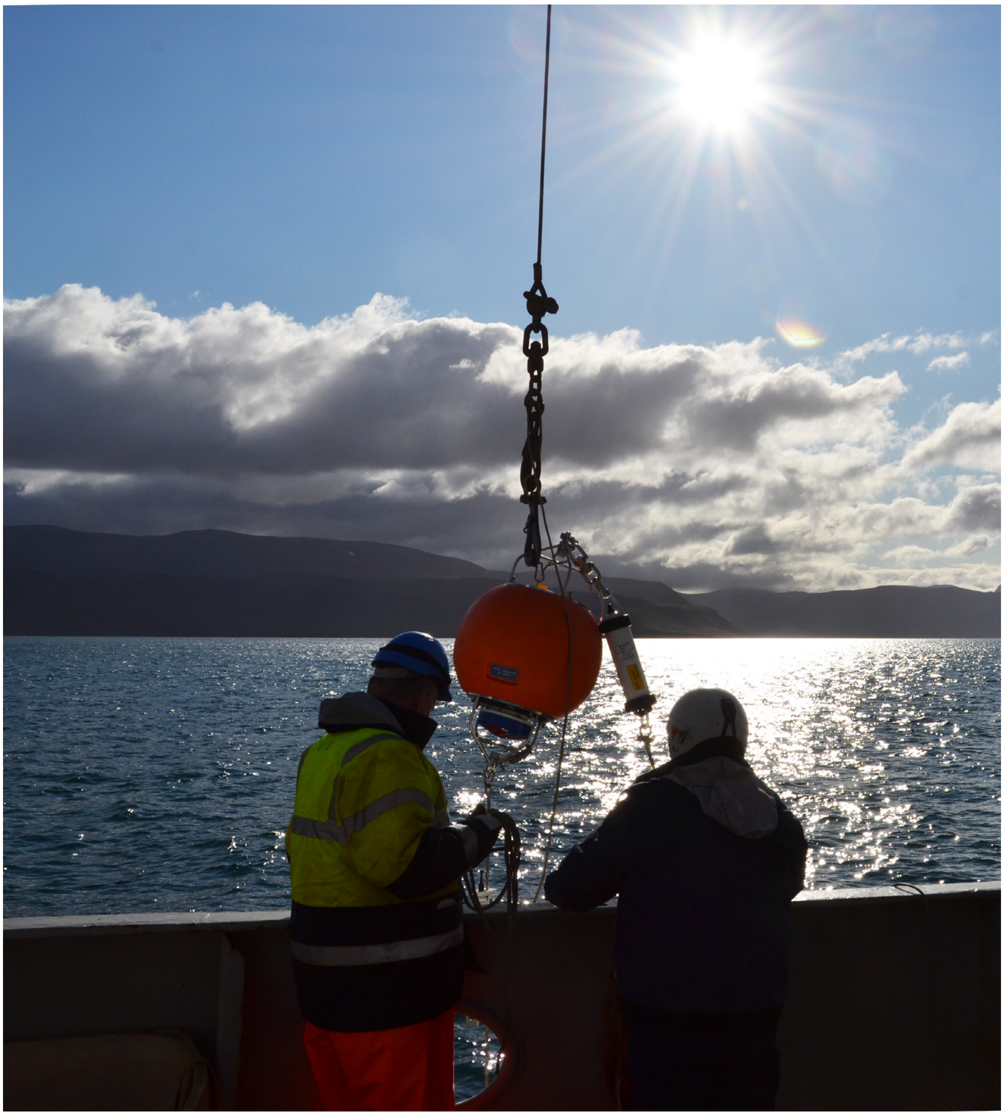

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Editors

Mathieu Doray • Guillermo Boyra • Jeroen van der Kooij

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I Background

This manual has been developed under the auspices of the ICES Working Group on Acoustic and Egg Surveys for small pelagic fish in the Northeast Atlantic (WGACEGG; Massé *et al.* 2018) to document the methodologies used to collect and analyse acoustic data during WGACEGG coordinated surveys.

The group coordinates ten individual acoustic surveys conducted in the Northeast Atlantic shelf waters (ICES Areas 6, 7, 8 and 9) by five countries (Portugal, Spain, France, UK, and Ireland). These surveys account for about 240 at-sea days per year on average. The group coordinates joint surveys covering shelf waters from southern Portugal to Ireland in spring and autumn, and an individual survey in the Gulf of Cadiz in summer. The spring and autumn joint surveys are a combination of five acoustic surveys. The main characteristics of each survey, including target species for which survey indices are directly input into fish stock assessments, are summarized in Table I.1. In Annex 1, a full list of the species covered can be found, including their common and scientific names.

Details on survey specific methods, as well as time-series of indices and gridded maps are reported annually in the WGACEGG report:

WGACEGG: http://www.ices.dk/community/groups/Pages/WGACEGG.aspx

Details of the ICES assessment working groups to which WGACEGG report can be found at:

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

http://www.ices.dk/community/groups/Pages/WGHANSA.aspx

ICES Working Group on Widely Distributed Stocks (WGWIDE):

http://www.ices.dk/community/groups/Pages/WGWIDE.aspx

ICES Herring Assessment Working Group for the Area South of 62° N (HAWG):

http://www.ices.dk/community/groups/Pages/HAWG

Table I.1. WGACEGG surveys summary. Month and peridocity column: "Month X – month Y" indicates a multiple month duration, "Month X / Month Y" indicates a shift in the survey start from Month X to Month Y.

Survey	Survey component	Institute (country)	Target fish stock(s) / life stage(s)	ICES stock assessment group[a]	Other data collected	Initial year	Month and periodicity	Missing year(s)
Spring joint survey	PELAGO	IPMA (Portugal)	9a anchovy and sardine / adults and eggs	WGHANSA	Horse mackerel, Atlantic mackerel, chub mackerel, bogue, hydrology, plankton, and top predators	1995	March / April–May Annual	2004 2012
	PELACUS	IEO (Spain)	9a and 8c horse mackerel, boarfish, mackerel and blue whiting / adults	WGWIDE	Egg counts from CUFES (sardine, anchovy, mackerel, horse mackerel and other), hydrology, plankton, top predators, and microplastics	1991	March / April Annual	1991
	PELGAS (Pélagiques GAScogne)	Ifremer (France)	8a, b, d anchovy and sardine / adults and eggs	WGHANSA	Adult horse mackerel, boarfish, chub mackerel, mackerel, and blue whiting, hydrology, phyto- and zooplankton, and megafauna	2000	May Annual	2020
	WESPAS	Marine Institute (Ireland)	6a and 7b,c, g, h, j horse mackerel, herring and boarfish / adults	WGWIDE	Hydrology, zooplankton, seabirds, and megafauna	2016	June–July Annual	None
Autumn joint survey	ECOCADIZ-RECLUTAS	IEO (Spain)	9a south anchovy and sardine / adults and juveniles	WGHANSA	Adult horse mackerel, mackerel, chub mackerel, boarfish, blue whiting, and hydrology	2012	October Annual	2013 2017
	IBERAS	IEO (Spain) /IPMA (Portugal)	9a North, 9a Central North, 9a Central South sardine / juveniles		Anchovy, horse mackerel, chub mackerel, mackerel, hydrology, and top predators	2018	September – November Annual	None

Table I.1 (continued)		Institute (country)	Target fish stock(s) / life stage(s)	ICES stock assessment group[a]	Other data collected	Initial year	Month and periodicity	Missing year(s)
	JUVENA	AZTI / IEO (Spain)	8a, b, c, d anchovy / juvenile (WGHANSA)	WGHANSA	Sardine, horse mackerel, sprat, boarfish, mackerel blue whiting and pearlside, hydrology, phyto- and zooplankton, and megafauna	2003	September Annual	None
	PELTIC	Cefas (UK)	7e, f sardine / adults 7d, e sprat / adults	WGHANSA HAWG	Anchovy, horse mackerel, mackerel, blue whiting, hydrology, zooplankton, seabirds, and megafauna	2012	October Annual	None [b]
	CSHAS	Marine Institute (Ireland)	7a, g–j south herring and sprat / adults	HAWG	Hydrology, zooplankton, seabirds, and megafauna	2003	October Annual	None
Gulf of Cadiz summer survey	ECOCADIZ	IEO (Spain)	9a south anchovy and sardine / adults and eggs	WGHANSA	Adult horse mackerel, mackerel, chub mackerel, boarfish, blue whiting, Hydrology, seabirds, and megafauna	2004	July–August Annual	2005 2008 2011 2012

[a] Details on indices provided to stock assessment groups are provided in Annex 2. WGACEGG reports to ICES for assessment purposes on the distribution and size and/or age disaggregated abundance of nine pelagic species (anchovy, blue whiting, boarfish, chub mackerel, herring, horse mackerel, mackerel, sardine, and sprat; see scientific names in Annex 1), from 35°N to 60°N and from 15°W to 0°. In addition to biological data for target species, the group also collects data and produces standard gridded maps for environmental biotic and abiotic parameters.

[b] Coverage has expanded.

1 General methodology for fish biomass estimation based on acoustic data

Mathieu Doray, Pedro Amorim, Guillermo Boyra, Pablo Carrera, Erwan Duhamel, Vitor Marques, Ciaran O'Donnell, Fernando Ramos, Silvia Rodriguez-Climent, Fabio Campanella, Jeroen van der Kooij, and Pierre Petitgas

This section describes the general methodology used to estimate fish biomass based on acoustic data collected by acoustic surveys coordinated by WGACEGG.

1.1 Sampling

1.1.1 Platform and equipment

Survey data are collected by research vessels equipped with downward-facing echosounders (beam angles at -3 dB: 7°) mounted on the ships hull, on a drop keel, or on a pole, mounted on the side of the vessel. *In situ* on-axis calibration of the echosounders is performed before or after each survey, using standard methodology (Demer *et al.*, 2015). Midwater trawling is performed during all surveys to identify acoustic targets. A variety of other parameters on hydrology, plankton, and megafauna are also collected during all surveys (Table I.1).

1.1.2 Survey design

The timing and spatial coverage of each survey component or individual survey has been defined to achieve stock containment of target species at the mesoscale of each survey component (and stocks, Table I.1 and Annex 2). At the large-scale of joint surveys, individual survey timings are coordinated within WGACEGG to achieve a quasi-synoptic sampling of the European western continental shelf pelagic ecosystem in spring and autumn. This quasi-synoptic sampling allows an overall assessment of the large-scale distribution of small pelagic fish, as well as potential local distribution shifts in response to, e.g. climate change.

Acoustic samples (pings) are typically recorded every half second along systematic parallel linear transects perpendicular to the coast and uniformly spaced (Figure 1.1). The inter-transect distance (i.e. spacing between transects) results from a compromise between available ship time and fish cluster mean size (Petitgas, 2003).

Acoustic data are typically collected at 1 m vertical resolution, from the bottom of the echosounders blind zone near the surface (typically 10 m depth), to the top of the acoustic dead-zone near the seabed (typically 1 m above the seabed). Acoustic samples are subsequently averaged along transects within Elementary Distance Sampling Units (EDSUs).

1.1.3 Species identification by trawling

The identification of species and size classes comprising fish echotraces (Reid, 2000) heavily depends on identification by means of midwater trawl hauls. Acoustic data are displayed in real time on echograms during the surveys, and trawl hauls are performed as often as possible to identify fish targets. Rationale for performing an identification haul include:

- observation of numerous fish echotraces over several EDSUs, or of very dense fish echotraces in one EDSU;
- changes in the echotrace characteristics (morphology, density or position in the water column); or

- observation of an echotrace type fished on previous transects, but not yet fished on the current transect.

Acoustic transects are adaptively interrupted to perform identification trawl hauls, and subsequently resumed at the point of interruption. Trawl stations are then performed on the positions of particular fish echotraces that are considered to be representative of similar echotraces observed elsewhere but not fished. Trawl catches do not allow for the identification of single schools, but are generally considered representative of fish schools observed over 2–3 nautical mile portions of the linear transects.

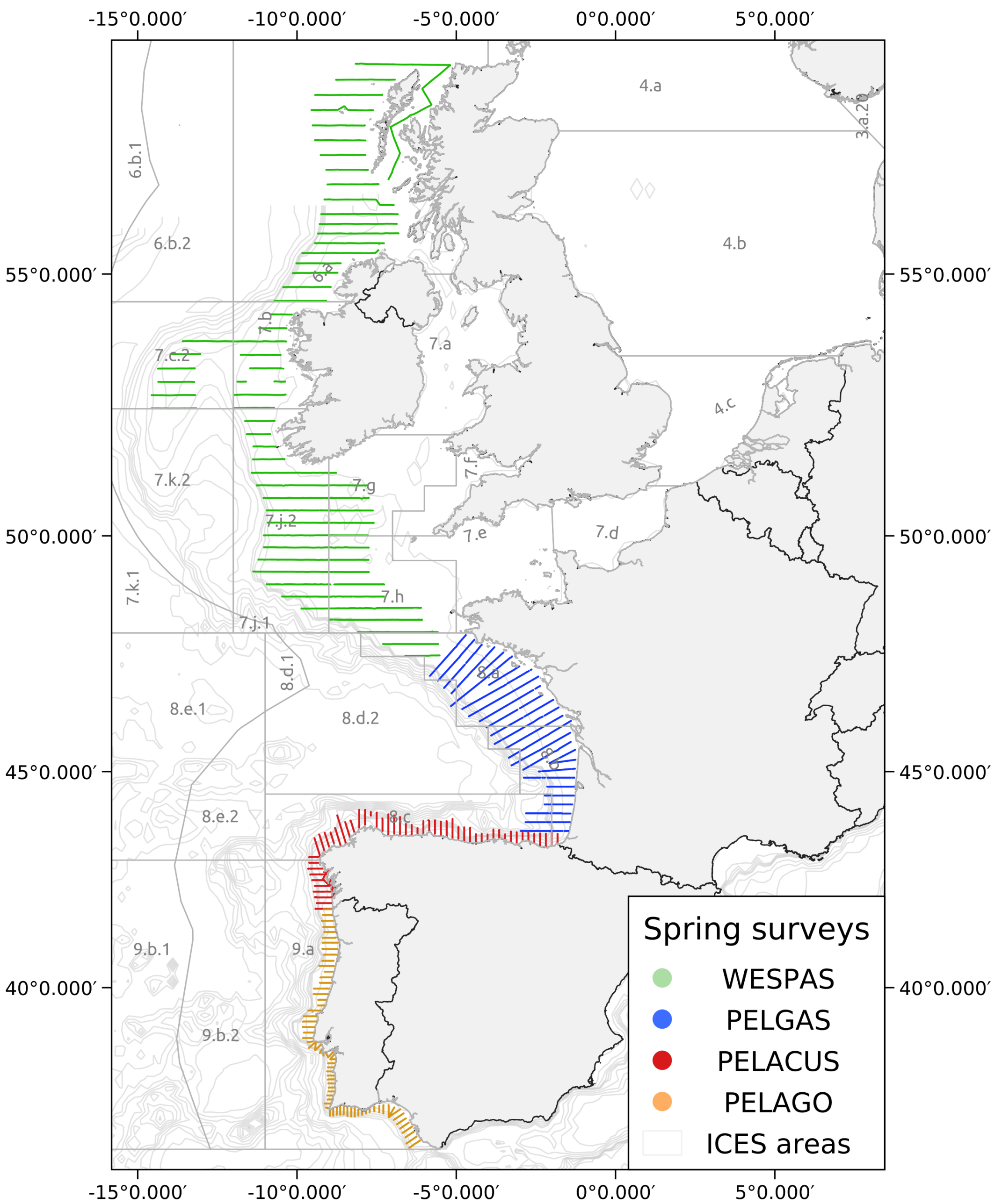

Figure 1.1. Example of parallel transects sampling scheme in ICES Areas 6, 7, 8 and 9. Spring joint acoustic surveys: PELAGO in orange, PELACUS in red, PELGAS in blue, and WESPAS in green.

1.1.4 Sampling time

Acoustic surveys are designed taking into account the phenology of the target species. Many small pelagic fish species exhibit migratory behaviour. In addition, distribution and behaviour can vary throughout their life cycle, seasonally and spatially, depending on habitat requirements, e.g: spawning, nursery, and feeding. An effective survey takes this behaviour into account, both spatially and temporally. Fish behaviour is also influenced by the time of day, which means careful consideration should be given to when the survey should be conducted during a 24 h period (only in daylight or at night, or both during daylight and at night). Consideration should also be given to transitional (crepuscular) periods when fish and aggregation behaviour is more dynamic than during other periods of the day.

For many small pelagic fish species, acoustic sampling is best carried out during daylight hours, when fish schools are aggregated in the water column or near the seabed, often in mono-specific schools. During the hours of darkness, schools often disperse forming loose scattering layers that migrate towards the surface to feed. Such near-surface distribution is in the surface blind zone of echosounders (~ 0–12 m), and, therefore, out of range. Performing integration of dispersed layers is also more complex because of the presence of multiple taxa.

For all but one WGACEGG coordinated survey (CSHAS - 24 h), acoustic data are collected during daylight hours from sunrise to sunset.

1.2 Acoustic fish stock biomass estimation

1.2.1 General framework

Acoustic biomass estimation requires the combination of data from various sources collected along the survey track: total acoustic backscatter, proportions by species and/or size class, and mean length (Woillez *et al.*, 2009; Figure 1.2).

Fish acoustic biomass estimation for each species and depth channel considered involves seven main steps (Simmonds and MacLennan, 2005) detailed in sections 1.2.2 to 1.2.7.

1.2.2 Step 1: defining the proportions by species from fishing data

Defining the species ratio from trawl catches can be done by:

i) allocating the proportions by species recorded in a specific 'reference haul' to each EDSU;

ii) defining regions where species/size compositions are homogeneous. Mean species/size compositions based on multiple trawls within these homogenous regions are then computed and applied to the EDSUs within the regions (Simmonds and MacLennan, 2005); or

iii) computing estimates of species proportions at the nodes of a grid overlain on the survey area, using a geostatistical model (kriging, geostatistical simulation; Gimona and Fernandes, 2003; Walline, 2007; Woillez *et al.*, 2009). Modelled species proportions are then allocated to the closest EDSUs.

Acoustic surveys coordinated under the auspices of WGACEGG use the first two approaches to define the species ratio from trawl catches.

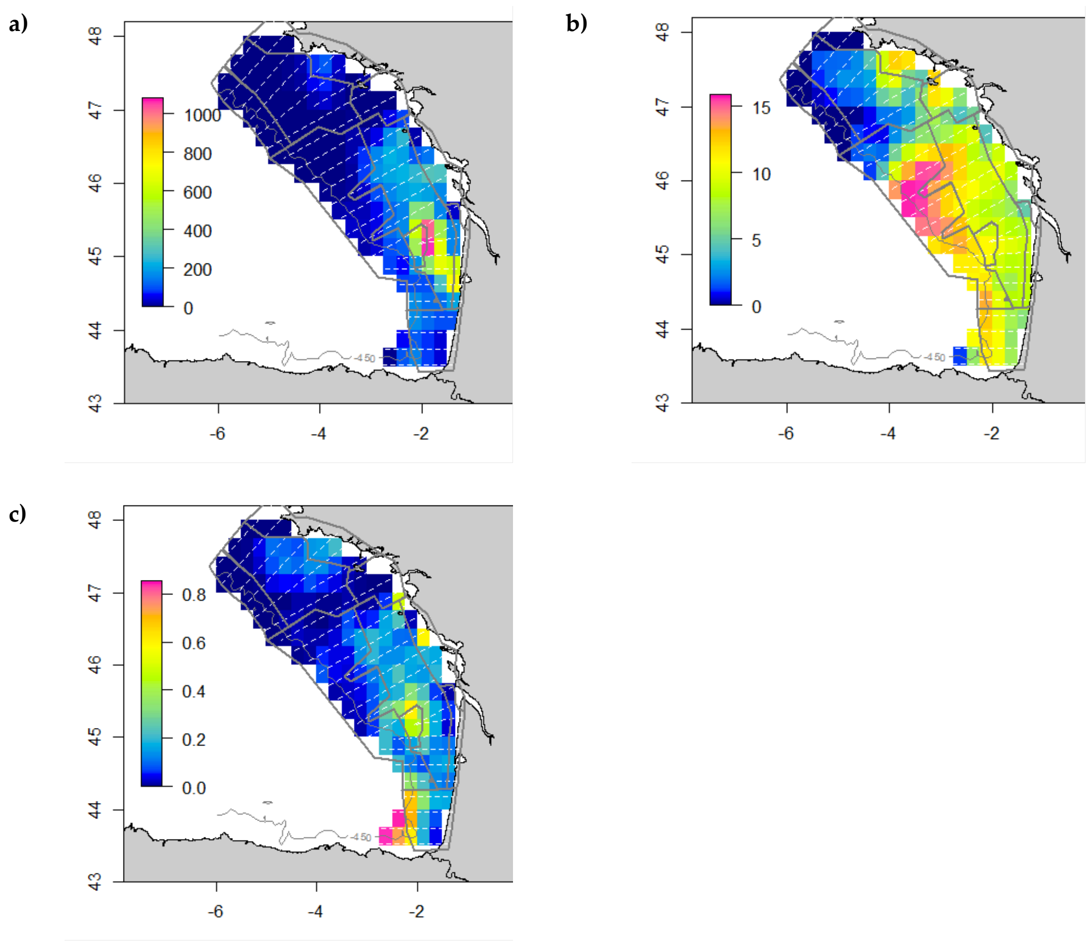

Figure 1.2. Data fields required for acoustic biomass assessment of a given species: a) total fish acoustic backscatter (NASC, m² nautical mile⁻²); b) species mean length (cm); c) proportion by species and/or size class (%). White dotted lines represent the ship track; grey lines delineate homogeneous regions or strata.

1.2.3 Step 2: partitioning of the total echo integrals by species

Echogram scrutiny aims at extracting fish from other acoustic backscatter (e.g. noise, sound scattering layers, plankton) and partitioning the total fish echo integrals by species.

When acoustic marks can be visually allocated to a single species with good confidence, no further echo integrals partitioning is needed after the scrutinizing process, although a trawl station is needed in order to know their length and/or age structure.

Conversely, when two or more species are found in mixed concentrations and their marks cannot be distinguished on the echogram, further partitioning to species level is possible by including the composition of trawl catches (ICES, 1977). Echo-integrals (*Ei*) allocated to species *i* can be determined according to Equation 1 (Simmonds and MacLennan, 2005):

$$E_i = \frac{w_i\langle\sigma_i\rangle}{\sum_{j=1}^{N} w_j\langle\sigma_j\rangle} E_m \qquad (1)$$

where *Wi* are expressed as the proportional number or weight of each species *j* in the trawl catches [eventually weighted by total haul catches or mean acoustic backscatter in the vicinity of the haul(s)]; σ_i is the mean backscattering cross section of the species *i*; and *Em* is the total echo integral.

The mean backscattering cross section is derived from the mean target strength of one fish TS_1, as a function of its length (L; usually expressed in cm):

$$TS_1 = b_i + m_i log(L) \tag{2}$$

where b_i and m_i are species-specific coefficients, assumed to be known from experimental evidence. log represents here, and in the rest of the document, log base 10. The formula for the mean backscattering cross section $\langle\sigma_{bs-i}\rangle$ (expressed in m² of backscattering surface) is:

$$\langle\sigma_{bs-i}\rangle = 10^{TSi/10} = 10^{(b_i+m_i log(\langle L\rangle))/10} = \langle L\rangle^{m_i/10}10^{b_i/10} \tag{3}$$

where TS_i, is the mean target strength of one fish of species i, L is species i mean length, and b_i and m_i are coefficients taken from a species-specific TS-length equation.

If echo integrals (Ei) are expressed as nautical area-scattering coefficients [NASC; S_A (in m² nautical mile^{-2})], backscattering cross sections must be expressed in Equation 1 as spherical backscattering cross sections: $\sigma_{sp-i} = 4\pi\sigma_{bs-i}$, to derive fish density estimates (Simmonds and MacLennan, 2005).

Using mean lengths (L) in TS equations is thought to be more conservative in the multispecies context of some WGACEGG surveys, where some species can be represented by few fish in the identification hauls. When the biological sample is too small to safely represent the true length distributions, a few large values can indeed induce a strong positive bias in the overall TS estimate, because of the non-linear nature of the TS function. Moreover, catch length measurements are split into unimodal size categories. Mean lengths per species are calculated within each category, to ensure that those values are representative of the length distribution of each size category in subsequent TS calculations.

1.2.4 Step 3: estimating the density of targets of species *i*

The density of target species i can be derived in each EDSU from the acoustic and trawl data obtained in steps 1 and 2 using the generic formula:

$$F_i = \frac{E_{iE}}{\langle\sigma_i\rangle} \tag{4}$$

where F_i is the areal density of target of species i; E_i is the mean acoustic backscatter of species i obtained through a calibrated echosounder; and σ_i is the mean backscattering cross section of the species i.

1.2.5 Step 4: calculating number-weight relationships

F_i can be expressed in weight of fish per surface unit by multiplying F_i by some estimate of the overall mean weight of species i.

Alternatively, a weight-based TS function can be employed, i.e. using the target strength of 1 kg of fish to compute F_i. To achieve this length is converted to weight following the mean relationship between the length L of a fish and its weight W, expressed as:

$$W = a_f L^{b_f} \tag{5}$$

Where a_f and b_f are the slope and intercept of the relationship, respectively.

In this case, the weight-based spherical scattering cross section $\langle\sigma_{sp-w}\rangle$ is expressed as (Simmonds and MacLennan, 2005):

$$\langle\sigma_{sp-w}\rangle = \frac{\langle\sigma_{sp-1}\rangle}{\langle W\rangle} = \frac{4\pi}{\langle W\rangle} \times \langle L^2\rangle \times 10^{b_i/10} \tag{6}$$

1.2.6 Step 5: estimating abundance in the survey area

Abundance is calculated independently for each species or target category defined during echo-partitioning. Assuming that the whole stock of the target species is contained in the survey area, and that the size distribution is homogeneous in the survey area, areal densities of species i per EDSU are extrapolated to the total surface area of the survey. If the fishing samples indicate consistent differences between regions within the survey area, size distributions must be determined separately for each post-stratification region, i.e., a region within which the population structure is considered to be homogeneous (Simmonds and MacLennan, 2005). Total abundance estimates in previously defined homogeneous post-stratification regions are usually calculated by multiplying the mean fish density per EDSU by the total surface of the region.

From equations 1 and 4, the total abundance in number (Q_i) of species i in a homogeneous region of surface A can be calculated as:

$$Q_i = F_i \times A = \frac{E_m}{\sigma_i}\frac{z_i\sigma_i}{\sum_j z_j\,\sigma_j} \times A = \frac{z_i}{\sum_j z_j\,\sigma_j}E_m \times A = Z_i \times E_m \times A \tag{7}$$

where Z_i is a region-specific weighting factor that depends only on trawl catches and TS equations (Diner and Le Men, 1983).

In the same way, the total abundance in weight (Q_{w-i}) of species i in a homogeneous region of surface A can be calculated as:

$$Q_{w-i} = \langle W_i\rangle \times F_i \times A = \langle W_i\rangle \times \frac{z_i}{\sum_j z_j\,\sigma_j}E_m \times A = X_{i-k} \times E_m \times A \tag{8}$$

where W_i is the mean weight (in kg) of species i in the region; and X_{i-k} is a region-specific weighting factor that depends only on trawl catches and TS equations (Diner and Le Men, 1983) and is expressed in kg m^{-2}.

Using the weight-based spherical scattering cross section from Equation 6, the region-specific weighting factor X_{i-k} is expressed as:

$$X_{i-k} = z_i \Big/ \left(\sum_j z_j\,\langle\sigma_{w-j}\rangle\right) \tag{9}$$

where $\langle\sigma_{w-j}\rangle$ is the weight-based mean spherical scattering cross section of all species j in the region. To express the abundance in number of fish, the weighting factor X_{i-1} should be used:

$$X_{i-1} = X_{i-k}\langle W\rangle \tag{10}$$

1.2.7 Step 6: calculating abundance-at-length and -at-age

Abundance-at-length can be calculated either by estimating abundance per length class from scratch, or by splitting abundance per EDSU and/or region by length class using length distributions. Biomass-at-length is then derived by applying length-weight relationships (WLR) to abundance-at-length.

Abundance-at-age can be derived from abundance-at-length by splitting abundance-at-length between ages using length-age relationships. Global mean weights-at-age can be estimated through the following steps:

1. calculating total abundance per length class;
2. splitting total abundance per length class between ages using length-age relationships:
3. calculating total abundance per age by summing abundance-at-age over length class; and
4. calculating mean weights-at-age by applying global WLR to abundances-at-age.

1.2.8 Step 7: estimating the abundance estimate precision

Two main approaches are used under the auspices of WGACEGG for estimating the precision of abundance estimates: random sampling theory and bootstrapping.

An estimation variance $\sigma^2_{E\text{-}d,i,j}$, that takes into account the catches and acoustic backscatter E variability can be derived based on random sampling theory. It can be calculated for each species i found in echotype d and region j as the product variance: $\sigma^2_{E-d,i,j} = Var(\overline{E_{d,j}X_{d,i,j}})$ (Doray *et al.* 2010).

The product variance can be developed to:

$$\sigma^2_{E-d,i,j} = var(\overline{E_{d,j}})\overline{X_{d,i,j}}^2 + var(\overline{X_{d,i,j}})\overline{E_{d,j}}^2 + var(\overline{E_{d,j}})var(\overline{X_{d,i,j}}) \tag{11}$$

where:

$\overline{E_{d,j}}$ and $var(E_{d,j})$ are the average and the variance of acoustic backscatters allocated to echotype d in region j, respectively; and

$\overline{X_{d,i,j}}$ and $var(X_{d,i,j})$ are the average and the variance of the $X_{d,i,j}$ scaling factors of species i in region j and echotype d.

Note that the total estimation variance $\sigma^2_{E\text{-}d,i,j}$ can be written as :

$$\sigma^2_{E-d,i,j} = \sigma^2_{Eid-d,i,j} + \sigma^2_{space-d,i,j} + \sigma^2_{E2-d,i,j} \tag{12}$$

where :

$\sigma^2_{Eid-d,i,j} = var(\overline{E_{d,j}})\overline{X_{d,i,j}}^2$ is the species identification variance ;

$\sigma^2_{space-d,i,j} = var(\overline{X_{d,i,j}})\overline{E_{d,j}}^2$ is the acoustic backscatter spatial variance; and

$\sigma^2_{E2-d,i,j} = var(\overline{E_{d,j}})var(\overline{X_{d,i,j}})$ is the second order product of mean acoustic backscatter and X variances.

Assuming that :

$var(\overline{E_{d,J}}) = var(E_{d,j})w_{E-j}$, where $w_{E-j} = \frac{1}{N_j}$, N_j being the number of EDSUs in region j; and:

$var(\overline{X_{d,\iota,J}}) = var(X_{d,i,j})w_{X_{d,i,j}}$, where: $w_{X_{d,i,j}} = \sum_k (\frac{E_{kd}}{\sum_k E_{kd}})^2$ is the weight of the X factor of species i in region j and deviation d, computed over trawl hauls k, as the mean fish backscatter value E_{kd} around the hauls.

Hence, the estimation variance of species i is:

$$\sigma^2_{E-i} = \sum_d \sum_j [w_{A-j} \cdot \sigma^2_{E-d,i,j}] = \sum_d \sum_j [w_{A-j} \cdot (\sigma^2_{Eid-d,i,j} + \sigma^2_{space-d,i,j} + \sigma^2_{E2-d,i,j})] \quad (13)$$

with:

$$\sigma^2_{Eid-d,i,j} = \overline{E_{d,J}}^2 var(X_{d,i,j})w_{X_e-j} \quad (14)$$

$$\sigma^2_{space-d,i,j} = \overline{X_{d,\iota,J}}^2 var(E_{d,j})w_{E-j} \quad (15)$$

$$\sigma^2_{E2-d,i,j} = var(X_{d,i,j})w_{X_e-j} var(E_{d,j})w_{E-j} \quad (16)$$

and $w_{Aj} = \frac{{A_j}^2}{(\sum_j A_j)^2}$ the weighting factor of region j of area A_j. This methodology is implemented in the EchoR R package (Doray *et al.*, 2013).

Bootstrapping (Simmonds and MacLennan, 2005) is used to assess survey precision in the StoX software (Johnsen *et al.*, 2019). In the bootstrapping procedure in StoX, transects and the associated trawls are randomly selected with replacement within each stratum. Biomass and abundance are then calculated in each n iteration (typically n = 500) using the resampled data. Finally, the output of all the runs are used to calculate the relative sampling error.

1.3 Reporting and harmonization

A standard survey summary sheet (Annex 6) is filled out by each survey component to report on eventual sampling issues and assess the fitness of the survey for use in the assessment. Survey summary sheets are sent to stock assessment groups and annexed to WGACEGG annual reports.

One of the objectives of WGACEGG is to standardize data collection and analysis methodologies used within the different survey groups. While this aim has been achieved in many areas, some inconsistencies remain, specifically regarding TS values and the post-processing software packages used. Several ongoing studies on the TS of European small pelagic fish have been initiated by WGACEGG (e.g. Doray *et al.* 2016) and will lead to a harmonization of TS values used in biomass estimation procedures. The recent development and adoption by group members of standardized software packages (EchoR, Doray *et al.* 2013; and StoX, Johnsen *et al.* 2019) should also help ensure that: i) all survey groups use equivalent and sound data analysis methodologies, and ii) an estimation of the error is provided for each survey-derived biomass and abundance value.

2 Joint surveys

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2.1 Joint spring acoustic survey

2.1.1 Background

The PELGAS (Doray *et al.*, 2018c), PELACUS (Carrera, 2015; Massé *et al.*, 2018), and PELAGO (Massé *et al.*, 2018) acoustic surveys have sampled the French, Spanish and Portuguese continental shelves, respectively, since the early 2000s. The surveys initial objectives were to estimate the spring biomass of sardine (PELACUS and PELAGO) and anchovy (PELGAS). The list of fish species targeted for stock assessment purposes has expanded over time (Table 2.1). As surveys started to be coordinated under the auspices of WGACEGG in 2002, and other surveys were included, the focus expanded to cover the biomass assessment of the whole small pelagic fish community, and, more recently, to monitoring the small pelagic fish community within their ecosystem (Massé *et al.*, 2018, Table 2.1). On from 2016, the geographical coverage of the surveyed area was extended from the northern Bay of Biscay to the northern Hebrides by the addition of the WESPAS survey (O'Donnell *et al.*, 2016). Although not temporally aligned (June–July, Table I.1), the inclusion of WESPAS has significantly expanded spatial coverage, enabling inclusion of widely distributed species like horse mackerel and boarfish.

The PELAGO, PELACUS and WESPAS surveys are conducted on single research vessel platforms (Table 2.2). The PELGAS survey has been performed on RV Thalassa II since the beginning of the series. However, since 2007 a consort survey is routinely organized with French pairs trawlers which accompany RV Thalassa during 20 days on average, and conduct supplementary identification hauls (Massé *et al.*, 2016).

Protocols for the spring acoustic surveys have been standardized within WGACEGG since 2003. Standardised biological sampling for anchovy, sardine, and other small pelagic fish populations, have also been performed every year since 2003. Details on PELGAS survey protocols can be found Doray *et al.* (2014 and 2018a). Detailed protocols for the PELACUS and PELAGO surveys can be found in Massé et al. (2018), and for the WESPAS survey in ICES (2015).

The PELAGO, PELACUS, PELGAS, and WESPAS surveys are co-funded by the European Commission's Data Collection Framework (DCF) to provide biomass estimates for anchovy and sardine since the mid-2000s. They constitute the quarter 2 component of the DCF Sardine, Anchovy and Horse Mackerel Acoustic Survey (SAHMAS).

2.1.2 Sampling design

2.1.2.1 Sampling effort and spatial coverage

Figure 2.1 shows the design and coverage of the spring acoustic surveys in the European Atlantic area. WGACEGG spring joint survey covers an area extending from 35°N to 60°N and from 15°W to 0°. The details of the main sampling schemes are summarized in Table 2.3. The inter-transect distance varies from 8 (PELACUS and PELAGO surveys) to 15 nautical miles (WESPAS survey), and is considered appropriate for the small pelagic species and fish aggregation patterns generally found in these survey areas.

Table 2.1. Summary table of sardine, anchovy, horse mackerel and boarfish acoustic survey objectives, their contribution to fish stock assessment, other species of interest for which population biomass is estimated, and time frame.

Survey component	PELAGO	PELACUS	PELGAS (Pélagiques GAScogne)	WESPAS
Survey objectives	Assess small pelagic fish biomass and monitor the pelagic ecosystem in spring in western Iberia and the Gulf of Cadiz	Assess small pelagic fish biomass and monitor the pelagic ecosystem in spring in northern Spanish waters	Assess small pelagic fish biomass and monitor the pelagic ecosystem in spring in the Bay of Biscay	Age stratified relative abundance and biomass of herring, boarfish and western horse mackerel for stock assessment purposes
Target fish stock(s) / life stage (s) (Stock assessment group)	9a anchovy and sardine / adults and eggs (WGHANSA)	9a north and 8c anchovy and sardine / adults and eggs (WGHANSA) 9a and 8c horse mackerel, boarfish, mackerel, and blue whiting / adults (WGWIDE)	8a, b, and d anchovy and sardine / adults and eggs (WGHANSA)	6a and 7b, c, g, h, and j horse mackerel and boarfish / adults (WGWIDE)
Other data collected	Horse mackerel, mackerel, chub mackerel, bogue, hydrology, plancton, and top predators	Egg counts from CUFES (sardine, anchovy, mackerel, horse mackerel, and other), hydrology, plancton, top predators, and microplastics	Adult horse mackerel, boarfish, chub mackerel, mackerel, and blue whiting, hydrology, phyto- and zooplankton, and megafauna	Hydrology, zooplankton, seabirds, and megafauna
Month	March / May	March–April	May	June–July
Survey time-series				
Initial year	1995	1991	2000	2016
Periodicity	Annual	Annual	Annual	Annual
Missing years	2004, 2012	2020	2020	None

Table 2.2. Vessels used during spring acoustic surveys in ICES Areas 6, 7, 8 and 9.

Survey component	PELAGO	PELACUS	PELGAS	WESPAS
Number of vessels	1	1	1 before 2007 3 after 2007	1
Vessel(s) name(s)	RV Noruega until 2019 RV Miguel Oliver in 2020	RV Cornide de Saavedra before 1997 RV Thalassa II 1997–2012 RV Miguel Oliver after 2013	RV Thalassa II Joint survey with French FV pair trawlers since 2007	RV Celtic Explorer
Vessel(s) length(s) (m)	RV Noruega: 49 RV Miguel Oliver: 70	RV Cornide de Saavedra: 67 RV Thalassa II: 73 RV Miguel Oliver: 70	RV Thalassa II: 73 FV pair trawlers: 15–20	RV Celtic Explorer: 64
Vessel(s) crew	RV Noruega: 18 RV Miguel Oliver: 22	RV Cornide de Saavedra: 24 RV Thalassa II: 25 RV Miguel Oliver: 22	RV Thalassa II: 25 FV pair trawlers: 10	RV Celtic Explorer: 12
Scientific crew	RV Noruega: 13 RV Miguel Oliver: 19	RV Cornide de Saavedra: 16 RV Thalassa II: 23 RV Miguel Oliver: 19	RV Thalassa II: 23 FV pair trawlers: 1	RV Celtic Explorer: 16

Two surveys have a random starting point (PELACUS and WESPAS). All survey tracks (transects) are decided in advance.

The sampling design described in Table 2.3 allows an exhaustive coverage of the spring distribution of small pelagic fish over the European Atlantic continental shelf area (Figure 2.1).

The sampling design is not stratified, as small pelagic fish can potentially be distributed over the whole sampling area. Post-stratification regions in all surveys are delineated as polygons where species/size composition and echo integrals are assumed to be homogeneous, in order to estimate total fish biomass. The number and shape of post stratification regions varies year-to-year, depending on the annually observed spatial heterogeneity in species and size distribution.

EDSU are 1 by 1 nautical mile squares centred around ship track (Figure 2.2).

In each EDSU, acoustic densities are integrated over depth, except for the PELGAS survey, where a distinction is made between near seabed and near sea surface (10–30 m depth) echoes (Doray *et al.*, 2014, 2018c). For the PELACUS survey, fish echotraces are extracted using the school detection module (SHAPES algorithm) included in Echoview.

Mean linear sampled distances vary from 1230 (PELAGO) to 5900 nautical miles (WESPAS), depending on the sampled area surface and inter-transect distance (Table 2.3). The mean total linear sampled distance is 10 378 nautical miles per year.

Mean sampling area ranges from 10 000 (PELAGO) to approximately 60 000 nautical miles² (WESPAS). The total surveyed area in spring is 106 131 nautical miles². Mean sampling coverage (ratio of the mean linear distance sampled in relation to the whole sampling area) varies from 7% (PELGAS) to 13% (PELACUS), with an average of 10%.

The mean number of identification hauls per surveyed linear distance is about 0.03 per nautical mile for surveys conducted on a single RV, and can be doubled when consort surveys are used (Table 2.3).

About 100 hydrological stations are surveyed every year by each survey component, totalling 427 hydrological stations in the European Atlantic area in spring.

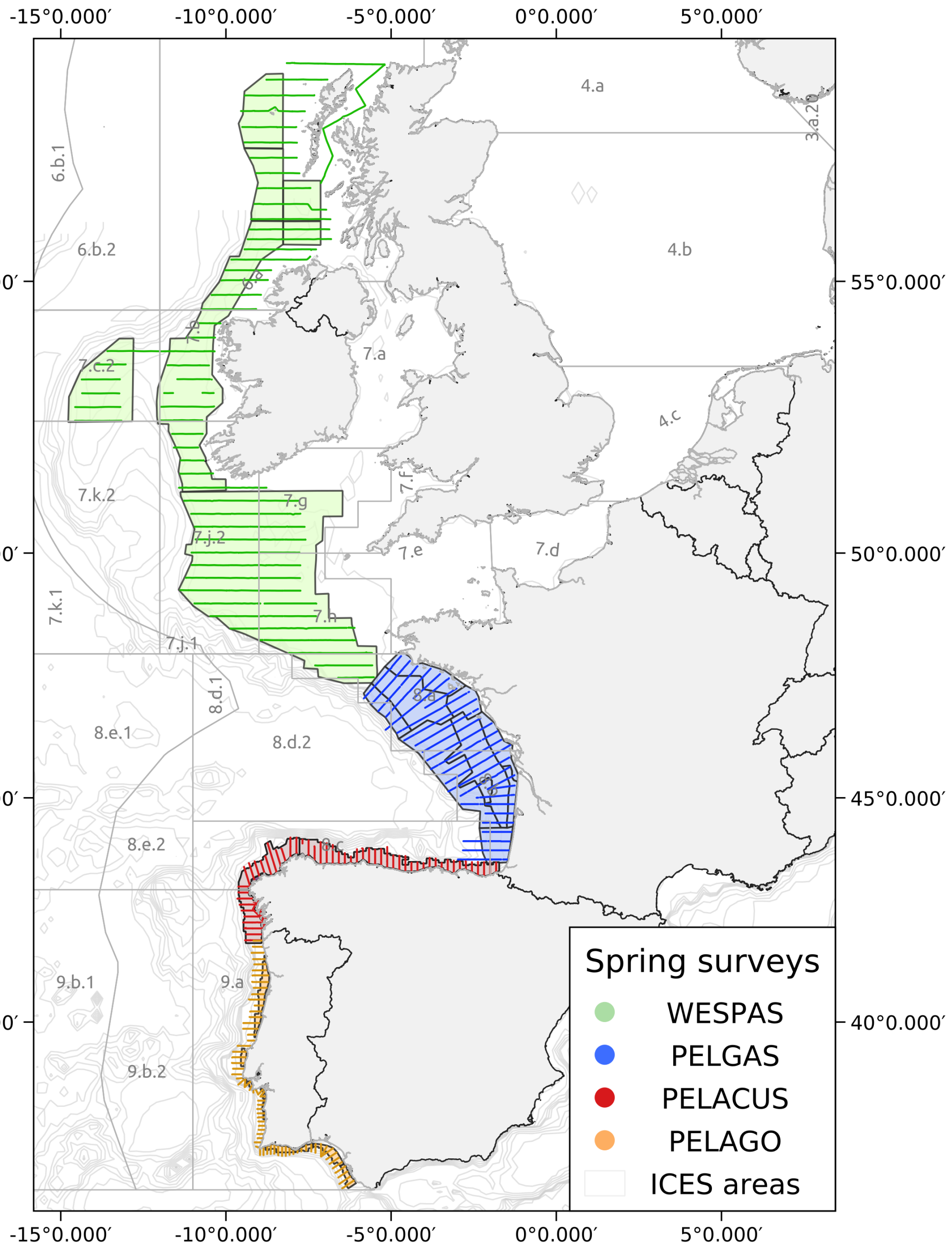

Figure 2.1. Map showing the combined coverage and design of the spring acoustic surveys in ICES Areas 6, 7, 8 and 9, including transect (colour-coded by survey) and post-stratification regions (strata). PELAGO in orange, PELACUS in red, PELGAS in blue, and WESPAS in green.

Table 2.3. Spring acoustic surveys sampling design summary table. NM: nautical mile.

Survey component	PELAGO	PELACUS	PELGAS	WESPAS	Total
Time period	March / May	Mid-March–mid-April	May	June–July	Mid-March–July
Average survey duration (days)	25	26	31	42	113
Sampling period (day, night, both)	Day	Day	Day	Day	Day
Sampling design (random / systematic / adaptive) parallel transects	Systematic	Systematic with random start	Systematic	Systematic with random start	Systematic
Minimum seabed depth (m)	10	20	20	20	10
Maximum seabed depth (m)	5000	1500–5000	5000	350	5000
Inter-transect distance (NM)	8	8	12	15	8–15
Acoustic EDSU length (NM)	1	1	1	1	1
Mean linear distance sampled (NM)	1230	1400	1848	5900	10 378
Nominal vessel speed (knots)	9	10	10	10	9–10
Maximum sampling depth (m)	150	1000	200	350	5000
Average surface sampled (NM^2)	10 000	11 000	25 131	60 000	106 131
Mean sampling coverage	12%	13%	7%	10%	10%
Mean number of fishing stations	50	45	60 before 2007 115 after 2007	45	255
Mean number of fishing stations per surveyed NM	0,04	0,03	0.03 before 2007 0.06 after 2007	0,01	0,04
Mean number of hydrological stations	125	110	104	88	427

2.1.2.2 Stock containment and survey timing

The timing and spatial coverage of each spring survey component has been defined to achieve stock containment of target species at the mesoscale of the survey components (and stocks, Annex 2).

At the larger scale of the combined spring surveys, individual survey timings are coordinated within WGACEGG to ensure a quasi-synoptic sampling of the European continental shelf from Gibraltar to Brest every year in spring (Table I.1). The PELGAS survey has generally been conducted in May since 2003. The PELACUS survey has started at least one month before the PELGAS survey since 2003 on account of vessel availability. The PELAGO survey has started at least one month before the PELGAS survey from 2003 to 2010, and has been conducted at the same time as the PELGAS survey since 2011. The WESPAS survey has been conducted in June–July since 2016.

Despite attempts to achieve coordinated timing of the different surveys, their ability to capture the same ecological period may vary based on annual variations in seasonality. The timing of the late winter warming and phytoplankton blooms over the large latitudinal gradient, determine whether the respective spring survey components capture late winter or early spring ecological conditions (Huret *et al*., 2018). Lags in the timing of the different survey components can compromise the synopticity of the coverage of the acoustic spring surveys, depending on species migrations and spawning timing. This potential lack of synchronicity at the larger scale does not impact the assessment of target species, which are defined at the mesoscale, where stock containment remains effective.

Table 2.4 summarizes the available information on the adequacy of survey components to capture species distribution patterns in a synoptic way at the joint spring survey large-scale.

Atlantic mackerel and horse mackerel adults are known to undergo a spawning migration from southern Portugal, to north of the British Isles, and then to the Norwegian Sea, from May to August (Iversen *et al.*, 2002; Petitgas, 2010). Blue whiting is thought to migrate from spawning areas west of the British Isles to feeding areas in the Bay of Biscay (Petitgas, 2010) at the time of joint spring survey. Spatial patterns on grid maps of large adult Atlantic mackerel (> 30 cm) and horse mackerel (> 35 cm), produced by merging PELACUS, PELGAS and WESPAS data, might therefore be affected by large-scale migrations occurring during the surveys. However, given the extension of the WESPAS survey to 60°N, geographical coverage is considered good for horse mackerel. Temporal alignment between consecutive surveys running from south to north could be improved. Similarly, PELACUS might not capture the actual spring component and full spawning activity of the anchovy population in the Cantabrian Sea if the survey is performed under winter conditions. However, this survey is conducted around sardine and mackerel peak spawning times. To the group's best knowledge, grid maps produced by WGACEGG based on the joint spring surveys, provide a reasonably synoptical view of the large-scale spring distribution of herring, sprat, blue whiting, boarfish, horse mackerel north of 48°N, sardine, anchovy (except sometimes in the Cantabrian Sea), and chub mackerel (Table 2.4).

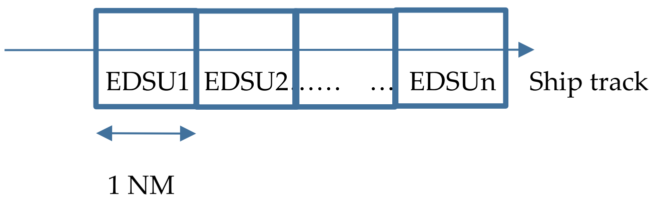

Figure 2.2. Graphical representation of the Acoustic EDSUs. NM: nautical mile.

Table 2.4. Survey timings and small pelagic populations. NA: species not sampled; Synoptic: survey components provide synoptic coverage; *: non synoptic coverage for some stock components and/or lack of biological information.

Species / survey components	PELAGO	PELACUS	PELGAS	WESPAS
Anchovy	Synoptic	*	Synoptic	NA
Atlantic Mackerel	NA	*	*	*
Blue whiting	NA	Synoptic	Synoptic	Synoptic
Boarfish	NA	Synoptic	Synoptic	Synoptic
Chub mackerel	Synoptic	Synoptic	Synoptic	NA
Herring	NA	NA	Synoptic	Synoptic
Horse mackerel	Synoptic	*	*	Synoptic
Sardine	Synoptic	Synoptic	Synoptic	NA
Sprat	NA	NA	Synoptic	Synoptic

2.1.3 Sampling procedure

2.1.3.1 Acoustic sampling

As stated previously, acoustic records are collected using standardized sampling methods. Details on acoustic sampling are summarized in Table 2.5.

The acoustic equipment used during PELAGO surveys used to be a Simrad EK500 echosounder, which was replaced in 2017 by a Simrad EK60. PELACUS and PELGAS surveys were conducted on the same vessel until 2012 (i.e. RV Thalassa II) and used the same equipment. Since then, PELACUS surveys have switched to the RV Miguel Oliver, and use a Simrad EK60 echosounder, whereas for PELGAS surveys the Simrad EK60 echosounder on-board of the RV Thalassa II was replaced by an EK80 in 2017. A Simrad EK60 echosounder is used during WESPAS surveys.

The reference frequency used by all surveys is 38 kHz with 2000 W power. Ping rate on WESPAS surveys is fixed at 2 pings per second to ensure a uniform linear acoustic sampling effort at varying water depths (20–350 m). During the other spring surveys, the ping rate is set at the maximum possible value for the given seabed depth, to avoid false bottom echoes. Ping rate is set manually during PELAGO and PELACUS surveys, whereas it is controlled by the HERMES software on PELGAS surveys. Outside the continental shelf, all surveys set the ping rate manually at the maximum rate that avoids false bottom echoes. Pulse length is set at 1.024 ms on all surveys. Recorded range varies according to depth. On PELAGO surveys the recorded range is set at 500 m, and extended to 1000 m once the former depth is reached; on PELACUS surveys it ranges from 250 m to 1000 m in the same way; whereas on PELGAS surveys the range is controlled by HERMES, and varies according to depth from 20 to 250 m. The maximum range for WESPAS surveys is set to 350 m. In addition to the reference frequency used for stock assessments (38 kHz), all surveys use other frequencies: 120 kHz during PELAGO surveys; 18, 70, 120 and 200 kHz during PELACUS surveys; 18, 120, and 200 kHz during WESPAS surveys; and 18, 70, 120, 200 and 333 kHz during PELGAS surveys.

All transducers are calibrated every year, before each survey, using standard spheres calibration (Demer *et al.*, 2015).

Table 2.5. Acoustic sampling during joint spring surveys (PELAGO, PELACUS PELGAS, and WESPAS).

Survey component	PELAGO	PELACUS	PELGAS	WESPAS
Echosounder settings (per vessel)				
Echosounder(s)	Until 2016: EK500. Since 2017: EK60	Vertical EK60	Vertical EK80, ME70 multibeam sounder, and lateral echosounders on RV Thalassa II	EK60
Frequency	Until 2019: 38 and 120 kHz Since 2020: 18, 38, 70, 120, and 200 kHz	18, 38, 70, 120, and 200 kHz	EK80: 18, 38, 70, 120, 200, and 333 kHz (vertical); 200 kHz (lateral) ME70: 70–120 kHz	18, 38, 120, and 200 kHz
Primary frequency for biomass assessment	38 kHz	38 kHz	38 kHz	38 kHz
Transducer installation	Until 2019: hull mounted, downward-facing Since 2020: drop keel, downward-facing	hull mounted, downward-facing	hull mounted, downward- and starboard facing	Drop keel, downward-facing
Transducer depth (m)	Until 2019: 4.5 Since 2020: 5.7	5.7	6.14	8.8
Upper integration limits (m)	3 to 10	10	10 to 20	12
Pulse length (ms)	1,024	1,024	1,024	1,024
Transmit power	2000 W (38 kHz)	2000 W (38 kHz)	2000 W (38 kHz)	2000 W (38 kHz)
Angle sensitivity (°)	7	depending on calibration, around 7	7	7
Maximum range (m)	1000	1000	250	350
Operating software	Simrad EK60	Simrad EK60	Simrad EK80 and Hermes	Simrad ER60

Table 2.5 (continued)	PELAGO	PELACUS	PELGAS	WESPAS
Post processing software	Movies+	Echoview	Movies3D	Echoview
Ping rate (no. of pings per second)	Ping rate set automatically at maximum, depending on the recorded range, sometimes changed to fixed interval to avoid false bottom echoes	Ping rate set automatically at maximum, depending on the recorded range, sometimes changed to fixed interval to avoid false bottom echoes	Ping rate set automatically using the Hermes software over the shelf, as a function of seabed depth to avoid false bottom echoes; manual max ping rate outside the shelf to avoid false bottom (4 to 5 pings per second)	2
Calibration	Sphere calibration prior to the survey (Demer *et al.* (2015)	One standard sphere calibration (Demer *et al.*, 2015), before each survey or when possible during the survey	One sphere calibration (Demer *et al.*, 2015), before or after each survey	Sphere calibration prior to the survey (Demer *et al.* (2015)
References	Massé *et al.* (2018)	Massé *et al.* (2018)	Doray *et al.* (2014, 2018)	O'Donnell *et al.* (2016, 2018)

Table 2.6. Summary of the main characteristic of the trawls used for the joint spring acoustic surveys.

Survey component	PELAGO	PELACUS	PELGAS	WESPAS
Fishing gears				
Type	RV Noruega: pelagic gear 10 m vertical opening; bottom gear 3 m vertical opening. RV Miguel Oliver: 2 pelagic polyice doors 4.5 m². 63.5/51 Pelagic and Gloria 352 pelagic trawls	RV Thalassa II: 2 doors, headline: 76 m footrope: 70 m (or 57 m x 52 m at depths below 50 m) pelagic trawls. RV Miguel Oliver 2 pelagic polyice doors 4.5 m². 63.5/51 Pelagic and Gloria 352 pelagic trawls	RV Thalassa II: 2 doors, headline: 76 m footrope: 70 m (or 57 m x 52 m at depths below 50 m) pelagic trawls.	Single pelagic midwater trawl.

Table 2.6 (continued)	PELAGO	PELACUS	PELGAS	WESPAS
Circumference (m)		RV Thalassa II: 146 or 109 m Miguel Oliver: 86 or 78 m	RV Thalassa II: 146 or 109 m Commercial fishers: pair trawls: ~430 m	422 m
Vertical opening (m)	RV Noruega - pelagic trawl: 10 m, and bottom trawl: 3 m RV Miguel Oliver: 22–16 m	RV Thalassa II: 18 m (large trawl) -15 m (small trawl) RV Miguel Oliver: 22–16 m	RV Thalassa II: 18 m (large trawl) -15 m (small trawl) Commercial fishers: pair trawls, ~30 m	25 m
Typical towing speed (kn)	4	4.2	4	4
Typical fishing operation duration (min)	20	20	30	30
Mesh size in codend (mm)	20	20	20	20
Net monitoring system	RV Noruega: SCANMAR net sounder trawl-eye and a depth sensor. RV Miguel Oliver: Simrad fs20/25+ MARPORT wireless door sensors and TE (trawl speed sounder)	RV Miguel Oliver: Simrad fs20/25+ MARPORT wireless door sensors and TE (trawl speed sounder)	MARPORT wireless net sounder	Simrad FS70 net sonde, SCANMAR/Marport catch and distance sensors
Rationale for identification hauls				
Numerous fish echotraces within 2–3 nautical miles	Yes	Yes	Yes	Yes
Changes in echotraces characteristics	Yes	Yes	Yes	Yes
Echotrace not fished on this transect	Yes	Yes	Yes	Yes

2.1.3.2 Biological sampling

2.1.3.2.1 Fishing gear

Biological sampling is used to assess the species and length composition of echotraces (see Section 1). Because the main target species of the survey are pelagic species, all vessels use midwater trawls, the characteristics of which are described in Table 2.6.

During PELGAS surveys, commercial pairtrawlers work with Thalassa and use a 115 m headrope pelagic trawl. A bottom trawl is also used during the PELAGO survey when target schools are very close to the seabed.

Fishing operations are performed following the rationale presented in Section 1 and Table 2.6. Trawl geometry is monitored using acoustic sensors (door spread) and a netsonde is used to assess vertical opening and fishing efficiency in real time. The vertical opening of the pelagic trawls ranges from about 10 m (PELAGO) to 25 m (WESPAS). The vertical opening of the bottom trawl used during PELAGO (the only survey using bottom trawl gear) is approximately 3 m.

2.1.3.2.2 Catch processing

The catch of the trawl haul is subsampled and sorted by species to calculate relative species composition. In recent years, the most abundant species caught by both Portuguese and French surveys are sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*), whereas the Spanish survey (PELACUS) observed a dominance of mackerel (*Scomber scombrus*). Main species in WESPAS catch include herring (*Clupea harengus*), sprat (*Spratus spratus*), boarfish (*Capros aper*), and horse mackerel (*Trachurus trachurus*).

Sampling levels per target species and surveys are presented in Table 2.7. Catch subsampling strategies are summarized in Table 2.8.

Table 2.7. Sampling levels for target species by survey. L: length; W: weight; O: otoliths; M: maturity; G: gender; NA: species absent in survey area.

Species	PELAGO	PELACUS	PELGAS	WESPAS
Catch processing				
Anchovy	LWOMG	LWOMG	LWOMG	LW
Blue whiting	LW	LWOMG	LW	LW
Boarfish	LW	L	LW	LWOMG
Chub mackerel	LWOMG	LWOMG	LW	NA
Herring	NA	LWOMG	LW	LWOMG
Horse mackerel	LWOMG	LWOMG	LW	LWOMG
Atlantic mackerel	LWOMG	LWOMG	LW	LW
Sardine	LWOMG	LWOMG	LWOMG	LW
Sprat	NA	LWOMG	LW	LWOMG

Table 2.8. Spring surveys: catch subsampling strategies for length measurements and otolith reading.

		PELAGO	PELACUS	PELGAS	WESPAS
Length measurments					
	Catch subsampling strategy	100 individuals subsampled per haul and species	Species subsampled until a stable length frequency is achieved	100 individuals subsampled per haul and species. Fewer individuals if clear length mode obtained	Species subsampled until clear length–frequency profile is achieved.
	Species	All species in the catch	All species in the catch	All species in the catch	All species in the catch
Otolith reading					
	Catch subsampling strategy	Selection of 10 individuals per size class from subsamples until maximum of 10 otoliths by size class in each geographic area: 9a Central North (CN), 9a Central South (CS), 9a algarve (SA), 9a Gulf of Cadiz (SC)	Random sample of 40 indiviuals. For target species (e.g. sardine, anchovy, or mackerel) additional samples to fill gaps in length distribution	Selection of 40 individuals over size range from subsamples	Random sample of 100 individuals
	Species	Sardine, anchovy, chub mackerel, mackerel, and horse mackerel	Sardine, anchovy, chub mackerel, mackerel, blue whiting, horse mackerel, and hake	Anchovy and sardine	Herring, boarfish, and horse mackerel

2.1.3.2.3 Length measurements

Length measurements are collected for all species. Clupeiforms (sardine, anchovy, sprat, herring) are usually measured within 0.5 cm length classes, whereas other species are measured within 1 cm length classes.

Micronekton organisms (e.g. swimming crabs and jellyfish) are counted and measured during PELGAS surveys (Doray *et al.* 2018) to get insights into the composition of the Sound Scattering Layers. For the same reason, the rest of the catch is also weighed and counted during PELACUS surveys.

2.1.3.2.4 Maturity analysis

Maturity analysis consists of determining the sex of fish, and the macroscopic stage of development of the gonads. For sardine and anchovy, PELGAS and PELACUS surveys use the 6-stage scale developed by the ICES Workshop on Small Pelagics (*Sardina pilchardus*, *Engraulis encrasicolus*) maturity stages (WKSPMAT; ICES, 2008). PELAGO surveys use a specific scale, where stages 4 and 6 are merged to have a unique scale for partial prespawning and partial post-spawning (Table 2.9).

Maturity analysis are performed for mackerel, horse mackerel, and chub mackerel during PELAGO and PELACUS surveys. Blue whiting maturity is only assessed during PELACUS surveys. Maturity analysis is performed for anchovy and sardine during PELGAS surveys, and for boarfish, herring, sprat, and horse mackerel during WESPAS surveys (Table 2.9).

2.1.3.2.5 Age sampling

Fish age determination is performed by reading annual rings (annuli) on whole otoliths (sagitae) of species listed in Table 2.7. After extraction, otoliths are cleaned, and read either in water or embedded in resin, with direct lighting from above, and against a dark background. During PELGAS surveys, otoliths are embedded in resin on black plaques, and age determination is conducted on-board. During PELAGO surveys, otoliths are stocked in Eppendorf tubes and the age reading is done after the survey. During PELACUS surveys, otoliths of all species are embedded in resin on a black plaque, except for the otoliths of horse mackerel and blue whiting which are stored in Eppendorf tubes. Age reading is performed after the survey. During WESPAS surveys, all herring are aged on-board, whereas horse mackerel and boarfish are aged post survey in the laboratory.

Table 2.9. Details of maturity analysis performed and reference of scale during spring surveys. No: not performed. NA: species not present in survey area.

Common name	PELAGO	PELACUS	PELGAS	WESPAS
Herring	NA	NA	No	ICES (2008)
Sprat	NA	NA	No	ICES (2008)
Blue whiting	No	ICES (1990); six-stage scale	No	No
Boarfish	No	No	No	Farrel et al., 2012
Mackerel	ICES (1990)	ICES (1990); six-stage scale	No	ICES (1990); six-stage scale
Horse mackerel	ICES (1990)	ICES (1990); six-stage scale	No	ICES (1990); six-stage scale
Sardine	Afonso-Dias *et al.* (2007)	ICES (2008)	ICES (2008)	ICES (2008)
Anchovy	Afonso-Dias *et al.* (2007)	ICES (2008)	ICES (2008)	ICES (2008)
Chub mackerel	ICES (1990)	ICES (1990); six-stage scale	No	NA
Mediterranean horse mackerel	ICES (1990)	ICES (1990); six-stage scale	No	NA
Bogue	No	No	No	NA
Round sardinella	No	NA	NA	NA

Table 2.10. Hydrographic and plankton data collected during joint spring acoustic surveys. NA: parameter is not collected.

Survey component	PELAGO	PELACUS	PELGAS	WESPAS
No. of stations	125	110	80	80
Sampling nets	Bongo60 WP2	WP2 nets (70 cm diameter, 500 μm mesh; 35 cm diameter, 200 μm mesh) Sample from bottles taken at different depths	3 WP2 nets (57 cm diameter, 200 μm mesh) fitted in a single frame, equipped with a Hydrobios (back-run stop) mechanical flowmeter. Further, a “filet Carré” (Bourriau, 1991) fitted with 315 or 500 μm mesh nets, and a 315 μm mesh-size Multinet (Hydrobios) fitted with 5 nets were also adaptively and opportunistically deployed. 9 Niskin bottles for phytoplankton	WP2 nets (57 cm diameter, 200 μm mesh) fitted in a single frame, equipped with a Hydrobios mechanical flowmeter.
Mesh size (μm)	50 to 500	315	315	200
Sampling depth (m)	200	200	200	100
No. of stations	125	110	80	80–90
Hull mounted thermosalinometer	A hull-mounted Seabird SBE21 thermosalinometer	A hull-mounted Seabird SBE21 thermosalinometer, fitted with temperature, salinity and fluorescence sensors records surface hydrological conditions at a 30 seconds interval during the survey.	Before 2018: Hull-mounted Seabird SBE21 thermosalinometer Since 2018: Hull-mounted Seabird SBE21 thermosalinometer and Ferry box	Hull-mounted Seabird SBE21 thermosalinometer
Hull mounted sensors	Temperature and salinity	Temperature, salinity, and fluorescence	Before 2018: Temperature, salinity, and fluorescence Since 2018: Temperature, salinity, oxygen, and blue, green, and red algae	Before 2016: Temperature, salinity, and fluorescence Since 2016: Temperature, salinity, and oxygen

Table 2.10 (continued)

Survey component	PELAGO	PELACUS	PELGAS	WESPAS
CTD unit	Seabird SBE21, SBE19, RBR, Valeport	Seabird SBE19	Seabird SBE19	Seabird SBE19
Standard sampling depth (m)	200	200	200	200
CTD sensors	Fluorometer	Fluorometer, turbidimeter, oxygen sensor, and 6 Niskin bottles	Fluorometer, turbidimeter, oxygen sensor, and Laser Optical Particle Counter (LOPC, Herman, 2004)	Fluorometer, turbidimeter, and oxygen sensor
Fish egg sampling tool	CUFES system mounted with a 335 µm mesh collector and providing pumped surface (3 m depth) seawater at an average rate of 600 l min^{-1}.	CUFES system mounted with a 315 µm mesh collector and providing pumped surface (5 m depth) seawater at an average rate of 630 l min^{-1}.	CUFES system mounted with a 315 µm mesh collector and providing pumped surface (5 m depth) seawater at an average rate of 570 l min^{-1}.	NA
Fish egg sampling strategy	During daytime, a CUFES sample is collected every 3 nautical miles during acoustic sampling	During daytime, a CUFES sample is collected every 3 nautical miles (i.e. every ~ 18 min) during acoustic sampling	During daytime, a CUFES sample is collected every 3 nautical miles (i.e. every ~ 18 min) during acoustic sampling	NA

2.1.3.3 Hydrobiological sampling

2.1.3.3.1 Hydrographic data

Hydrographic data (at least temperature, salinity, and fluorescence) are measured by CTD casts (Table 2.10). All vessels perform at least ~ 80 casts along the surveyed area to depths of 100–200 m. Most vessels are equipped with hull-mounted thermosalinographs that record continuous subsurface (5 m depth) data on temperature, salinity and fluorescence. With advances in sampling equipment and increasing applications of oceanographic data for ecosystem monitoring, such as in the Marine Strategy Framework Directive (MSFD), more parameters are being collected along the vessel track (e.g. microplastics).

2.1.3.3.2 Plankton sampling

The standard equipment used for phytoplankton sampling are Niskin bottles. Generally, water samples are collected at several depths in order to measure chlorophyll-a concentration, and, in some cases, nutrient concentrations. Samples are normally collected from a subset of the CTD casts stations during each survey.

The standard equipment employed for zooplankton sampling is the WP2 net, with a 200 µm mesh size and a 50–100 cm aperture (Table 2.10). The net is hauled vertically from 100 or 200 m, or from the bottom to the surface, at a speed of 0.5 m s^{-1}.

Samples are divided in two. One-half is dried for 24 h at 70°C before weighing. Weighing of samples is carried out in a laboratory on land as a consequence of the size of the samples and the sensitivity of the scales used. The other half of the sample is fixed and buffered in 4% formaldehyde and seawater for later analyses (species determination, length measurements and abundance estimation). ZooScan (laboratory) or ZooCam (on-board) processing is carried out during PELGAS surveys, along with image analysis and a semi-automatated classification of major taxons (mesozooplankton and fish eggs).

2.1.3.3.3 Ichthyoplankton sampling

During some surveys, additional plankton sampling is performed to collect eggs of the main pelagic target species (anchovy and sardine). Typically, continuous fish egg samplers such as CUFES (Checkley *et al.*, 1997) are used to filter water at ~ 5 m depth along the survey (Table 2.10), and eggs are counted and staged using a microscope (on-board) or after image analysis through ZooCam processing.

2.1.3.3.4 Other

Other types of plankton sampling are also conducted during several surveys to study the regional ecology and improve understanding of mechanistic processed. During the last 4–5 years this has included surface plankton hauls to measure the abundance and spatial distribution of microplastics (Table 2.10).

2.1.3.4 Megafauna sampling

Dedicated marine mammal and bird observers take part in the three acoustic spring surveys and the summer WESPAS survey to study the distribution and abundance of megafauna (cetaceans and seabirds). Observers collect information on the presence, species, number, and behaviour of all individuals sighted during daytime. Data on macro-litter (larger than 30 cm), large pelagic fish (sharks, sunfish, swordfish, and tuna), turtles, and boats (fishing, sailing, and commercial) are also collected.

Megafauna sightings have been performed since 2003 during PELGAS and PELACUS surveys, since 2005 during PELAGO surveys, and since 2016 during WESPAS surveys. Due to the capacity of each vessel, the number of observers on-board varies from one survey to another: three observers during PELGAS and PELACUS surveys, one during PELAGO surveys, and four (two seabird and two marine mammal specialists) during WESPAS surveys.

For more information on survey specific protocols, see Doray *et al.* (2014) for PELGAS, PELACUS, and PELAGO surveys, and O'Donnell *et al.* (2018) for WESPAS surveys.

2.1.3.5 Vessel intercalibration

Vessel intercalibration exercises involve a comparison of the sampling performances between different vessels. They are necessary for understanding the impact of, for example, changing research vessels during a survey time-series; or for enabling the comparison of results between the coordinated (spring) surveys. For example, when PELACUS switched from RV Thalassa to RV Miguel Oliver in 2013, an intercalibration exercise was conducted to assess potential intership differences in the acoustic, CUFES, and fishing data collected by both vessels. Inter-ship variability was compared to intra-ship variability in order to assess the vessel effect. Details on this experiment can be found in Carrera (2015). As intra- and inter-ship variability were within the same order, it was assumed that the PELACUS time-series would not be affected by switching from RV Thalassa to RV Miguel Oliver.

2.1.4 Biomass estimation procedure

2.1.4.1 Echogram scrutiny

Echograms are scrutinised manually in 1 nautical mile EDSUs and involves (Korneliussen *et al.*, 2018):

- exclusion of unwanted areas (e.g. transit between transects or trawl stations) and removal of non-biological backscatter (e.g. bottom echoes and noise spikes); and
- identification and selection of regions with similar echotraces (echotypes).

Expert echogram scrutinizing is performed using various software packages (Movies+/3D, Echoview), and considers differences in echotrace characteristics (e.g. morphology and relative frequency response) and the data from identification hauls (Table 2.11).

Biomass estimates are derived from acoustic data collected at the 38 kHz frequency for all surveys. The echo-integration threshold varies from 70 dB (PELACUS and WESPAS surveys) to −60 dB (PELAGO and PELGAS surveys). Acoustic schools are extracted during scrutiny for PELAGO and PELACUS surveys.

2.1.4.2 Target strengths

Species-specific TS to length relationships used for spring surveys are presented in Table 2.12.

2.1.4.3 Biomass estimation

Biomass estimation, based on acoustic and fishing data, is performed using the methodology and equations presented in Section 1. In-house spreadsheets (PELAGO and PELACUS surveys), StoX package (WESPAS survey), or EchoR package (PELGAS survey) are used to perform calculations (Table 2.13).

Table 2.11. Spring surveys echogram scrutiny protocols and target strengths.

Survey component			PELAGO	PELACUS	PELGAS	WESPAS
Acoustic data processing software			Movies+	Echoview	Movies3D	Echoview
Echogram scrutiny						
	Scrutinised frequencies (kHz), (*) frequencies used for biomass estimation		**38*** and 120	18, **38***, 70, and 120	EK80: **38***, 120 ME70: 120	18, **38***, 120, and 200
	Echo-integration threshold (dB)		–60	–70	–60	–70
	Echo-integration layer width (m)		3–10	None	10	None
	EDSU length (nautical miles)		1	1	1	1
	Scrutinisation methodology					
		Manual allocation	Yes	Yes	Yes	Yes
		Multifrequency tools		Yes	Yes	
		Layer/school/region echo-integration	Layer / school	Region / school	Layer	Region
	TS - length equations		See Table 2.12			
TS						
	Length indicator used in the TS-length equation		Mean length per species and size category	Whole length distribution according to ICES (1975, 1977) method	Mean length per species and size category (unimodal length categories)	Mean length per species and size category

Table 2.12. Species-specific target strength (TS) to length (L) relationships ($TS = 20 \log L + b_{20}$) used for spring surveys.

SPECIES	PELAGO		PELACUS		PELGAS		WESPAS	
	b_{20}	Reference	b_{20}	Reference	b_{20}	Reference	b_{20}	Reference
Anchovy	−72.6	Degnbol *et al.* (1985)	−72.6	Degnbol *et al.* (1985)	−71.2	ICES (1982)	−71.2	ICES (1982)
Atlantic mackerel	−84.9	ICES (1984)	−84.9	ICES (1984, 2002)	−86	Misund and Betelstad (1996)	−86	Misund and Betelstad (1996)
Blue whiting	−65.2	Pedersen *et al*. (2011)	−65.2	Pedersen *et al*. (2011)	−67	Foote (1987)	−65.2	Pedersen *et al*. (2011)
Boarfish	−66.2	Fässler *et al*. (2012)	−66.2	Fässler *et al*. (2013)	−67	Foote (1987)	−66.2	Fässler *et al*. (2013)
Chub mackerel	−68.7	Lillo *et al*. (1996)	−68.7	Lillo *et al*. (1996)	−70	Guttierez and MacLennan (1998)	–	–
Hake	–	–	−67.5	Foote *et al*. (1986); Foote (1987)	−67	Foote (1987)	−67	Foote (1987)
Herring	–	–	–	–	−71.2	ICES (1982)	−71.2	ICES (1982)
Horse mackerel	−68.7	Lillo *et al*. (1996)	−68.7	Lillo *et al*. (1996)	−68.7	Lillo *et al*. (1996)	−68.7	Lillo *et al*. (1996)
Mediterranean horse mackerel	−68.7	Lillo *et al*. (1996)	–	–	−68.7	Lillo *et al*. (1996)	−68.7	Lillo *et al*. (1996)
Physoclists	–	–	–	–	−67	Foote (1987)	−67	Foote (1987)
Sardine	−72.6	Degnbol *et al*. (1985)	−72.6	Degnbol *et al*. (1985)	−71.2	ICES (1982)	−71.2	ICES (1982)
Sprat	–	–	–	–	−71.2	ICES (1982)	−71.2	ICES (1982)

Table 2.13. Summary of spring surveys acoustic biomass estimation procedures. NA: not available.

Survey component		PELAGO	PELACUS	PELGAS	WESPAS
Biomass estimation procedure					
Software		Spreadsheet	Spreadsheet	EchoR R package	StoX package
Biomass and abundance per species	**EDSU**	Yes	Yes	Yes	Yes
	Post stratification regions (Mean no. [min–max])	NA	Sardine: 5 [4–8] Mackerel: 3 [2–5]	0–30 m depth layer: 3 [2–5] > 30 m depth layer: 6 [4–10]	
Biomass and abundance-at-length per species	**EDSU**	Yes	Yes	Yes	Yes
	Post-stratification regions (Mean no. [min–max])	NA	Sardine: 5 [4–8] Mackerel: 3 [2–5]	NA	NA
Biomass and abundance-at-age per echotype and EDSUs	**EDSU**	Yes	NA	Yes	Yes
	Post-stratification regions (Mean no. [min–max])	NA	Yes	0–30 m depth layer: 3 [2–5] > 30 m depth layer: 6 [4–10]	7 [5–8]
Estimation error derivation	**Post-stratification regions (Mean no. [min–max])**		Partial (geostatistics)	0–30 m depth layer: 3 [2–5] > 30 m depth layer: 6 [4–10]	7 [5–8]
References		Massé *et al.* (2018)	Massé *et al.* (2018)	Doray *et al.* (2010, 2013)	ICES (2015)

Biomass is estimated at the EDSU level (PELAGO and PELGAS surveys) for mapping purposes, and/or by averaging acoustic and fishing data over larger post-stratification regions (PELAGO, PELACUS, PELGAS, and WESPAS surveys). The PELACUS survey provides NASC values per species, and EDSU for mapping purposes. Estimation errors are derived at the post-stratification region level using product variance (PELGAS and WESPAS surveys), bootstrap (WESPAS survey) or geostatistics (PELACUS survey; see Section 1 for details). No estimation error is calculated for biomass indices derived from the PELAGO survey.

2.1.5 Data storage

Acoustic data from the PELAGO survey are stored in the IPMA Data Collection Framework (DCF) database. Megafauna data are stored in the "SPEA" database.

For the PELACUS survey, acoustic and CTD raw data are stored at the IEO oceanographic data center.

For the PELGAS survey, preprocessed acoustic and fishing data, as well as results from biomass estimates and gridded maps are stored as .csv files in the dedicated national database EchoBase[1]. The raw acoustic and CTD data are stored in the French national oceanographic data center SISMER[2]. Various PELGAS gridded maps and datasets of indices have been published (Huret *et al.*, 2016; Doray *et al.*, 2018b, 2018c, 2019). NASC values per EDSU and biological data from the PELGAS series are in the process of being uploaded to the ICES acoustic-trawl database[3]. PELGAS mesozoo- and ichtyo-plankton images are stored online on Ecotaxa (Picheral *et al.*, 2016), a web application dedicated to the visual exploration and the taxonomic annotation of plankton images. Megafauna sighting data are deposited in the OBIS SEAMAP database[4] (Doray *et al.*, 2018c).

For the WESPAS survey, biological and aggregated acoustic data are submitted to the ICES acoustic-trawl database, and are available as open access download files. Hydrographic data, once quality controlled, are uploaded to the ICES oceanographic portal[5], and available as open access downloads. Compiled survey data, in the form of individual survey reports, are available for download on the Marine Institute online repository[6].

One of the objectives of WGACEGG is to produce grid maps and dataseries indices by merging spring acoustic surveys annual datasets. These dataseries are currently stored as flat .csv files, but the future aim is to store them in a database (EchoBase for instance) connected to the ICES acoustic-trawl database.

2.1.6 Data quality checks and validation

Data quality control (QC) checks and validations are performed for all spring surveys.

Echosounders are calibrated before or after each survey using a standard procedure (Demer *et al.* 2015). Standard quality criteria to check calibration results include RMS (square root of the mean of the squares) and consistency with previous calibration results (e.g. Transducer Gain and S_A correction). Other QC on acoustic data are performed during echogram cleaning and scrutiny. Noise and any other non-fish echotraces are removed from the echogram either

[1] http://echobase.codelutin.com/v/latest/en/

[2] http://www.ifremer.fr/sismer/index_EN.htm

[3] https://ices.dk/data/data-portals/Pages/acoustic.aspx

[4] http://seamap.env.duke.edu/dataset/1403

[5] https://ocean.ices.dk/HydChem/HydChem.aspx?plot=yes

[6] https://oar.marine.ie/discover

manually or using a semi-automated procedures. For the PELGAS survey, echogram scrutiny has been intercalibrated for three years to ensure consistent results. For the PELACUS survey, scrutiny is done manually by experienced acousticians, and is standardized by using virtual echograms. In addition, taylor-made routines are used to check internal consistency.

Finally, QC is also carried out on the biomass estimation, using taylor-made routines to check for internal consistency in spring survey data (mean weight, total abundance vs. sum of at-length abundances, comparison of mean weights, etc…).

Biological data are checked during (subsamples and observers/samplers training) and after collection (WLR, missing data, ouliers) to ensure consistency. Biological data QC is generally performed using R scripts (e.g. EchoR package) for spring surveys. Internal and international intercalibration of age readers is a common practice during spring surveys for biological parameters QC.

Megafauna data are checked during and after collection for consistency. Observers operate in shifts to limit the effects of fatigue, and validation of observations by other experts is common practice.

Instruments used to record environmental data require calibrations to ensure correct functioning. For the PELAGO survey, CTD and CT sensors are calibrated every two years, whereas for the PELGAS survey sensors are checked annually. Environmental data are also checked during collection by means of visual inspection and real time displays. During the PELAGO survey, the consistency of environmental data is ensured by comparing the values of the same parameters collected with different instruments, whereas standard consistency tests are performed by Sismer on PELGAS data.

Survey metadata are collected using specific softwares (e.g. TECHSAS/CASINO+ software suite[7]). The R language is used to perform a survey metadata consistency check for both PELAGO and PELGAS surveys.

Details on QC procedures used in joint spring acoustic surveys can be found in Annex 3.

2.1.7 Reporting

Survey results are reported annually to WGACEGG by means of standard survey summary sheets (Annex 6). The main deliverables, or WGACEGG products, from these surveys are: large-scale grid maps of both NASC per species and oceanographic variables [sea surface temperature (SST), and sea surface salinity (SSS)]; maps of trawl hauls with species composition; and acoustic estimates of abundance and biomass. Size- and age-based estimates of mean length and weight are provided specifically for anchovy and sardine (Table 2.14).

Spring acoustic surveys provide annual fishery-independent indices on sardine and anchovy to WGHANSA, and on boarfish, blue whiting, horse mackerel and mackerel to WGWIDE (Table 2.14 and Annex 2).

2.1.8 Caveats/limitations and perspectives

The PELAGO, PELACUS, PELGAS and WESPAS surveys aim at providing a synoptic snapshot of the state of small pelagic fish populations (see list in Table 2.1) and ecosystems in ICES Areas 6, 7, 8 and 9.

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[7]https://www.flotteoceanographique.fr/en/Facilities/Shipboard-software/Gestion-de-missions-et-des-donnees/TECHSAS

Table 2.14. Joint spring acoustic surveys reporting. X: reported

		PELAGO	PELACUS	PELGAS	WESPAS
WGACEGG products					
NASC grid maps		X	X	X	X
SST and SSS grid maps		X	X	X	X
Trawl haul species composition maps		X	X	X	X
Size- and age-based acoustic estimates of abundance and biomass		X	X	X	X
Mean length and weight by size and age		X	X	X	X
Cruise report		X	X	X	X
WGACEGG deliverables to other Expert Groups					
Size- and/or age-based acoustic estimates of abundance and biomass					
	WGHANSA	X	X	X	X
	WGWIDE	-	X	X	X

However, as previously discussed, not all these surveys are conducted at the same time, because of operational constraints. Limitations remain related to the mismatch between survey and ecological timings, which have been discussed for a few species of interest (Atlantic and horse mackerel). These limitations are a major caveat in the application of large-scale, multi-vessel, coordinated surveys to fish biomass assessments. However, the importance of combining survey efforts as a means to provide detailed, high resolution data on abundance and distribution over large areas, should not be discounted, especially where no other data source currently exists. Guidelines on survey synopticity provided for each species by WGACEGG should help end users make the best use of the grid maps provided by the group.

The survey sampling schemes have been enriched and optimized over time. Options to further improve ecosystem sampling will include the use of (i) image techniques to process mesozooplankton samples; (ii) broadband echosounders to improve the characterization of micronekton and mesozooplankton sound-scattering layers; and (iii) eDNA analysis to improve the assessment of pelagic diversity. However, sampling activities cannot be extended endlessly without compromising data quality (Shephard *et al.*, 2015). For this reason, survey protocols are regularly evaluated and adapted during WGACEGG meetings (Kupschus *et al.*, 2016). In addition, the automation of sampling will be crucial to improving integrated ecosystem survey sampling without compromising the quality of existing long-term dataseries (Doray *et al.*, 2018c).

The four coordinated spring acoustic surveys provide unique datasets that are merged at the scale of the European Atlantic area during WGACEGG meetings. These large-scale ecosystem datasets inform the EU Common Fisheries Policy (Data Collection Framework; ICES, 2016, 2018) and the EU Marine Strategy Framework Directive, and are used in ICES ecosystem studies (Massé *et al.*, 2018). One limitation to the grid map series produced by WGACEGG is the shortage of statistical methodologies to analyse the variability in space and time of these complex ecological datasets. Multivariate data processing methods (Doray *et al.*, 2018d; Petitgas *et al.*, 2018) are now being tested by WGACEGG to summarize the spatial and temporal patterns of the grid map series though an efficient statistical framework.

2.2 Joint autumn acoustic survey

2.2.1 Background

Autumn is also an important season for the small pelagic fish communities of western European waters (from the Iberian Peninsula to the Celtic Sea). Several pelagic fish species are found across this range, with the species diversity reflecting the latitudinal gradient, which ranges from warmer Lusitanian waters in the south to cooler, boreal waters in the north. Similarly, the gradient of environmental conditions affects the seasonality of pelagic fish life cycle stages.

In the southern end of the study area, three surveys were developed to specifically monitor juvenile anchovy, as an indicator of the abundance of recruits that will enter the adult stock the following year:

i) The IEO-led ECOCADIZ-RECLUTAS survey commenced in 2012 in the Gulf of Cadiz, after a one-off survey in 2009, and provides an estimate of Gulf of Cadiz autumn anchovy biomass and abundance.
ii) The IBERAS survey was started in 2018 by IEO and IPMA north of the Gulf of Cadiz, and covers the shelf waters to the west of the Iberian Peninsula, with the main aim of quantifying sardine recruitment.
iii) The JUVENA survey (Boyra *et al.* 2013, 2016; Massé *et al.* 2018) was initiated by AZTI in 2003, and has been jointly run with IEO from 2011. It is the longest autumn time-series, and estimates juvenile anchovy abundance in the Bay of Biscay and Cantabrian coast. This survey was initiated in response to a succession of low recruitment years which lead to the closure of the fishery from 2005 to 2009.

Two surveys operate in the northern end of the study area:

i) The Marine Institute (Ireland)-led CSHAS has been monitoring the prespawning aggregations of the Celtic Sea herring stock since 2004.

ii) The Cefas-led PELTIC survey started in 2012 as a monitoring programme for all small pelagic fish in the eastern Celtic Sea and English Channel. One of the main PELTIC survey objectives is to map and quantify ICES Area 7 sardine, which spawn in autumn, and which, since 2017, are considered a separate stock from sardine in ICES Area 8. PELTIC fills in the spatial gap left between CSHAS and JUVENA, providing near-synoptic continuous coverage from the Celtic Sea to the Gulf of Cadiz.

The original objectives of some of the autumn surveys focused on a single species. However, under WGACEGG, the remit of all surveys broadened to include all small pelagic fish, as well as other components of the ecosystem, in order to understand the ecological processes operating in the study area, and to assess the health of the ecosystem (Table 2.15).

The surveys are conducted on-board oceanographic research vessels, which vary in length depending on the region (28–74 m; Table 2.16), with the exception of the first years of the JUVENA survey that involved commercial fishing vessels. The ECOCADIZ-RECLUTAS, IBERAS, PELTIC and CSHAS surveys are conducted on single research vessel platforms. The JUVENA survey is performed by two vessels since 2005.

Protocols for the autumn acoustic surveys have been standardized within WGACEGG. Survey protocol details for the different surveys can be found in Boyra *et al.* (2013) and Massé *et al.* (2018) for the ECOCADIZ-RECLUTAS and JUVENA surveys; in Carrera *et al.* (2019) for the IBERAS survey; and in ICES (2015) for the PELTIC and CSHAS surveys.

Table 2.15. Summary table of autumn joint acoustic survey objectives and time frame. (*) Coverage has expanded.

Survey Component	ECOCADIZ-RECLUTAS	IBERAS	JUVENA	PELTIC	CSHAS
Survey objectives	Assess small pelagic fish biomass, with special reference to anchovy and sardine juveniles (age 0 fish), and monitor the pelagic ecosystem in the Gulf of Cadiz	Assess sardine recruitment in Atlantic waters of the Iberian Peninsula, and monitor small pelagic fish and the ecosystem	Assess small pelagic fish biomass, and monitor the pelagic ecosystem in the Bay of Biscay, with emphasis on juvenile anchovy	Assess small pelagic fish biomass and monitor the pelagic ecosystem in the western English Channel and eastern Celtic Sea	Assess small pelagic fish biomass and monitor the pelagic ecosystem in the Celtic Sea
Target fish stock(s) / life stage (s) (stock assessment group)	9a South anchovy and sardine / adults and juveniles (WGHANSA)	9a North, Central North, and Central South sardine / juveniles (WGHANSA)	8a–d anchovy / juveniles (WGHANSA)	7d– f sardine / adults (WGHANSA) 7d and e sprat / adults (HAWG)	7a South, 7g-j herring / adults and juveniles (HAWG);
Other data collected	Adult horse mackerel, mackerel, chub mackerel, boarfish, blue whiting, and hydrology	Anchovy, horse mackerel, boarfish, mackerel, chub mackerel, hydrology, zooplankton, and megafauna	Sardine, horse mackerel, sprat, boarfish, mackerel blue whiting, pearlside, hydrology, phyto- and zooplankton, and megafauna	Anchovy, horse mackerel, mackerel, boarfish, herring, blue whiting, hydrology, phyto- and zooplankton, nutrients, and megafauna	Sprat, anchovy, sardine; hydrology, and megafauna
Month	October	2018: November 2019/2020: September	Before 2007: September/October Since 2007: August/September	October	October
Survey time-series					
Initial year	2012	2018	2003	2012	2003
Periodicity	Annual	Annual	Annual	Annual	Annual
Missing years	2013, and 2017	None	None	None*	None

All autumn acoustic surveys, apart from the IBERAS survey, are co-funded by the European Commission's DCF to provide biomass estimates of herring, sprat, anchovy and sardine to the relevant stock assessment working groups.

Table 2.16. Characteristics of vessels used during autumn joint acoustic surveys. AA: RV Angeles Alvariño; CE: RV Celtic Explorer; CEF: RV Cefas Endeavour; EB: RV Emma Bardán; RM: RV Ramón Margalef.

	JUVENA	ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
Number of vessels	2	1	1	1	1
Vessel(s) name(s)	**Vessel 1 -** Various purse-seiners (2003–2010), RM (2010–2019); AA (since 2019) **Vessel 2 -** EB (since 2006)	EB (2012); RM (since 2014)	CEF	RM (2018 and 2020); AA (2019)	CE
Vessel(s) length(s) (m)	**Vessel 1 -** Various purse-seiners: ~35, RM: 47; AA: 47 **Vessel 2** - EB: 28	EB: 28 RM: 47	74	RM: 47 AA: 47	64
Vessel crew (number)	**Vessel 1 -** Various purse-seiners: ~10; RM: 13; AA: 13 **Vessel 2 -** EB: 8	EB: 8 RM: 13	13	RM: 13 AA: 13	12
Scientific crew (number)	**Vessel 1 -** Various purse-seiners: 2-3; RM: 10; AA: 12 **Vessel 2 -** EB: 3	EB: 6 RM: 10	16	RM: 8–12 AA: 8–12	16

2.2.2 Sampling design

2.2.2.1 Sampling effort and spatial coverage

The five coordinated autumn surveys cover a significant portion of the west European Atlantic continental shelf waters from Gibraltar (36°N) to the south coast of Ireland (52°N; Figure 2.3). All surveys follow predetermined transects according to the general survey sampling strategy described above (see Section 1). Specific survey characteristics can be found in Table 2.15.

The main sampling characteristics are summarized in Table 2.17. The inter-transect distance ranges from 4 (IBERAS and CSHAS surveys) to 15 nautical miles (JUVENA survey) and is adapted to best capture patchiness in small pelagic fish aggregations.

The IBERAS and CSHAS surveys have a random starting point. The cruise track is adjusted based on observations made during the JUVENA and CSHAS surveys (adaptive surveys), to ensure that target species stocks are contained in the survey area (JUVENA survey), or to oversample areas with high fish density (CSHAS survey).

The sampling design described in Table 2.17 allows an exhaustive cover of the autumn distribution of target species (Table 2.15) over the European Atlantic area continental shelf. Biomass and distribution of other species of interest can also be assessed based on survey data, as discussed in the next section.

The mean number of identification hauls per surveyed distance ranges from 0.001 to 0.06

hauls per nautical mile, with the highest coverage achieved by the ECOCADIZ-RECLUTAS survey, which covers a relatively small area, and the JUVENA survey, which benefits from the use of two vessels (Table 2.16).

Each survey covers approximately 100 hydrological stations every year, resulting in a total of about 450 hydrological stations sampled in the European Atlantic area during autumn. The stations are supplemented by continuous subsurface recordings by thermosalinographs, ferrybox systems, and fluorometers.

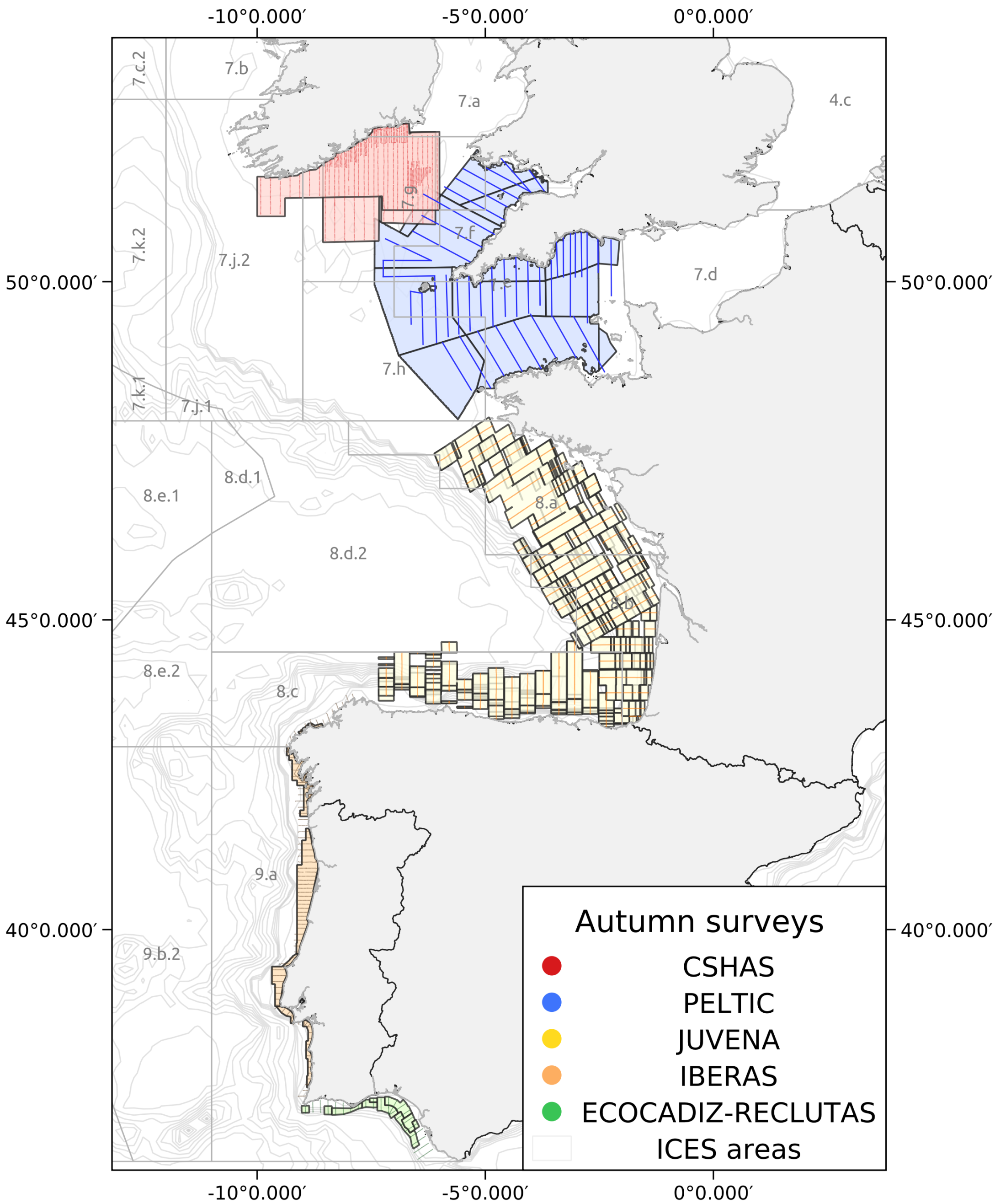

Figure 2.3. Map showing combined coverage of the autumn acoustic surveys in ICES Areas 7, 8, and 9, including transect (colour-coded by survey) and post-stratification regions: ECOCADIZ-RECLUTAS (green), IBERAS (orange), JUVENA (yellow), PELTIC (blue) and CSHAS (red). Please note that PELTIC survey coverage depicted represents the expanded coverage (from 2017).

Table 2.17. Autumn acoustic surveys sampling design. NM: nautical miles.

Survey component	ECOCADIZ-RECLUTAS	IBERAS	JUVENA	PELTIC	CSHAS	Total
Time period	October	September / November	September	October	October	September / October
Average survey duration (days)	20	18	30	28	21	23
Sampling period (day, night, both)	Day	Day	Day	Day	Both	Day/Both
Sampling design (Random / Systematic / Adaptive)	Systematic	Systematic with random start	Systematic/Adaptive	Systematic	Systematic with random start / adaptive	Systematic/Adaptive
Minimum seabed depth (m)	20	15	20	20	20	15–20
Maximum seabed depth (m)	200	125	4000	150	150	125–4000
Inter-transect distance (NM)	8	4–8	15	5–15	4	4–15
Acoustic EDSU length (NM)	1	1	0.1	1	1	0.1–1
Mean linear distance sampled (NM)	320	840	2000	1800	2000	1392
Nominal vessel speed (knots)	10	10	10	10	10	10
Maximum sampling depth (m)	200	125	Before 2017: 200 Since 2017: 450	150	150	125–450
Average surface area sampled (NM^2)	2270	3390	30 000	28 000	20 000	83 660
Mean sampling coverage (%)	14	25	6	6	10	12
Mean no. of fishing hauls	20	20	Before 2007: 60 Since 2007: 110	Before 2017: 25 Since 2017: 40	20	215
Mean no. of fishing stations per surveyed nautical mile	0.06	0.024	Before 2007: 0.03 Since 2007: 0.06	0.025	0.001	0.04
Mean no. of hydrological stations	155	48	104	100	36	443

2.2.2.2 Stock containment and survey timing

The timing and spatial coverage of each autumn survey component has been defined to achieve stock containment of target species at the mesoscale of the survey components (and stocks) for which indices are used in stock assessments (Table 2.15 and Annex 2).

Where possible, the timing of the different autumn surveys is coordinated within WGACEGG to ensure a quasi-synoptic sampling of the European continental shelf from Gibraltar to the Celtic Sea, although this can be affected by logistical aspects, such as vessel availability. The first IBERAS survey in 2018 was conducted in November, but on from 2019 the survey moved to September to coincide better with the presence of juvenile anchovy. The JUVENA survey has consistently taken place in September since 2007 (September/October before 2007), whereas the CSHAS, PELTIC, and ECOCADIZ-RECLUTAS surveys are typically conducted in October.

Table 2.18 summarizes the available information on the adequacy of survey components to capture species distribution patterns in a synoptic way, at the joint autumn survey large-scale.

Table 2.18. Autumn joint acoustic survey timings and small pelagic populations coverage. NA: species not sampled; Synoptic: survey components provide synoptic coverage; Asterisks: non synoptic coverage for some stock components, and/or lack of biological information.

Parameter / survey components	ECOCADIZ-RECLUTAS	IBERAS	JUVENA	PELTIC	CSHAS
Anchovy	Synoptic	Synoptic	Synoptic	Synoptic	Synoptic
Blue whiting	Synoptic	NA	Synoptic	Synoptic	NA
Boarfish	Synoptic	Synoptic	Synoptic	Synoptic	NA
Chub mackerel	Synoptic	Synoptic	NA	NA	NA
Herring	NA	NA	NA	Synoptic	Synoptic
Horse mackerel	Synoptic	Synoptic	Synoptic	**	**
Mackerel	Synoptic	Synoptic	Synoptic	*	*
Sprat	NA	NA	Synoptic	Synoptic	Synoptic
Sardine	***	***	****	Synoptic	Synoptic

*** size dependant: synoptic coverage for fish < 30 cm; ** size dependant: synoptic coverage for fish < 35 cm; *** synoptic for juvenile only; **** some inshore sardine may be missed**

Several species actively migrate during autumn. In the Celtic Sea, in the northern part of the study area, sprat appears to be migrating towards the east into the very shallow waters of the Bristol Channel (beyond the reach of the survey). Therefore, the timing of the PELTIC survey relative to this migration process affects the availability of this species to the survey and, as a consequence, the sprat biomass estimate. While the complementary coverage of the PELTIC and CSHAS surveys should allow for an estimate of sprat biomass in the Celtic Sea, the CSHAS estimates are partially affected by an anticipated reduced availability of sprat near the surface layers at night.

To the north of the survey coverage area, both mackerel and horse mackerel are dominated by 0–group specimens, spawned over spring/summer, which provide a potential recruitment index when combined. The herring population structure in the Celtic Sea is thought to be complex, although the two northern-most surveys appear to provide synoptic coverage. The CSHAS survey captures the autumn spawning component, and the coastal coverage by the PELTIC survey north of Cornish Peninsula provides further information on the recruitment of this species. However, it is thought that other, spring-spawning stocks also contribute to the biomass.

Sardine and anchovy in the northern survey area (ICES Area 7) are thought to be different stocks from those further south (ICES Areas 8 and 9). Sardine is one of the main PELTIC target species, and the survey captures this population well, as evidenced by only few specimens being observed in CSHAS trawl catches. Migration at this time of year appears minimal, with most adult sardine showing similar interannual spawning distributions, and juveniles found throughout the PELTIC survey area, including along the French coast and north of the Cornish Peninsula. Anchovy in ICES Area 7 appears to be migrating from the southern North Sea (Huret *et al.*, 2020) to overwinter in the western English Channel and, increasingly, in the eastern Celtic Sea.

For the JUVENA survey, the assumption of synopticity with the rest of the autumn surveys is considered to be valid for all species present, because of the large distance between areas, the perceived population structures, and the relatively consistent spatial distribution of the species assessed. However, preliminary comparisons with the results of a bottom-trawl survey on the French shelf suggest that some inshore sardine may be missed by this survey in the Bay of Biscay. This is thought to be caused by part of the population being close to the seabed, and thus, not detectable by echosounders.

Due to time constraints, the IBERAS survey focuses primarily on coastal waters, from 15 to 120 m depth, where the main sardine recruitment grounds are located. This survey also provides information on other pelagic fish species found in the same areas in autumn, including horse mackerel (recruits), anchovy, chub mackerel, and mackerel, although their distribution extends beyond the area covered by the IBERAS survey.

In the southernmost waters, the ECOCADIZ-RECLUTAS survey offers good coverage of the Spanish coastal waters of the Gulf, which is one of the main anchovy and sardine recruitment hotspots, and the main source for their respective stock status [anchovy in ICES Area 9a and Iberian-Atlantic sardine in ICES Areas 8c and 9a; see Silva *et al.* (2019) for sardine]. Conversely, the survey does not capture the actual extension of blue whiting, mackerel, horse mackerel, blue jack mackerel, boarfish, snipefish, and pearlside in the Gulf of Cadiz, because either the population, or a component of these species (larger fish), are distributed in the upper slope waters not sampled by the survey.

2.2.3 Sampling procedure

2.2.3.1 Acoustic sampling

2.2.3.1.1 Equipment

Acoustic data are collected using a Simrad EK60 or EK80 scientific echosounder (Table 2.19). Split-beam transducers are mounted on the hull, on the drop keel, or on a pole, mounted on the side of the vessels. When appropriate, additional, side-looking, echosounders are deployed for monitoring the presence of schools close to the surface. The JUVENA survey emphasizes sampling in surface layers, where a large part of juvenile anchovies are distributed. In addition to hull mounted echosounders, which have a surface blind zone extending down to 11.5 m depth, a set of downward-facing, pole-mounted, transducers (38, 120, and 333 kHz) are used during this survey, reducing the surface blind zone to 8 m. A side-looking 200 kHz transducer, also mounted on the pole, is used to check that no juvenile anchovy is present near the sea surface over 7.5 consecutive nautical miles at the offshore end of transects. Transects are ended when this criterion is met, to adaptively sample offshore areas. Different combinations of the following operating frequencies: 18, 38, 70, 120, 200, and 333 kHz, are used during the surveys. The frequency used for echointegration-based abundance calculations is 38 kHz for all surveys. The 200 kHz frequency is used for echo integration-based estimates for mackerel on the PELTIC survey. Other frequencies are used during the echogram scrutinisation process, to distinguish between different species, and to separate targets from other echoes such as plankton (see Section 2.2.6 for further details).

Table 2.19. Echosounder settings used during autumn acoustic joint surveys. AA: RV Angeles Alvariño, RM: RV Ramón Margalef, EB: RV Emma Bardán, CEF: RV Cefas Endeavour; and CE: RV Celtic Explorer.

Acoustic Equipmpent	JUVENA		ECOCADIZ-RECLUTAS		PELTIC	IBERAS	CSHAS
Vessel	RM After 2019: AA	EB	RM	EB	CEF	RM/AA	CE
Echosounders	Until 2017: EK60 After 2017: EK80	EK60	Before 2017: EK60 Since 2017: EK80	EK60	EK60	EK80	EK60
Frequencies	6	3	6	3	4	6	4
Primary frequency for biomass assessment (kHz)	38 (120 for mackerel and krill)	38	38	38	38 (200 for mackerel)	38	38
Transducer installation*	D vert; P vert and hor	H vert	D vert	H vert	D vert	D vert	D vert
Transducer depth (m)	D: 6.5; P: 3	3	6.5	3	8	6.5	8.8
Upper integration limits (m)	8	8	10	10	13	12	12
Pulse duration (ms)	1.024		1.024		0.512	1.024	1.024
Transmit power (W) at 38 kHz	1600		2000		2000	2000	2000
Maximum range (m)	Until 2014: 200 After 2014: 450		250		800	125	200
Operating software	Until 2017: ER60 After 2017: EK80	ER60	Simrad ER60 Since 2018: EK80		Simrad ER60 Since 2018: EK80	Simrad EK80	Simrad ER60
Post processing software	Until 2017: Movies+ After 2017: Echoview		EchoView		Echoview	Echoview	Echoview
Ping rate (No. of pings per second)	Shelf: 2–3 Slope: 1–2		Normally set at maximum, adjusted to avoid false bottom echoes.		2	Normally set at maximum, adjusted to avoid false bottom echoes.	2.5

***D: drop-keel; H: hull; P: pole; vert: vertical; hor: horizontal**

2.2.3.1.2 Instrument settings

Most autumn acoustic surveys are restricted to the continental shelf, sampling the water column from ~ 10 to 200 m depth (Table 2.17). The JUVENA survey samples areas further offshore, which are occupied by juvenile anchovy, and a larger depth range (down to 450 m) to sample krill and mesopelagic species. Ping rates are set between 1 to 3 per second. Echosounders are operated in narrowband mode using pulse durations of 512 (PELTIC survey) or 1024 µs (other surveys).

Acoustic backscatter by surface unit (S_A, MacLennan *et al.* 2002) are echo-integrated within geo-referenced EDSUs of 1 nautical mile length, except for JUVENA (0.1 nautical mile length), using a minimum threshold of −60 dB or −70 dB. Surface offset ranges from 8 to 13 m. Acoustic densities are integrated over the entire water column in each EDSU, except for the JUVENA survey, where echointegration is performed by depth layer (10 layers before 2017 and 100 layers since then), and for the PELTIC survey since 2019, where a distinction is made between surface and seabed associated echotraces. Echo-integration is performed using the Echoview software prior to biomass estimation (Section 2.2.6).

2.2.3.2 Biological sampling

Fishing operations are performed following the rationale presented in Section 1, to assess the species and length composition of echotraces.

2.2.3.2.1 Trawl gear

All autumn surveys use a pelagic trawl for biological sampling. PELTIC and CSHAS surveys use the same CE trawl and a similar fishing configuration, whereas the other surveys use a Gloria HOD 352 trawl (Table 2.20). In order to monitor the net opening, fishing depth, and fishing efficiency, all pelagic trawls are equipped with a net sounder (Marport or Simrad system, Table 2.20) and door sensors. Trawl vertical opening varies from 10 to 15 m. The typical towing speed ranges from 4 to 4.5 knots through water.

2.2.3.2.2 Catch processing

Fishing hauls are normally conducted to ground-truth echotraces recorded by the echosounders, as well as to collect information on age and length for the main pelagic fish species. Sampling levels for target species by survey are presented in Table 2.21. Catch subsampling strategies are summarized in Table 2.22.

2.2.3.2.3 Species composition

The main target species of the coordinated autumn acoustic surveys are: anchovy (*Engraulis encrasicolus*), blue whiting (*Micromesistius poutassou*), boarfish (*Capros aper*), chub mackerel (*Scomber colias*), herring (*Clupea harengus*), horse mackerel (*Trachurus trachurus*), mackerel (*Scomber scombrus*), sardine (*Sardina pilchardus*), and sprat (*Sprattus sprattus*). In the south (ECOCADIZ-RECLUTAS and IBERAS surveys) species such as blue jack mackerel (*Trachurus picturatus*), bogue (*Boops boops*), and Mediterranean horse mackerel (*Trachurus mediterraneus*) are also commonly present in the catches. Pearlsides (*Maurolicus muelleri*) have been found in recent years in the Gulf of Cadiz (ECOCADIZ-RECLUTAS survey), in the Bay of Biscay (JUVENA survey), and occasionally during the PELTIC survey. Longspine snipe fish (*Macroramphosus scolopax*) has been observed in Atlantic waters off the Iberian peninsula (IBERAS survey). The main species caught are sardine and anchovy in the south (ECOCADIZ-RECLUTAS survey), sardine along the Iberian coast (IBERAS survey), anchovy in the Bay of Biscay (JUVENA survey), sprat, sardine, and anchovy in the English Channel and eastern Celtic Sea (PELTIC survey), and herring and sprat in Irish waters (CSHAS survey).

Table 2.20. Summary of the main characteristic of the pelagic trawl during the autumn joint surveys. AA: RV Angeles Alvariño; RM: RV Ramón Margalef; EB: RV Emma Bardán; CEF: RV Cefas Endeavour; CE: RV Celtic Explorer.

	JUVENA		ECOCADIZ-RECLUTAS		PELTIC	IBERAS	CSHAS
Fishing vessel	RM	EB	RM	EB	CEF	RM/AA	CE
Gear type	Hampidjan Gloria 352	Hampidjan Gloria 352	Hampidjan Gloria 352	Hampidjan Gloria 352	VDK 20 x 40	Hampidjan Gloria 352	KT Nets 20 x 40 Herring Trawl
Circumference (m)	352	352	352	352	330	352	330
Vertical opening (m)	13	13	10–13	10–13	10–15	13–14	15
Typical towing speed (kn)	4	4	4–4.2	4–4.2	4.5	4.2	4.5
Mesh size in codend (mm)	8 / 2 *	8	20	20	20	20	10
Typical fishing operation duration (min)	30	30	30	30	30	20	30
Net monitoring system	Simrad FS70	Marport	Simrad FS20 SCANMAR wireless door sensors	Marport	Marport	Simrad FS20 SCANMAR wireless door sensors	Simrad FS70, Marport

*** Gradual codend with two mesh sizes**

Table 2.21. Sampling levels for target species during autumn joint acoustic surveys. O: otoliths; L: length; M: maturity; G: gender; W: weight; NA: not applicable, species not found in survey area.

Species	JUVENA	ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
Anchovy	OLMG	OLMGW	OLMGW	OLMG	LW
Blue whiting	L	LW	LW	NA	LW
Boarfish	L	LW	OLMGW	L	LW
Chub mackerel	L	OLMGW	NA	OLMG	NA
Herring	L	NA	OLMGW	NA	OLMG
Horse mackerel	L	LMGW	OLMGW	OLMG	LW
Mackerel	L	LMGW	OLMGW	OLMG	LW
Pearlside	L	LW	NA	NA	LW
Sardine	L	OLMGW	OLMGW	OLMG	LW
Sprat	L	NA	OLMGW	NA	LW

Table 2.22. Autumn survey catch subsampling strategies for length measurements and otolith reading.

	JUVENA	ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
Length measurements					
Catch subsampling strategy	100 individuals per haul or until clear modes are obtained	Until clear modes and a representative 0.5 cm size class LFD are obtained	Catch (sub) sampled until a clear length frequency profile is achieved.	100 individuals per haul	Catch sampled until a clear length frequency profile is achieved
Species	All species in the catch	All species in the catch	All species in the catch	All species in the catch	All species in the catch
Otoliths reading					
Catch subsampling strategy	From the subsample, a maximum of 10 individuals per 1 cm length range	A random subsample of 50 specimens per haul, used for individual biological sampling	A subset of up to 5 specimens per 0.5 cm length class. For fish age ≥ 1, two per length class for age 0.	A random subsample of 40 specimens per haul, used for individual biological sampling	Random sample of 100 individuals
Species	Anchovy	Anchovy, sardine (since 2014), and chub mackerel (since 2019)	Sardine, sprat, anchovy, mackerel, horse mackerel, herring, blue whiting, and boarfish	Sardine, anchovy, mackerel, chub mackerel, and horse mackerel	Herring

2.2.3.2.4 Length measurements

Length measurements are performed on all species in the catch. Target species lengths are usually measured within 0.5 cm length classes, whereas other species are measured within 1 cm length classes. All fish species are measured within 0.5 cm length classes during the ECOCADIZ-RECLUTAS survey (Table 2.23).

Table 2.23. Length measurements precision (in cm) during autumn surveys. NA: not sampled.

Species	JUVENA	ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
Anchovy	0.5	0.5	0.5	0.5	0.5
Blue whiting	1	0.5	0.5	1	1
Boarfish	1	0.5	1	1	0.5
Chub mackerel	0.5	0.5	NA	1	NA
Herring	1	NA	0.5	NA	0.5
Horse mackerel	1	0.5	1	1	1
Mackerel	1	0.5	1	1	0.5
Pearlside	0.5	0.5	0.5	NA	0.5
Sardine	0.5	0.5	0.5	0.5	0.5
Sprat	1	NA	0.5	NA	0.5

2.2.3.2.5 Maturity analysis

Maturity analysis involves determining the sex of the species and the development stage of the gonads. Standardized maturity scales are used for each species (Table 2.24).

2.2.3.2.6 Age sampling

Fish age determination is performed by reading annual rings (annuli) on whole otoliths (saggita) for species listed in Table 2.25. After extraction, otoliths are cleaned and read, either in water or embedded in resin, with direct lighting from above, against a dark background.

2.2.3.3 Hydrobiological sampling

2.2.3.3.1 Hydrographic data

Vertical profiles of hydrographic data (mainly temperature, salinity, and fluorescence) are measured by means of CTD casts (Table 2.26). All vessels perform at least ~ 30 casts along the surveyed area, deploying the CTD down to (just above) the seabed and a maximum depth of 200 m (off the shelf edge). In addition, several vessels also collect continuous hydrographic data using a hull-mounted thermosalinograph (temperature, salinity, and fluorescence fitted-sensors) located at approximately 5 m depth. Alternatively, a thermograph is used, logging temperature data continuously near the surface throughout the survey.

2.2.3.3.2 Plankton sampling

The standard equipment for zooplankton sampling is the WP2 net, with a 80–315 µm mesh size and a 50–100 cm aperture (Table 2.26). The net is hauled vertically from 100–200 m or just above the seabed to the surface at a speed of 0.5 m s^{-1}.

Table 2.24. Details of maturity analysis performed during autumn surveys. No: not performed; Absent: species not present in survey area.

Common name	JUVENA	ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
Anchovy	No	ICES (2008)	ICES (2008) adapted to distinguish in stage 1 between immature and rest	ICES (1990) six-stage scale	No
Blue jack mackerel	No	ICES (1990) six-stage scale	Absent	ICES (1990) six-stage scale	Absent
Blue whiting	No	No	No	Absent	No
Boarfish	No	No	No	No	No
Bogue	No	ICES (1990) six-stage scale	Absent	No	Absent
Chub mackerel	No	ICES (1990) six-stage scale	Absent	ICES (1990) six-stage scale	Absent
Herring	Absent	Absent	8 stages adapted from van Damme *et al.* (2009); conversion detailed in ICES (2014)	Absent	ICES (2008)
Horse mackerel	No	ICES (1990) six-stage scale	ICES (1990) six-stage scale	ICES (1990) six-stage scale	ICES (1990) six-stage scale
Mackerel	No	ICES (1990) six-stage scale	ICES (1990) six-stage scale	ICES (1990) six-stage scale	No
Mediterranean horse mackerel	No	ICES (1990) six-stage scale	Absent	ICES (1990) six-stage scale	Absent
Pearlside	No	No	No	No	Absent
Round sardinella	Absent	ICES, 2008	Absent	Absent	Absent
Sardine	No	ICES, 2008	ICES (2008) adapted to distinguish in stage 1 between immature and rest	ICES (1990) six-stage scale	No
Sprat	No	Absent	8 stages adapted from de Silva (1973); conversion detailed in ICES (2014)	Absent	ICES (2008)

Zooplankton processing procedures are survey specific. Most commonly, samples are divided in two. One half is dried for 24 h at 70°C, frozen, and weighed back on land. The other half is fixed in 4% buffered formaldehyde for later analyses (e.g. species determination). If samples are very dense, further subsampling may be conducted. On PELTIC, samples are stored in 4% buffered formaldehyde, and processed by zooscan back in the laboratory, to provide quantitative information on taxa and size of the mesozooplankton community.

2.2.3.3.3 Ichthyoplankton sampling

In addition to the mesoplankton hauls, some surveys collect additional information on the ichthyoplankton community, specifically to sample eggs of the main pelagic target species (anchovy and sardine). As in spring surveys, one of the most commonly used instruments is CUFES (Checkley *et al.*, 1997), which collects samples at ~5 m depth along the survey (Table 2.26). On the PELTIC survey, a vertical cast with a 1 m diameter ringnet with a 270 µm mesh size (including flowmeter and mini-CTD) is taken at approximately 90 stations. These samples are processed on-board, which involves counting, staging, and measuring of sardine eggs and larvae respectively.

2.2.3.3.4 Other

Other types of plankton sampling are also conducted during the surveys. Some surveys have started sampling microplastics with surface plankton nets (Table 2.26).

During the PELTIC survey, water samples are taken at approximately 40 stations, to sample the microzooplankton community, among other parameters. Samples are stored and processed back in the lab by flow cam, an image-based processing method that counts and categorizes individual particles in the sample. The PELTIC survey is also trialling a new autonomous plankton image analysis system (PIA, Pitois *et al.*, 2018) which continuously samples water from the sub-suface, takes high frequency images, and automatically classifies these into taxonomic groups.

Table 2.25. Age sampling during joint autumn surveys. Yes: age reading performed; No: not performed; Absent: absent in survey area

Common name	JUVENA	ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
Anchovy	Yes	Yes	Yes	Yes	No
Blue jack mackerel	NA	No	Absent	Yes	Absent
Blue whiting	No	No	Yes	No	No
Boarfish	No	No	Yes	No	No
Bogue	No	No	Absent	Yes	Absent
Chub mackerel	No	Yes	Absent	Yes	Absent
Herring	Absent	Absent	Yes	Absent	Yes
Horse mackerel	No	No	Yes	Yes	Yes
Mackerel	No	No	Yes	Yes	No
Mediterranean horse mackerel	Absent	No	Absent	Yes	Absent
Pearlside	No	No	No	No	No
Sardine	No	Yes	Yes	Yes	No
Sprat	No	Absent	Yes	Absent	No

Table 2.26. Hydrographic and plankton data collected during joint autumn surveys. Temp: temperature; sal: salinity; fluor: fluorescence; and tur: turbidity. Vessels: AA: RV Angeles Alvariño, RM: RV Ramón Margalef, EB: RV Emma Bardán, CEF: RV Cefas Endeavour; and CE: RV Celtic Explorer.

	JUVENA		ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
Vessel	RM/AA	EB	RM/AA	CEF	RM/AA	CE
Plankton sampling						
No. of stations	80	40	0	90	0	50
Sampling nets	WP2, Bongo, Newston	WP2	-	0.5 m ringnet	-	WP2, Bongo
Mesh size (µm)	200	200	-	80	-	315
Sampling depth (m)	100	100	-	Water-column up to 4 m above seabed	-	200
Hydrographic sampling						
No. of stations	80	40	155	90	35	45
Hull mounted thermosalinometer	Seabird SBE21	Seabird SBE21	Seabird SBE21	Ferrybox system	SeaBird SBE21	SeaBird SBE21
Hull mounted sensors	Temp, sal, and fluor		Temp, sal, and fluor	Temp, sal, fluor, and flow cytometer	Temp, sal, and fluor	Temp, sal, and fluor
CTD unit	Seabird SBE19	Seabird SBE25	Seabird SBE19 / Seabird SBE 911+	Rosette with Seabird SBE9; ESM2 (custom made) and SAIV mini CTD	Seabird 911+	Seabird SBE25
Standard sampling depth (m)	200	200	Up to 10 m above seabed (max depth 750 m)	Water-column up to 5 m above seabed	Up to 3-5 m above seabed	200
CTD sensors	Temp, sal, fluor, oxygen, and 6 Niskin bottles	Temp, sal, and fluor	Temp, sal, fluor, oxygen, and tur	Temp, sal, fluor, oxygen, and tur	Temp, sal, fluor, oxygen, and tur	Temp, sal, fluor, oxygen, and tur

Table 2.26 (continued)

Water sampling	Niskin bottle (salinity, disolved oxygen, HPLC, phytoplankton, and eDNA)	-	-	Niskin bottle (salinity, disolved oxygen, HPLC, phytoplankton, and inorganic nutrients)	-	-
Ichtyoplankton sampling	-	-		-	-	-
Sampling tool	-	-	-	1 m ringnet	-	CUFES
Sampling strategy	-	-	-	90 stations, 270 μm mesh, 1 m ringnet	-	500 stations, 315 μm mesh size, 630 l min^{-1}

Table 2.27. Megafauna and debris observation during joint autumn surveys. AA: RV Angeles Alvariño; RM: RV Ramón Margalef; EB: RV Emma Bardán; CEF: RV Cefas Endeavour; CE: RV Celtic Explorer; NM: nautical mile.

	JUVENA		ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
Vessel	RM/AA	EB	RM/EB	CEF	RM/AA	CE
Years of activity	Since 2011	-	-	Since 2013	Since 2019	Since 2004
Number of observers	2–3	-	-	2–3	2–3	2–4
Observation length (NM)	1000	-	-	~ 1800	~ 600	2000
Observation time (h)	200	-	-	270	~ 140	270
Mammals	Yes	-	-	Yes	Yes	Yes
Tuna	Yes	-	-	Yes	Yes	Yes
Birds	Yes	-	-	Yes	Yes	Yes
Debris	Yes	-	-	No	Yes	No
Human activity	Yes	-	-	No	Yes	No

2.2.3.4 Megafauna sampling

Dedicated observers take part in all acoustic autumn surveys to study the distribution and abundance of megafauna (cetaceans and seabirds; Table 2.27). They collect information on marine mammals (cetaceans and pinnipeds), birds, large pelagic fish (sharks, sunfish, swordfish, and tuna), turtles, and, in some instances, macrolitter and boats (fishing, sailing, and commercial). During the JUVENA survey, only the largest vessel (RM/AA) includes observers.

For more information about specific survey protocols for megafauna observation, see García-Barón *et al.* (2019) and Louzao *et al.* (2019); and for debris observation, see Declerck *et al.* (2019).

2.2.3.5 Vessel intercalibration

The ECOCADIZ-RECLUTAS survey has been conducted with two different research vessels: RV Emma Bardán (in 2012) and RV Ramón Margalef (see Table 2.19). However, no vessel intercalibration was carried out. For the JUVENA survey, intercalibration exercises between both vessels are conducted every year during the survey to assure coherent acoustic data collection.

2.2.4 Biomass estimation procedure

2.2.4.1 Echogram scrutiny

Because of the aggregative behaviour of small pelagic fish, fishery acoustic methods, which record at metre (horizontal) and centimetre (vertical) resolution, rather than trawls alone, are used to map and quantify the fish. A range of methods are then applied during the autumn surveys to attribute acoustic data to species (scrutinizing). The different scrutiny protocols adopted by each survey series are summarised in Table 2.28. Expert echogram scrutinizing is performed using the Echoview software package, and, in all cases, uses information from ground-truth hauls and the different acoustic properties recorded in the echogram. For the JUVENA survey, scrutiny is performed within homogeneous post-stratification areas, eventually associated with reference hauls. Scrutiny is performed at the EDSU scale for the PELTIC, CSHAS, IBERAS, and ECOCADIZ-RECLUTAS surveys.

Virtual echograms are generated from multifrequency algorithms (templates) to extract fish echotraces for all surveys. For the JUVENA survey, two multifrequency masks are applied: (1) a collective threshold to enhance fish echoes over plankton and noise, and (2) a S_V difference frequency response mask to separate fish with and without swimbladders. A similar approach is applied for the PELTIC, IBERAS, and ECOCADIZ-RECLUTAS surveys: after cleaning the data, which includes applying filters to remove attenuation, an Echoview processing template makes use of typical multifrequency responses to classify four different echo-types: (1) fish with a swimbladder, (2) jellyfish and juvenile fish, (3) fish without swimbladder, and (4) fluid-like zooplankton (Ballon *et al.*, 2011).

For the PELTIC, IBERAS, and ECOCADIZ-RECLUTAS surveys, the swimbladder-fish virtual echogram is then further processed to obtain species information: (i) representative fishing trawls are manually attributed to each of the depth strata for every 1 nautical mile EDSU, and (ii) the species ratio based on acoustically converted catch is applied to the swimbladder fish backscatter to obtain species-specific NASC. This method assumes equal catchability between species (and ages), which is likely to be incorrect, although the exact details are not known. Therefore, data from the trawlnet sonde (Marport) as well as footage from a GoPro camera within the trawl are monitored to assess the representativeness of the catch. To correct for these catchability issues, and when appropriate, a combination of frequency response, school morphology and expert judgement, are used to select schools, layers, or aggregations, and classify them into species, or groups of species (e.g. "Clupeid" echotype). If schools or aggregations are manually attributed to a species (or group of species), a new species ratio is calculated and applied to the residual backscatter, with the option to include a contribution of the selected species in the residual mix.

For the PELTIC survey, a separate Echoview processing file is created which contains a different algorithm specifically designed to extract mackerel at 200 kHz (van der Kooij *et al.*, 2016). This process requires very little manual input apart from removing occasional plankton layers.

As for other autumn surveys, schools (CSHAS and IBERAS), echogram regions (CSHAS and ECOCADIZ-RECLUTAS), layers (JUVENA), or a combination of the three approaches (PELTIC) are echo-integrated, and allocated during echogram scrutiny either to single fish species or to multispecies aggregations. Fish backscatter is split between species using either the reference haul or post-stratification methodologies (Section 1.2.3). All valid fishing hauls have the same weight for all the surveys series, except for the JUVENA survey, where weights are proportional to the fish backscatter near the haul.

2.2.4.2 Target Strengths

Species-specific target strength to length relationships are provided in Table 2.29.

2.2.4.3 Biomass estimation

Biomass estimation procedures are partly survey-specific (Table 2.30). For instance, the software and approaches used are different, and include Excel spreadsheets, tailor-made R-code, and ICES endorsed software packages such as EchoR (Doray *et al.*, 2013) and StoX (Johnsen *et al.* 2019). The PELTIC survey uses both EchoR and StoX. For the ECOCADIZ-RECLUTAS and IBERAS surveys, biomass and abundance per species are calculated at the post-stratification region level only, and NASC values per species and EDSUs are used for mapping purposes. For the JUVENA, CSHAS, and PELTIC surveys, biomass estimates per species are calculated at both the EDSU and post-stratification region scales. For the JUVENA survey, the post-stratification procedure involves two steps: (i) fish echoes are aggregated into small-scale post-stratification regions during scrutiny (Section 2.2.4.1); and (ii) small-scale regions are merged into larger post-stratification regions with homogeneous species, length, and age compositions.

At size- and at-age-abundance and biomass estimates are calculated in each post-stratification region (which are defined as areas with homogeneous species and size composition) for the JUVENA, ECOCADIZ-RECLUTAS, IBERAS, PELTIC and CSHAS surveys. For the PELTIC survey, post-stratification regions are adapted to also consider areas with similar inter-transect distance. Estimation errors (CV) are calculated for PELTIC, IBERAS, and CSHAS acoustic biomass and abundance estimates.

2.2.5 Data storage

ECOCADIZ-RECLUTAS survey data (i.e acoustic, fishing hauls, biological, ichthyoplankton-CUFES, mega-fauna, and hydrographic and environmental data) are stored in IEO's Cadiz laboratory's database [see Section 3.1.8 and ICES (2018b) for details on the open-source system utilized for data storage]. Processed acoustic data, catch data, acoustic estimates of abundance and biomass, and gridded maps are stored as Excel spreadsheets and flat .csv files. Compiled survey data in the form of individual survey reports are also available on that database. Hydrographic data, once quality controlled, are stored at the IEO oceanographic data centre. Fishing haul data are also stored in the SIRENO (Seguimiento Integrado de los REcursos Naturales Oceánicos) IEO DCF database.

IBERAS data are shared and stored in both IPMA and IEO databases.

Table 2.28. Echogram scrutiny and single target (Target Strength, TS) methodologies used during joint autumn surveys. NM: nautical mile.

	JUVENA	ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
Scrutiny protocol					
Acoustic data processing software	Echoview	Echoview	Echoview	Echoview	Echoview
Scrutinized frequencies (kHz)*	18, **38***, 120, 333, and 200 lateral	18, **38***, 70, 120, and 200	**38***, 120, 200, and 333	18, **38***, 70, 120, and 200	18, **38***, 120, and 200
Echo-integration threshold (dB)	2003–2017: −60 Since 2018: −65	−70	−65	−70	−70
Echo-integration layer width (m)	5–450 m by 5 m	None	10 m depth stratified	None	None
EDSUs length (NM)	0,1	1	1	1	1
Scrutinisation methodology					
Manual allocation	Occasional	X	X	X	X
Multifrequency tools	X	X	X	X	X
Layer/School/Region echointegration	Layer / Region	Region	Layer / School / Region	School / Region	Layer / School / Region
TS					
Species-specific TS to length relationships	See Table 2.29				
Length indicator used in the TS-length equation	Whole length distribution according to ICES (1975, 1977) method				

*** Frequencies used for biomass estimation**

Table 2.29. Species-specific target strength to length relationships (*TS = 20 log(L) + b_{20}).

Species	JUVENA		ECOCADIZ-RECLUTAS		PELTIC		IBERAS		CSHAS	
	b_{20}	Reference	b_{20}	Reference	b_{20}	Reference	b_{20}	Reference	b_{20}	Reference
Belone belone	−67.5	Foote *et al.* (1987)	-	-	-	-	-	-	-	-
Boops boops	−67.5	Foote *et al.* (1987)	−67.5	Foote et al., 1986	-	-	−67.5	Foote et al., 1986	-	-
Capros aper	−67.5	Foote *et al.* (1987)	−66.2	Fässler *et al.* (2013)	−66.24	Fässler *et al.* (2013)	−66.2	Fässler *et al.* (2013)	−66.24	Fässler *et al.* (2013)
Clupea harengus	-	-	-	-	−71.2	ICES (1982)	-	-	−71.2	ICES (1982)
Engraulis encrasicolus	−72.6	Degnbol *et al.* (1985)	−72.6	Degnbol *et al.* (1985)	−71.2	ICES (1982)	−72.6	Degnbol *et al.* (1985)	−71.2	ICES (1982)
Macroramphosus scolopax	-	-	−80,0		-	-	-	-	-	-
Maurolicus muelleri	−69.2	Sobradillo et al. (2019)	−72,2		-	-	-	-	-	-
Melanogrammus aeglefinus	-	-	-	-	−67.4	Foote *et al.* (1987)	-	-	−67.4	Foote *et al.* (1987)
Merluccius merluccius	−67.5	Foote *et al.* (1987)	−67.5	Foote *et al.* (1986); Foote (1987)	−67.5	Foote *et al.* (1986); Foote (1987)	−67.5	Foote *et al.* (1986); Foote (1987)	−67.5	Foote *et al.* (1986); Foote (1987)
Micromesistus pautassou	−67.5	Foote *et al.* (1987)	−65.2	Pedersen *et al.* (2011)	−65.2	Pedersen *et al.* (2011)	−65.2	Pedersen *et al.* (2011)	−65.2	Pedersen *et al.* (2011)
Physoclists	−67.5	Foote *et al.* (1987)	−67.5	Foote *et al.* (1987)	-	Foote *et al.* (1987)	-	-	-	Foote *et al.* (1987)

Table 2.29 (continued)

Species	JUVENA		ECOCADIZ-RECLUTAS		PELTIC		IBERAS		CSHAS	
	b_{20}	Reference	b_{20}	Reference	b_{20}	Reference	b_{20}	Reference	b_{20}	Reference
Sardina pilchardus	−72.6	Degnbol *et al*. (1985)	−72.6	Degnbol *et al.* (1985)	−71.2	ICES (1982)	−72.6	Degnbol *et al.* (1985)	−71.2	ICES (1982)
Sardinella aurita	-	-	−72.6	Degnbol *et al.* (1985)	-	-	-	-	-	-
Scomber colias	−68.7	Lillo *et al*. (1996)	−68.7	Lillo *et al*. (1996)	-	-	−68.7	Lillo *et al*. (1996)	-	-
Scomber scombrus	−88.0	Clay and Castonguay (1996)	−84.9	ICES (1984, 2002)	−81.9	Soulding *et al.* (2016) (at 200 kHz)	−84.9	ICES (1984, 2002)	−81.9	Soulding *et al.* (2016) (at 200 kHz)
Scomberesox saurus	−67.5	Foote *et al.* (1987)	-	-	-	-	-	-	-	-
Sprattus spratus	−72.6	Degnbol *et al*. (1985)	-	-	−71.2 −74.2	ICES (1982) Sauders *et al*. (2012) at 120 kHz	-	-	−71.2	ICES (1982)
Trachurus mediterraneus	−68.7	Lillo *et al*. (1996)	−68,7	Lillo *et al*. (1996)	-	-	-	-	-	-
Trachurus picturatus	-		−68,7	Lillo *et al*. (1996)	-	-	-	-	-	-
Trachurus trachurus	−68.7	Lillo *et al*. (1996)	−68.7	Lillo *et al*. (1996)	−68.7	Lillo *et al*. (1996)	−68.7	Lillo *et al*. (1996)	−68.7	Lillo *et al*. (1996)
Trisopterus luscus	−67.5	Foote *et al.* (1987)	-	-	−67.5	Foote *et al*. (1986); Foote (1987)	-	-	-	-

Table 2.30. Biomass estimation procedures.

		JUVENA	ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
Software		Excel spreadsheets/VBA macros	User-tailored programme	EchoR and StoX	User-tailored programme	StoX
Biomass and abundance per species	**EDSU**	X	-	X	-	-
	Post stratification regions (Mean No. [min–max])	20 [5—50]	9 [5–14]	9 [7–14]	5 [4–8]	-
Biomass and abundance-at-length per species	**EDSU**	X	-	X	-	-
	Post-stratification regions (Mean No. [min–max])	20 [5—50]	9 [5–14]	[7–14]	5 [4–8]	-
Biomass and abundance-at-age per echotype and EDSU	**EDSU**	X	-	X	-	-
	Post-stratification regions (Mean No. [min–max])	20 [5—50]	9 [5–14]	[7–14]	5 [4–8]	3 [2–6]
Error derivation estimation	**Post-stratification regions (Mean No. [min–max])**	Not yet. EchoR-based estimates from 2020	Not yet	EchoR and StoX	Geostatistics (for the whole survey)	StoX

All PELTIC survey data collected undergo thorough quality control and are stored in a series of dedicated databases that are part of Cefas data infrastructure. NASC by species and biological sampling results from the trawl catches are uploaded onto the ICES database to enable post-processing in StoX. Zooscan results obtained for the meso-zooplankton data are uploaded on the Ecotaxa cloudbased storage platform (Picheral *et al.*, 2016).

For the CSHAS survey, biological and aggregated acoustic data are submitted to the ICES trawl acoustic survey database[8] and are available as open access download files. Hydrographic data, once quality controlled, are uploaded to the ICES oceanographic portal[9] and are available as open access downloads. Complied survey data, in the form of individual cruise reports are available for download on the Marine Institute (Ireland) online repository[10].

JUVENA data are stored in internal AZTI and IEO databases. Acoustic scrutinized and hydrographic data for the whole temporal series will be updated to the ICES trawl acoustic survey database and ICES oceanographic portals during 2021.

WGACEGG has been producing grid maps and indices dataseries from autumn joint surveys. Those dataseries are so far stored as flat .csv files. They will be progressively stored in an EchoBase[11] database instance, connected to the ICES acoustic-trawl database.

2.2.6 Data quality checks and validation

Data QC checks and validations are a common practice among the autumn surveys (Annex 4).

Echosounders are calibrated before, during, or after each survey using a standard procedure (Demer *et al.* 2015). Common quality criterion to check for correct calibration include RMS and consistency with previous calibration results (e.g. Transducer Gain and S_A correction).

After assuring correct acoustic data acquisition, further QC on acoustic data include cleaning and scrutiny. During the cleaning process, noise and any other echotraces not belonging to fish are removed from the echogram either manually or using a semi-automated procedure with the Echoview software. For the ECOCADIZ-RECLUTAS survey, acoustic data for two consecutive years are scrutinized to ensure consistent results, whereas for the PELTIC and JUVENA surveys, inter-calibration with different experts is carried out. Finally, the biomass estimation goes through taylor-made QC routines to check for internal consistency in the ECOCADIZ-RECLUTAS survey (mean weight, total abundance vs. sum at-length abundances, comparison of mean weights, etc.), whereas two different methods for biomass estimation (EchoR and StoX) are currently used for the PELTIC survey. Taylor-made QC routines used in JUVENA also involve inspection of the echoes producing the highest NASC values each survey and building plots to compare biomass values per strata for several years.

Biological data collected during the autumn surveys is checked during its compilation (skilled observers/samplers, electronic data capture during the PELTIC survey) and thereafter (WLR, missing data check, length distributions, etc.) to ensure its consistency. R software (R Core Team, 2017) is used for the PELTIC survey, and OSB-PELAKAMP for ECOCADIZ-RECLUTAS survey. Internal checks for age readers and maturity scales are performed for the ECOCADIZ-RECLUTAS, JUVENA and PELTIC surveys. Moreover, international intercalibration of age readers and maturity scales is done by particpants of the ECOCADIZ-RECLUTAS survey. For

[8] https://ices.dk/data/data-portals/Pages/acoustic.aspx

[9] https://ocean.ices.dk/HydChem/HydChem.aspx?plot=yes

[10] https://oar.marine.ie/discover

[11] http://echobase.codelutin.com/v/4.0.9/en/index.html

the JUVENA survey, biological data are summarized in an Excel sheet with macros and automatic consistency checks.

Megafauna data are checked during and after collection.

The oceanographic sensors deployed during ECOCADIZ-RECLUTAS, IBERAS, CSHAS, and PELTIC surveys are calibrated externally every year, and every three years for the JUVENA survey. Additionally, sensors for the PELTIC survey are checked every three months in-house. Environmental data are also checked during operation by means of visual inspection, and by collecting additional discrete samples (e.g. HPLC samples for calibration of fluorometers). Environmental data consistency is checked by comparing *in-situ* data to real time satellite images for the ECOCADIZ-RECLUTAS survey, and following internal operational procedures for the PELTIC survey.

Collection and consistency checks for the global survey metadata are also performed for the autumn surveys. Each survey uses its own database for metadata collection (e.g. IEO database for the ECOCADIZ-RECLUTAS survey, or the Cefas internal database for the PELTIC survey), and performs consistency analyses once the data are entered.

See Annex 4 for more details on autumn surveys QC procedures.

Table 2.31. Reporting of the autumn survey series results.

	JUVENA	ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
WGACEGG products					
NASC grid maps	X	(*)	X	X	X
SST and SSS grid maps	X	(*)	X	X	X
Trawl haul species composition maps	X	(*)	X	X	X
Size- and Age-based acoustic abundance and biomass estimates	X	(*)	X	X	X
Mean length and weight by size and age	X	(*)	X	X	X
Survey report	X	(*)	X	X	X
WGACEGG deliverables to other Expert Groups					
Size- and Age-based acoustic abundance and biomass estimates					
WGHANSA	X	X	X	X	-
WGWIDE	-	-		-	-
HAWG			X		X

(*): These survey results are currently not usually provided to WGACEGG in due time because the survey does not end until late October. Results are provided to WGHANSA the following year (see Section 2.2.8).

2.2.7 Reporting

Autumn joint acoustic surveys results are reported annually to WGACEGG using standard survey summary sheets (Annex 6).The main autumn survey WGACEGG products include: large-scale grid maps of both NASC per species and oceanographic variables (SST, SSS); maps of trawl hauls with species composition; and acoustic estimates of abundance and biomass. Size- and age-based estimates of mean length and weight are provided specifically for anchovy and sardine (Table 2.31). Target species for each survey are listed in Table 2.15. As several autumn surveys aim to monitor anchovy recruitment, acoustic estimates differentiate between juvenile (age 0) and adult fish. Individual survey reports are annexed to the WGACEGG report. Autumn joint acoustic surveys also provide fishery-independent annual indices for sardine, anchovy, sprat, and herring to WGHANSA, WGWIDE, and HAWG (Table 2.31 and Annex 2).

2.2.8 Caveats/limitations and perspectives

Adverse weather conditions, which are a regular occurrence during autumn, can seriously constrain both fishery acoustic data acquisition and sampling gears. Both sampling activities are also constrained in shallower water, as a consequence of gear dimensions, vessel draft, and the occurrence of obstacles (e.g. static gear), and closed areas, which limit opportunities for safe trawl deployment (see Table 2.32 for more details). Furthermore, naval exercises can alter the acoustic surveying plans, requiring adaptation at short notice. The facilities aboard smaller research vessels can also be a constraining factor, affecting the number of scientific crew that can be taken on-board to carry out additional sampling activities.

Some surveys, including the ECOCADIZ-RECLUTAS, CSHAS, and PELTIC surveys, dock very close to the time frame of the WGACEGG meeting, challenging data provision in due time. Consequently, ECOCADIZ-RECLUTAS results obtained in year N are provided to WGHANSA at its year N+1 meeting.

Regarding recent developments and future perspectives for these survey series:

- The PELTIC survey has expanded its sampling area since its inception in 2012, to include French waters from 2017, the eastern English Channel during 2018 only, and Cardigan Bay in 2020.
- The ECOCADIZ-RECLUTAS survey could increase its current sampling activities (e.g. larvae/plankton sampling, top predator census), when the research vessel's facilities are improved (Table 2.32).
- The JUVENA survey will be conducted on-board larger vessels on from 2020, which should increase the effective survey duration, allowing the sampling of a larger area.
- Platform changes are also scheduled for the IBERAS survey, which should improve the synopticity with ECOCADIZ-RECLUTAS, IBERAS, and JUVENA coverage.

Table 2.32. Caveats/limitations and perspectives for autumn joint acoustic surveys. RM: RV Ramón Margalef; AA: RV Angeles Alvariño; EB: RV Emma Bardán, CEF: RV Cefas Endeavour; CE: RV Celtic Explorer.

	JUVENA		ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
Vessel	**RM/AA**	**EB**	**RM**	**CEF**	**RM/AA**	**CE**
Caveats and limitations						
Sea conditions	Heavy swell (≥ 2.5 m height waves and wind ≥ force 5 in Beaufort scale)	Heavy swell (≥ 1.5 m height waves and wind ≥ force 3 in Beaufort scale)	Heavy swell (≥ 2.5 m height waves and wind ≥ force 5 in Beaufort scale)	Heavy swell, strong winds, strong tidal currents > 3 m sec^{-1}, and heave	Tidal currents > 3 m sec^{-1}, heave, and swell	Heavy swell, and tidal currents
Obstacles to the acoustic sampling and ground-truthing fishing	Fixed artisanal gears, marine fishing reserve, closed areas for fishing, naval/army exercises.		Fixed artisanal gears (including tuna "almadraba" traps), marine fishing reserve, dissuasive artificial reefs, closed areas for fishing, fish-farm cages, submarine cables and fuel pipes, and naval/army exercises.	Fixed artisanal gears, marine fishing reserve, dissuasive artificial reefs, closed areas for fishing, fish-farm cages, submarine cables and fuel pipes, and naval/army exercises.	Fixed artisanal gears (including tuna "almadraba" traps), marine fishing reserve, dissuasive artificial reefs, closed areas for fishing, fish-farm cages, submarine cables and fuel pipes, and naval/army exercises.	Fixed artisanal gears, gas rigs, and highly variable bathymetry inshore with limited fishing areas in some instances
Other limitations	Maximum autonomy: 10 days Maximum scientific crew: 10	Maximum autonomy: 5 days Maximum space for scientists: 3, limits the	Space constraints on-board the RV prevents the increase of scientific personnel on-board to carry out additional sampling activities.	Days available to cover the whole area	Days available to cover the whole area	Post-storm recovery – the schools are dispersed in inshore waters and take time to

		extent of the multidisciplinary ecological scope of the survey	The change to an EK80 echosounder in 2018 has required some time for adaptation. The survey end dates are too close to WGACEGG meeting, hampering the provision of results in due time.			recover and aggregate again.
Perspectives	The change of RV from RM to AA will increase the maximum autonomy to 15 days and the scientific crew to 12	Possible change of RV from EB to Vizconde de Eza, which would increase the maximum autonomy to 25 days and the maximum scientific crew to 15	Adding new samplers to existing devices (e.g. bongo and plankton nets, top-predator census).	Sampling has been expanded since 2012 to include French waters (from 2017) and eastern English Channel (2018). PIA (plankton image analyser) was added in 2016, but is still in test phase.	Inter-transect distance was set a 6/4 nautical miles to accommodate expected mean school cluster length in shallower waters.	Herring stock at current historical low level and has required some adaptive surveying strategies.

3 Individual surveys

Fernando Ramos

3.1 Gulf of Cadiz summer survey

3.1.1 Background

The ECOCADIZ acoustic survey has sampled the Portuguese and Spanish Gulf of Cadiz continental shelf (ICES Subdivision 9a South) since 2004 (Massé *et al.*, 2018). The main survey objectives are to estimate summertime biomass of the small pelagic fish community, and to monitor the pelagic ecosystem (Massé *et al.*, 2018; Table 3.1).

Table 3.1. Summary table of Gulf of Cadiz summer acoustic survey ECOCADIZ objectives and time frame.

Survey component	**ECOCADIZ**
Survey objectives	Assess small pelagic fish biomass and monitor the pelagic ecosystem in summer in the Gulf of Cadiz
Target fish stock(s) / life stage(s) (stock assessment group)	9a south anchovy and sardine / adults and eggs (WGHANSA)
Other data collected	Adult horse mackerel, mackerel, chub mackerel, boarfish, blue whiting, hydrology, seabirds, and megafauna
Month	July–August
Survey time-series	
Initial year	2004
Periodicity	Annual
Missing years	2005, 2008, 2011, and 2012

The series started in 2004 with the BOCADEVA 0604 pilot acoustic-anchovy daily egg production method (DEPM) survey. Subsequent surveys within this new series (named ECOCADIZ on from 2006) have been routinely performed on a yearly basis, although gaps exist in 2005, 2008, 2011, and 2012. The three first gaps were caused by vessel unavailability. The 2008 economic crisis affected the original planning of the 2009–2013 surveys, which were at that time financed only by IEO own funds, and resulted in a gradual reduction of survey duration (e.g. 10 days in 2009, and 7 days in 2010, instead of the usual 14), and no survey being conducted in 2012. The drastic reduction in available ship-time in 2010 resulted in a partial coverage of the survey area (only the waters located east of Cape Santa Maria were surveyed). Since 2014, ECOCADIZ summer surveys have been co-funded by the European Community DCF to provide biomass estimates of anchovy and sardine.

Late spring (early to mid-June) was initially considered as the most suitable time for conducting the ECOCADIZ surveys, because these dates coincide with the peak spawning of anchovy in the Gulf of Cádiz (Millán, 1992), and is, therefore, the best season to acoustically sample and estimate the anchovy Spawning Stock Biomass (SSB) in the area. However, the survey start has been progressively delayed to midsummer, as a consequence of both a reduction of available ship time and scheduling issues. These issues are not likely to be solved in a near future. The main effect observed as a result of the delayed ECOCADIZ start is the increased detection of age-0 anchovies and sardines. As those juvenile fish are assessed separately from adult ones, their increased detection is not thought to compromise target species stock containment.

ECOCADIZ surveys were carried out on-board IEO's RV Cornide de Saavedra until 2013, when the vessel was decommissioned (Table 3.2). Since 2014, surveys have been conducted on-board RV Miguel Oliver, which belongs to the Spanish Fisheries General Secretariat.

ECOCADIZ acoustic protocols have been standardized within WGACEGG since 2005. Details on ECOCADIZ survey protocols can be found in Massé *et al.* (2018).

Table 3.2. Vessels used during the Gulf of Cadiz summer acoustic survey ECOCADIZ series.

Survey component	ECOCADIZ
Number of vessels	1
Vessel(s) name(s)	2004–2013: RV Cornide de Saavedra Since 2014: RV Miguel Oliver
Vessel(s) length(s) (m)	RV Cornide de Saavedra: 66.7 m RV Miguel Oliver: 70 m
Vessel(s) crew	RV Cornide de Saavedra: 27 RV Miguel Oliver: 22
Scientific crew	RV Cornide de Saavedra: 19 RV Miguel Oliver: 19

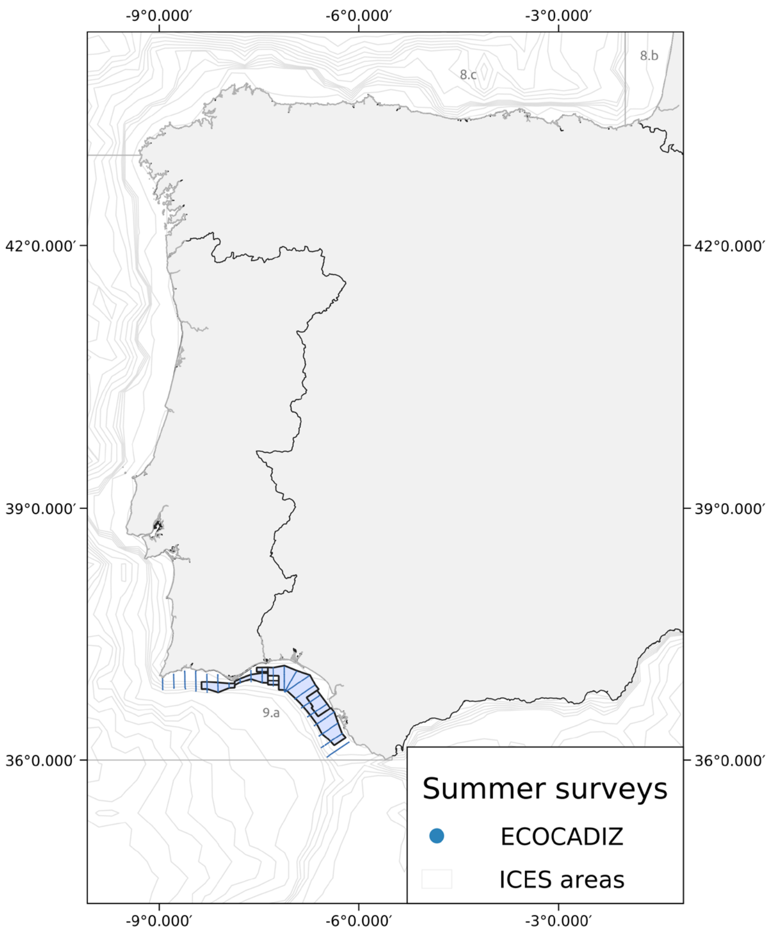

Figure 3.1. Parallel transects sampling scheme in Gulf of Cadiz (ICES Subdivision 9a South) summer survey ECOCADIZ.

3.1.2 Sampling design

3.1.2.1 Sampling effort and spatial coverage

The sampling design allows an exhaustive coverage of the summer distribution of small pelagic fish over the Gulf of Cadiz continental shelf. Figure 3.1 shows the survey design of the ECOCADIZ summer acoustic surveys in the Gulf of Cadiz area. The main sampling scheme characteristics are summarized in Table 3.3.

The sampling design is not stratified, as small pelagic fish can potentially be distributed over the whole sampling area. Post-stratification regions, where species/size compositions and echo integrals are assumed to be homogeneous, are defined to estimate total fish biomass.

EDSUs are 1 by 1 nautical mile squares centred around ship track (Figure 2.2). Acoustic densities are integrated over depth in the EDSUs. The mean linear sampled distances are around 320 nautical miles. The mean sampling area is about 2270 nautical miles^2. The mean sampling coverage is estimated at 14%.

The mean number of identification hauls per surveyed linear distance is about 0.06. About 165 hydrological stations are surveyed every year.

Table 3.3. ECOCADIZ summer acoustic survey sampling design summary table. NM: nautical mile

Survey component	ECOCADIZ
Time period	July/August
Average survey duration (days)	14
Sampling period (day, night, both)	Day
Sampling design (random / systematic / adaptive) parallel transects	Systematic
Minimum seabed depth (m)	20
Maximum seabed depth (m)	200
Inter-transect distance (NM)	8
Acoustic EDSU length (NM)	1
Mean linear distance sampled (NM)	320
Nominal vessel speed (knots)	10
Maximum sampling depth (m)	200
Average surface sampled (NM^2)	2270
Mean sampling coverage	14%
Mean number of fishing stations	20
Mean number of fishing stations per surveyed NM	0,06
Mean number of hydrological stations	165

3.1.2.2 Stock containment and survey timing

The timing and spatial coverage of the Gulf of Cadiz summer survey has been defined to achieve stock containment of target species at the mesoscale of the survey (and stocks). Containment is consistently achieved at the survey mesoscale for target species whose survey indices are used in analytical stock assessment (Annex 2). Containment of other stocks in the survey area are presented in Table 3.4 and discussed below. Table 3.4 summarizes the available information on the adequacy of the survey to capture species distribution patterns in summertime in a synoptic way.

ECOCADIZ does not capture the full summer distribution of blue jack mackerel, blue whiting, boarfish, horse mackerel, mackerel, pearlside, and snipefish because at least a component of the population of these species (e.g. larger fish) are distributed in upper continental slope waters not sampled by the survey. To the group's best knowledge, grid maps produced by WGACEGG for other species provide a reasonably synoptical view of their summertime distribution.

Table 3.4. Survey timing and small pelagic populations. Synoptic: survey provide synoptic coverage; *: non synoptic coverage for some stock components and/or lack of biological information.

Species	Synoptic coverage
Anchovy	Synoptic
Atlantic mackerel	*
Blue jack mackerel	*
Blue whiting	*
Bogue	Synoptic
Boarfish	*
Chub mackerel	Synoptic
Horse mackerel	*
Longspine snipefish	*
Mediterranean horse mackerel	Synoptic
Pearlside	*
Round sardinella	*
Sardine	Synoptic

3.1.3 Sampling procedure

3.1.3.1 Acoustic sampling

3.1.3.1.1 Equipment

Acoustic data are collected using Simrad EK60 scientific echosounders (Table 3.5). Split-beam transducers of 18, 38, 70, 120, and 200 kHz are hull mounted and downward-facing. The echosounder settings described below are applicable to the acoustic equipment used by both research vessels utilized over the series.

3.1.3.1.2 Instrument settings

The water column is sampled from ~20 to 250 m depth (Table 3.5). The ping rate is set at the maximum possible value for the given seabed depth, to avoid false bottom echoes. The echosounder is operated in narrowband mode at a pulse length of 1.024 ms. The recorded range is set at 250 m.

The acoustic backscattered energy by surface unit (S_A, MacLennan *et al.* 2002) is computed for each geo-referenced EDSU of 1 nautical mile. The upper integration depth is 10 m. Acoustic data, thresholded to −70 dB, are processed using the software Echoview for biomass estimation (see Section 3.1.6).

The reference frequency for echointegration-based abundance estimates is 38 kHz (2000 W transmit power). Together with the reference frequency (38 kHz), the 18, 70, 120 and 200 kHz transducers provide information on the spectral signature of the echotraces used for echogram scrutinisation (see Section 3.1.6).

All transducers are calibrated every year before each survey, using standard spheres calibration (Demer *et al.*, 2015).

Table 3.5. ECOCADIZ echosounder settings.

Survey component		ECOCADIZ
Echosounder settings		
	Echosounder	Vertical EK60
	Frequency	18, 38, 70, 120, and 200 kHz
	Primary transducer for biomass assessment	38 kHz
	Transducer installation	Hull mounted downward-facing
	Transducer depth (m)	5.7
	Upper integration limits (m)	10
	Pulse length (ms)	1.024
	Transmit power	2000 W (38 kHz)
	Angle sensitivity (°)	~ 7 (depending on calibration)
	Maximum range (m)	250
	Operating software	Simrad ER60
	Post processing software	Echoview
	Ping rate	Set automatically at maximum. Depending on the recorded range, sometimes changed to fixed interval to avoid false bottom echoes
Calibration		One standard sphere calibration, before each survey (Demer *et al.* (2015)
References		Massé *et al* (2018)

3.1.3.2 Biological sampling

Biological sampling is used to verify the species and length composition of echotraces during echo integration (see Section 1).

3.1.3.2.1 Trawl gear

The trawl used during the ECOCADIZ survey is a pelagic trawl, with a theoretical vertical opening of about 20–22 m, which does not exceed 10–15 m in practice. The typical towing speed varies from 4 to 4.5 knots through water (Table 3.6).

A Simrad FS20 net sounder has been used to monitor the net opening and depth at which the net is fishing, and to provide a measure of fish catchability. The distances between doors have been monitored since 2014 using a Marport Trawl Eye/Trawl Speed combi system and Simrad ITI wireless door sensors.

3.1.3.2.2 Fishing strategy

Catches from the fishing hauls and echotrace characteristics are used to identify fish species and determine the population size and age structure. Trawls hauls are performed whenever changes are detected in echotraces, and according to the survey time constraints (see Section 1). The number of fishing operations carried out during the surveys varies from year-to-year, but is 20–25 on average.

Table 3.6. Summary of the main characteristic of the pelagic trawl used in the Gulf of Cadiz summer acoustic ECOCADIZ survey. CS: RV Cornide de Saavedra; MO: RV Miguel Oliver.

Survey component	ECOCADIZ	
Vessel	2004–2013: CS	Since 2014: MO
Type	Two pelagic *Jet Droppy* doors (3.4 m²), two 63.5/51 pelagic trawls	Two pelagic Poly-Ice Apollo doors (4.5 m²), two 63.5/51 pelagic trawls, one Hampidjan Gloria HOD 352 pelagic trawl
Circumference (m)	86	86 and 78
Vertical opening (m)	15–20	15–20, and 10–13
Typical towing speed (knots)	4–4.2	4–4.2
Mesh size in codend (mm)	20	20
Typical fishing operation duration (min)	30	30
Net monitoring system	Simrad FS20 net sonde	Simrad FS20 net sonde, Marport TE-TS, and Simrad ITI wireless door sensors

3.1.3.2.3 Species composition

The main target species caught during the ECOCADIZ acoustic surveys are: anchovy (*Engraulis encrasicolus*), blue jack mackerel (*Trachurus picturatus*), bogue (*Boops boops*), chub mackerel (*Scomber colias*), horse mackerel (*Trachurus trachurus*), mackerel (*Scomber scombrus*), Mediterranean horse mackerel (*Trachurus mediterraneus*), and sardine (*Sardina pilchardus*). Round sardinella (*Sardinella aurita*) has also been caught occasionnaly. Deeper water species [blue whiting (*Micromesistius poutassou*), boarfish (*Capros aper*), longspine snipefish (*Macroramphosus scolopax*), and pearlside (*Maurolicus muelleri*)] have also been occasionally caught at the edge of their core distribution area during ECOCADIZ surveys. In recent years Atlantic pomfret (*Brama brama*) and transparent goby (*Aphia minuta*) have also been found in the outer and inner-middle shelf waters, respectively.

3.1.3.2.4 Catch processing

Trawl catches are sorted and identified to species level, counted, and weighed (either the total catch or of a representative subsample of it). The length frequency distribution (LFD) in the catch is recorded for all the fish species within 0.5 cm size classes. Individual length and weight measurements, gender identification, and maturity stage are recorded for all the main species during all surveys, whereas otolith extraction is only carried out for anchovy, sardine, and chub mackerel (Table 3.7).

The catch subsampling strategy is summarized in Table 3.8.

3.1.3.2.5 Maturity analysis

Maturity analysis consists in determining the sex of the species and the macroscopic stage of development of the gonads, according to maturity scales presented in Table 3.8.

3.1.3.2.6 Age sampling

Fish age determination is done by reading annual rings (annuli) on whole otoliths (saggita) for the species listed in Table 3.8. After extraction, otoliths are cleaned and embedded in resin, then read using direct lighting from above, and against a dark background.

Table 3.7. Sampling levels for target (*) and secondary species in the Gulf of Cadiz summer acoustic ECO-CADIZ surveys. O: otoliths; S: scales; L: length; M: maturity; G: gender; W: weight.

Common name	ECOCADIZ
Anchovy*	OLMGW
Blue jack mackerel*	LMGW
Blue whiting	LW
Boarfish	LW
Bogue*	LMGW
Chub mackerel*	OLMGW
Horse mackerel*	LMGW
Longspine snipefish	LW
Mackerel*	LMGW
Mediterranean horse mackerel*	LMGW
Pearlside	LW
Round sardinella	LMGW
Sardine*	OLMGW

Table 3.8. ECOCADIZ catch subsampling strategies for length measurements and otolith reading

Survey component	ECOCADIZ
Catch subsampling strategy for length measurements	Until clear modes and a representative 0.5 cm size class LFD are obtained
Species for length measurements	All fish species in the catch
Catch subsampling strategy for otholiths reading	A random subsample of 50 specimens per haul, used for individual biological sampling
Species for otolith reading	Anchovy, sardine (since 2015), and chub mackerel (since 2019)

3.1.3.3 Hydrobiological sampling

3.1.3.3.1 Hydrographic data

A hull-mounted thermosalinograph and a fluorometer, placed at approximately 5 m depth below the sea surface, are used during acoustic sampling to continuously monitor (at 30 sec intervals) subsurface sea temperature, salinity, and *in vivo* fluorescence. Vertical profiles of hydrographical variables are also recorded by performing an average of 160 CTD-LADCP casts at night. The CTD is a probe which measures pressure, temperature, salinity, oxygen, fluorimetry, and turbidity, and is also fitted with a LADCP acoustic current profiler. Hull-mounted acoustic current profiler (VMADCP) records are also continuously recorded at night between CTD stations (Table 3.9).

3.1.3.3.2 Plankton sampling

Plankton sampling is, so far, not routinely performed during the ECOCADIZ survey. However, the 2013–2016 surveys were utilized as an observational platform for a specific research project aimed at studying the early life-stages of anchovy, and the role of the environment in the species recruitment process. In 2013, an *ad hoc* sampling grid of four stations, including Carousel-CTD-LADCP, Bongo 40, and suprabenthic sledge samplings, and four opportunistic additional

Bongo 90 hauls, were carried out in order to characterize the ichthyoplankton, mesozooplankton, and suprabenthos species assemblages in the eastern sector of the study area (coastal area surrounding the Guadalquivir river mouth) and their relationships with environmental conditions. This sampling campaign was completed during the 2014 survey with Multinet casts. Bongo 90 samples for anchovy larvae were also collected during the 2015 and 2016 surveys for different studies framed within the abovementioned research project.

Table 3.9. Hydrographic and plankton data collected during the Gulf of Cadiz summer ECOCADIZ acoustic surveys.

Survey component	ECOCADIZ
Plankton sampling	Not conducted regularly
Hydrographic sampling	
Hull mounted thermosalinometer	Seabird SBE21 (SST, SSS)
Hull mounted flourometer	Turner 10 AU 005 CE (*in vivo* fluorescence)
Hull mounted ADCP	RDI 150 kHz (current profiles, by night)
Lowered ADCP	T-RDI WHS 300 kHz (current profiles, by night)
CTD unit	Seabird SBE19 / Seabird SBE 911+
Number of stations	160
Standard sampling depth (m)	Up to 10 m over the bottom (max depth 1800–1900 m)
CTD sensors	Temperature, salinity, fluorescence, oxygen, and turbidity
Ichtyoplankton sampling	
Sampling tool	CUFES
Sampling strategy	140 stations; 350 μm mesh size; 570 l min^{-1}

3.1.3.3.3 Ichthyoplankton sampling

The Gulf of Cadiz anchovy spawning habitats in the ECOCADIZ survey area are characterized based on the spatial distribution of anchovy eggs sampled by the CUFES system (Checkley *et al.*, 1997). This system is mounted with a 350 μm mesh collector providing pumped surface seawater (from 5 m depth) at an average rate of 570 l min^{-1}. Sampling is carried out during daytime, at the same time as the acoustic sampling, with samples collected every 3 nautical miles (i.e. every ~18 min). The total number of CUFES samples varies from year-to-year, but on average 140 stations are sampled. Anchovy, sardine, and “others” eggs are manually sorted and counted on-board. Anchovy egg development stages are also assessed, and anchovy larvae sorted and counted (Table 3.9).

3.1.3.3.4 Other

Weather variables are recorded by an AANDERAA [12] weather station.

Manta trawl hauls have been carried out since 2016 to characterize the distribution pattern of microplastics over the shelf. These hauls do not follow a pre-established sampling scheme, but aim to have good, homogeneous spatial coverage over both the coastal and oceanic areas of the shelf. To ensure this, the hauls are opportunistically carried out after a fishing haul, at the start or end of an acoustic transect, or at hydrobiological stations.

[12] https://www.aanderaa.com/

3.1.3.3.5 Megafauna sampling

A dedicated observer takes part in the ECOCADIZ survey to assess the distribution and abundance of megafauna (cetaceans and seabirds, Table 3.10). In addition, human debris and human activity are also registered. The census follows the methods proposed by Tasker *et al.* (1984) and Heinemann (1981), consisting in a 300 m-band transect scanning with "snap-shot" correction.

Table 3.10. Megafauna and debris observation. X: collected.

Survey component	ECOCADIZ
Observation length (nautical miles)	320
Observation time (h)	60
Mammals	X
Tuna / sharks	X
Sea turtles	X
Birds	X
Debris	X
Human activity	X

3.1.3.4 Vessel intercalibration

ECOCADIZ surveys have been carried out with two different vessels throughout its series (RV Cornide de Saavedra, and RV Miguel Oliver; see Table 3.2). RV Cornide de Saavedra was decommissioned in 2013 and replaced by the RV Miguel Oliver. Unfortunately, no vessel intercalibration was carried out at the time of the change.

3.1.4 Biomass estimation procedure

Acoustic scrutiny is based on the combination of trawl information and aggregation typologies observed on the echogram. The echogram scrutiny protocols adopted by the ECOCADIZ survey are summarized in Table 3.11. Expert echogram scrutinizing is performed using the Echoview software package.

Virtual echograms referred to the 38 kHz frequency are generated based on multifrequency algorithms (templates) to extract fish echotraces from plankton. Virtual echograms are segmentated into homogeneous regions with similar echotraces while comparing the 38 kHz-based virtual echogram to the 38 and 120 kHz "raw" echograms. Before echo-integration, echogram regions are allocated either to a single fish species (by direct allocation based on expert judgment) or, more commonly, to multispecies aggregations. The composition of multispecies aggregations is given as the average species composition of fishing hauls performed on similar echotraces in the area of interest.

Species-specific target strength to length relationships are provided in the Table 3.12.

Biomass estimation procedures are presented in Table 3.13. The software used is a user-tailored programme. Biomass and abundance per species are calculated at the post-stratification region level only. NASC values per species and EDSUs are used for mapping purposes. A mean NASC value (arithmetic mean) is calculated in post-stratification regions with homogeneous species composition. Post-stratification regions are defined as areas where trawl hauls display no significant difference in the LFD averages, according to Kolgomorov Smirnov test. Haul LFDs and the scrutinized NASC of the target species are averaged within post-stratification regions.

The products of mean TS and NASC values per species per regions are multiplied by the region area to calculate fish biomass estimates. Estimates of abundance and biomass at length and age are then derived for each species and region as described in Section 2. Acoustic estimates are provided without estimation variance.

Table 3.11. ECOCADIZ echogram scrutinisation protocols. NM: nautical mile

Survey component			ECOCADIZ
Scrutinisation protocol			
	Acoustic data processing software		Echoview
	Frequencies to scrutinize data (kHz). (*)frequency used for biomass estimation.		18, **38***, 70, 120, and 200
	Echo-integration threshold (dB)		−70
	Echo-integration layer width (m)		None
	EDSUs length (NM)		1
	Scrutinisation methodology		
		Manual allocation	Yes
		Multifrequency tools	Yes
		School extraction	Regions extraction
Target strengths			
	Species-specific target strength to length relationships		See Table 3.12
	Length indicator used in the TS-length equation		Whole length distribution according to the method from ICES (1975, 1977)

Table 3.12. Species-specific target strength (TS) to length (L) relationships ($TS = 20 \log L + b_{20}$) used for the ECOCADIZ survey.

SPECIES	ECOCADIZ	
	b_{20}	**Reference**
Anchovy	−72.6	Degnbol *et al.* (1985)
Atlantic mackerel	−84,9	ICES (1984, 2002)
Boarfish	−66,2	Fässler *et al.* (2012)
Bogue	−67,5	Foote et al., 1986
Blue jack mackerel	−68,7	Lillo *et al*. (1996)
Blue whiting	−65,2	Pedersen *et al*. (2011)
Chub mackerel	−68,7	Lillo *et al*. (1996)
Hake	−67,5	Foote *et al*. (1986); Foote (1987)
Horse mackerel	−68,7	Lillo *et al*. (1996)
Mediterranean horse mackerel	−68,7	Lillo *et al*. (1996)
Physoclist	−67.5	Foote *et al.* (1987)
Round sardinella	−72.6	Degnbol *et al.* (1985)
Sardine	−72.6	Degnbol *et al.* (1985)

Table 3.13. ECOCADIZ biomass estimation procedure. NA: not available.

Survey component		ECOCADIZ
Software		User-tailored programme
Biomass and abundance per species		
	EDSU	NA*
	Post stratification regions (Mean No. [min-max])	7 [3–14]
Biomass and abundance -at-length per species		
	EDSU	NA*
	Post-stratification regions (Mean No. [min-max])	7 [3–14]
Biomass and abundance -at-age per echotype and EDSUs		
	EDSU	NA*
	Post-stratification regions (Mean No. [min-max])	7 [3–14]
Estimation error derivation		
	Post-stratification regions (Mean No. [min-max])	Not currently

* **Only global abundances are provided in this survey**

3.1.5 Data storage

ECOCADIZ survey data (i.e acoustic, fishing haul, biological, ichthyoplankton-CUFES, megafauna, and hydrographic/environmental data) are stored in the dedicated database at IEO's Cadiz laboratory [see Section 3.1.8 and ICES (2018b) for details on the open source–open hardware sampling system utilized for data acquisition]. Processed acoustic data, catch data, acoustic estimates of abundance and biomass, and gridded maps are stored as Excel spreadsheets and flat .csv files. Compiled survey data in the form of individual survey reports are also available on the database. Hydrographic data, once quality controlled, are stored at the IEO oceanographic data centre. Fishing haul data [i.e. location, species composition, number and weight by species, length frequency distributions by species, biological data on all the sampled species with individual age determination (anchovy, sardine, and chub mackerel)] are stored in the SIRENO (Seguimiento Integrado de los REcursos Naturales Oceánicos) IEO DCF database.

WGACEGG produces grid maps and indices dataseries from ECOCADIZ annual datasets. These dataseries are so far stored as flat .csv files, but should be progressively stored in an EchoBase database, eventually connected to ICES databases.

3.1.6 Data quality checks and validation

ECOCADIZ quality checks for data collection and consistency are described in Annex 5.

Echosounders are calibrated before or after each survey using a standard procedure (Demer *et al.* 2015). Common quality criterion to check for a correct calibration include RMS and consistency with previous calibration results (e.g. Transducer Gain and S_A correction).

Acoustic data QC include echogram cleaning and scrutiny. Noise and any other non-fish echotraces are removed from the echogram, either manually or using a semi-automated procedure in the Echoview software. Multi-frequency virtual echograms are used as guidance in the scrutiny process, and scrutinizers conduct inter-calibration exercises for two consecutive years to ensure consistent results. Finally, biomass estimation QC is carried out using taylor-made routines for checking internal consistency of species-specific size and age-based estimates per post-stratum, country, and total area.

Biological data are checked during and after collection using a digital measuring board connected to the OSB-PELAKAMP open source-open hardware paperless sampling system. Internal and international intercalibration of age readers and maturity scales are also performed as part of the obtained biological parameters QC.

Megafauna data are collected using standard protocols and are checked when entered in a dedicated relational database.

Hydrographic sensors are calibrated annually, and collected data are displayed and visually inspected during each cast. *In situ* environmental data are compared to real time satellite images to check for consistency during the survey.

Survey metadata describing all operations (acoustic transects, fishing hauls, CUFES and CTD-LADCP stations, and microplastic hauls) are uploaded to the SeaDataNet MIKADO tool[13]. OSB-PELAKAMP internal quality checks are performed on fishing haul metadata. Internal quality checks are also performed on CUFES, megafauna, hydrographic, and environmental metadata.

3.1.7 Reporting

ECOCADIZ surveys results are reported annually to WGACEGG through standard survey summary sheets (Annex 6). The main WGACEGG products derived from this survey series are: grid maps of both NASC per species and oceanographic variables (SST, SSS); maps of trawl hauls species composition; and size and age-based acoustic estimates of abundance and biomass. Size- and age-based estimates of mean length and weight are also provided specifically for anchovy and sardine. The survey report is annexed to the main WGACEGG report as a working document. ECOCADIZ also provides sardine and anchovy fishery-independent biomass indices to WGHANSA.

3.1.8 Caveats/limitations and perspectives

The European Community DCF co-funding allocated to the ECOCADIZ survey since 2014 has secured the survey, after an initial period marked by financial hardships, which caused inter-annual sampling intensity fluctuations (see Section 3.1.1).

Over time there has been a progressive delay in the survey's starting dates. However, there is currently no place in the RV Miguel Oliver's timetable to re-accommodate the ECOCADIZ dates to the most suitable ones (mid-June, Section 3.1.1). Therefore, the ECOCADIZ survey will continue to be conducted between late July and mid-August. As start dates have progressively been delayed, the detection of age-0 anchovies and sardines in the surveyed area has been increasingly more prevalent. However, these observations have not entailed a reduced containment. Furthermore, although the impact of the survey delay on fish schooling behaviour has not been investigated, we have not observed any problem related to the acoustic detection of schools of target species. A possible implication of changes in schooling behaviour is a change in acoustic detectability which, consequently, may affect the biomass estimate.

Acoustic and fishing sampling activities are constrained in shallower waters, as a consequence of the gear dimensions and vessel's draft, and of the occurrence of different types of obstacles (e.g. fixed artisanal gears, including tuna "almadraba" traps, artificial reefs, fish-farm cages, submarine cables, and fuel pipes) and closed areas (e.g. closed areas for fishing, such as the Guadalquivir river mouth marine fishing reserve), which limit trawling efficiency. Furthermore, naval exercises can alter the acoustic surveying plans, requiring adaptation.

[13] https://www.seadatanet.org/Software/MIKADO

The adoption of the OSB-PELAKAMP open source-open hardware paperless sampling system, developed by IEO, has improved biological data collection and storage. This sampling system consists of a suite of software/applications for data acquisition and management, the icrOS digital measuring board hardware, a server-based relational database management system for storing and managing data, and software/applications for the reporting and presentation of results (PostgreSQL, PostGIS, R-Shiny, and QGIS). A detailed description of this system can be found in ICES (2018b).

ECOCADIZ could increase and improve its current sampling activities by developing larvae/plankton sampling, image analysis techniques to process mesozooplankton samples, and stomach contents sampling and analysis. These potential future developments are dependent on the availability of skilled personnel and suitable equipment.

3.1.9 Data exchange and databases

ECOCADIZ indices provided to stock assessment groups (see details in Annex 2) are stored by ICES.

ECOCADIZ data are included into standardized gridded maps (Petitgas *et al.*, 2009), which cover the European Atlantic area and inform on the spatial dynamics of the various parameters collected during the surveys coordinated by WGACEGG (e.g. fish acoustic densities, egg m^{-2}, egg m^{-3}, SST, SSS, birds, and mammals). These standard maps can be used to compute indices for the survey areas describing the state of the European Atlantic pelagic ecosystem in spring and autumn (Massé *et al.*, 2018).

WGACEGG members are consolidating the time-series of survey indices and gridded maps, and plan to host them as an instance of the EchoBase relational database hosted at Ifremer. Indices and gridded maps datasets will then be published to ensure a wider dissemination of those survey products.

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Annex 1: Species names

Table A1.1. Common and scientific names of fish species surveyed during WGACEGG acoustic surveys.

Common name	Scientific name
Anchovy	*Engraulis encrasicolus*
Blue jack mackerel	*Trachurus picturatus*
Blue whiting	*Micromesistius poutassou*
Boarfish	*Capros aper*
Bogue	*Boops boops*
Chub mackerel	*Scomber colias*
Herring	*Clupea harengus*
Horse mackerel	*Trachurus trachurus*
Longspine spienfish	*Macroramphosus scolopax*
Mackerel	*Scomber scombrus*
Mediterranean horse mackerel	*Trachurus mediterraneus*
Blue jack mackerel	*Trachurus picturatus*
Pearlside	*Maurolicus muelleri*
Round sardinelle	*Sardinella aurita*
Sardine	*Sardina pilchardus*
Sprat	*Sprattus sprattus*

Annex 2: Indices provided to stock assessment groups by WGACEGG acoustic surveys

A2.1. Sardine and anchovy biomass indices provided to WGHANSA for analytical stock assessment

- Anchovy total biomass estimated by PELGAS acoustic survey in ICES Areas 8a, b and d.
- Anchovy proportion of biomass at age 1 estimated by PELGAS acoustic survey in ICES Areas 8a, b, and d.
- Anchovy juvenile abundance index estimated by JUVENA acoustic survey in ICES Areas 8a–d.
- Anchovy total biomass estimated by JUVENA acoustic survey in ICES Areas 8a–d.
- Anchovy total biomass estimated by PELAGO acoustic survey in ICES Area 9a.
- Anchovy total biomass estimated by ECOCADIZ acoustic survey in ICES Area 9a south.
- Anchovy total biomass in ICES Areas 9a north and 8c from PELACUS acoustic survey.
- Anchovy population in numbers-at-age in ICES Areas 8c and 9a north from PELACUS acoustic survey.
- Anchovy mean weight and length-at-age in ICES Areas 8c and 9a north from PELACUS survey.
- Anchovy biomass distribution and numbers-at-age estimated by PELACUS acoustic surveys in ICES Areas 9a north and 8c.
- Anchovy population in numbers-at-age in ICES Area 9a south from ECOCADIZ acoustic survey.
- Anchovy mean weight and length-at-age in ICES Area 9a south from ECOCADIZ acoustic survey.
- Sardine total biomass in ICES Area 9a from PELAGO acoustic survey.
- Sardine population in numbers-at-age in ICES Area 9a from PELAGO acoustic survey.
- Sardine total biomass in ICES Areas 9a north and 8c from PELACUS acoustic survey.
- Sardine population in numbers-at-age in ICES Areas 8c and 9a north from PELACUS acoustic survey.
- Sardine total biomass estimated in ICES Areas 8a, b, and d from PELGAS acoustic survey.
- Sardine population in numbers-at-age in ICES Areas 8a, b, and d from PELGAS acoustic survey.
- Sardine and anchovy distribution and numbers-at-age estimated by PELACUS acoustic surveys in ICES Areas 9a north and 8c.
- Sardine total biomass estimated by ECOCADIZ acoustic survey in ICES Area 9a south.
- Sardine population in numbers-at-age in ICES Area 9a south from ECOCADIZ acoustic survey.
- Sardine mean weight- and length-at-age in ICES Area 9a south from ECOCADIZ acoustic survey.

- Sardine and anchovy numbers-at-age in ICES Areas 8a, b, and d from PELGAS acoustic survey.
- Sardine juvenile abundance index estimated by IBERAS acoustic survey in ICES Areas 9a north–9a central north and 9a central south.
- Sardine juvenile abundance index estimated by ECOCADIZ-RECLUTAS survey in ICES Area 9a south.
- Anchovy juvenile abundance index estimated by IBERAS acoustic survey in ICES Areas 9a north–9a central north and 9a central south.
- Anchovy juvenile abundance index estimated by ECOCADIZ-RECLUTAS survey in ICES Area 9a south.
- Sardine total biomass in ICES Areas 7e and f from PELTIC acoustic survey.
- Sardine population in numbers-at-age in ICES Areas 7e and f from PELTIC acoustic survey.
- Anchovy total biomass in ICES Areas 7e and f from PELTIC acoustic survey.
- Anchovy population in numbers-at-age in ICES Areas 7e and f from PELTIC acoustic survey.
- Anchovy mean weight and length-at-age, and biomass at-age in ICES Areas 8a–d from PELGAS surveys.
- Sardine mean weight and length-at-age in ICES Areas 8a–d from PELGAS surveys.
- Sardine mean weight and length-at-age in ICES Areas 8c and 9a north from PELACUS survey.
- Sardine mean weight and length-at-age in ICES Area 9a from PELAGO survey.
- Sardine mean weight and length-at-age in ICES Areas 7e and f from PELTIC survey.
- Anchovy mean weight and length-at-age in ICES Areas 7e and f from PELTIC survey.

A2.2. Indices provided to WGWIDE

- Horse mackerel, boarfish, mackerel, and blue whiting distribution and numbers-at-age in ICES Areas 9a and 8c from PELACUS acoustic survey.
- Horse mackerel, boarfish, mackerel and blue whiting distribution and length distributions in ICES Areas 8a, b, and d from PELGAS acoustic survey.
- Boarfish, horse mackerel distribution and numbers-at-age from ICES Areas 6a and 7b, c, g, h, and j from WESPAS acoustic survey.

A2.3. Indices provided to HAWG for analytical stock assessment

- Sprat biomass (CV) estimated for Lyme Bay (ICES Areas 7d and e) stock from PELTIC acoustic survey.
- Sprat population in numbers at-age (CV) for Lyme Bay (ICES Areas 7d and e) from PELTIC acoustic survey.
- Herring biomass (CV) estimated for the Celtic Sea from CSHAS acoustic survey.
- Herring population in numbers at-age (CV) for Celtic Sea from CSHAS acoustic survey.

A2.4. Other survey products

- Sardine egg abundances from CUFES sampling during PELAGO, PELACUS and PELGAS spring acoustics surveys.
- Sardine egg abundances from CUFES sampling during ECOCADIZ summer acoustics survey.
- Anchovy egg abundances from CUFES sampling during PELAGO, PELACUS and PELGAS spring acoustics surveys.
- Anchovy egg abundances from CUFES sampling during ECOCADIZ summer acoustics survey.
- Sardine total daily egg production Ptot from CUFES from PELGAS acoustic survey.
- Anchovy total daily egg production Ptot from CUFES from PELGAS acoustic survey.
- SST and SSS from PELAGO, PELACUS and PELGAS spring acoustics surveys.
- SST and SSS from ECOCADIZ summer acoustics survey.
- SST and SSS from ECOCADIZ-RECLUTAS autumn acoustics survey.
- SST and SSS from PELTIC and JUVENA autumn acoustics surveys.
- Marine birds and mammals census during PELGAS, PELACUS and PELAGO spring acoustic surveys
- Marine birds and mammals census during ECOCADIZ summer acoustics survey
- Marine birds and mammals census during PELTIC and JUVENA summer and autumn acoustic surveys.

Annex 3: Data quality checks and validations performed during spring acoustic surveys

Table A3.14. Data quality checks and validations performed during spring acoustic surveys.

	PELAGO	PELACUS	PELGAS	WESPAS
Acoustic data				
Calibration	Calibration prior to the survey using a copper sphere for 38 KHz and a tungsten sphere for 120 KHz frequencies, according to standard procedures (Demer *et al.* 2015). Quality criterion: RMS and consistency with previous calibration results.	Calibration prior to the survey using a copper sphere for both 18 and 38 KHz, and a tungsten sphere for 70, 120, and 200 KHz, according to standard procedures. Quality criterion: RMS, and consistency (transducer Gain and s_A correction) with previous calibration results.	Procedure documented in specific manual available on-board, aligned with Demer *et al.* 2015. Calibration performed before or after each survey. Quality criterion: RMS, consistency with previous calibration results. Sensor history stored on Ifremer fleet intranet.	Calibration prior to the survey using a tungsten sphere for all frequencies, according to standard procedures. Quality criterion: RMS and consistency with previous calibrations. Additional quality check: raw EK60 data are processed using ESP3 software using the calibration routine.
QC cleaning	Echograms recorded with MOVIES+ software are cleaned of noise and surface turbulence, and the bottom is corrected manually. NASC values area obtained by echo-integration of the water column with a surface threshold of 3–10 m, depending on weather conditions, and a bottom threshold of 0.5 m	Several Echoview routines: background noise removal, ping subsample in case of buble swept-down, adding the surface and bottom line, controling maximum s_V, and performing virtual echograms to enhance fish schools from other scattering organisms.	Onboard manual correction with echo-integration 1 m above seabed depth, with a 0.7 m offset to detect very high backscatter values from the seabed in the water column	Echograms recorded using Echoview (V10, 2020) are cleaned within the programme for electrical noise sources (if present), bubble correction, and inclusion of bottom echoes. Echo-integration is performed from 12 m subsurface (8.8 m drop keel + nearfield allowance) and to within 0.5 m of the seabed.

Table A3.1 (continued)

	PELAGO	PELACUS	PELGAS	WESPAS
QC scrutiny	Echograms are inspected to detect typical schools (in which case they are assigned to the respective species). Quality criterion: s_A per echotype and frequency response analysis.	Virtual echograms to split swimbladder from non-swimbladder fish. Schools are processed, and a check is run on the main energetic, morphometric, and location (using a GIS system) characteristics, before allocation to either a single fish species or to a specific trawl haul performed to identifiy the corresponding echotraces.	Procedure documented in Movies3D manual available on-board. Scrutinisers intercalibration performed for 3 years to ensure consistent results. Acoustic referee and scrutiniser agree on a scrutinising strategy for each sequence during on-board processing. EchoR quality control checks: s_A per echotype distributions compared with previous years results, geolocalized piecharts of scrutinity results for each transect, and global s_A bubbleplots per echotype.	Echograms are clipped to remove off transect portions from the analysis, including fishing hauls, inter-transects, and CTD stations. School detection is carried out through processing routines within Echoview, using multifrequency analysis by means of dB differencing to identify schools and aggregations containing swimbladdered fish. Visual checks are then carried out to determine final species allocation using visual recognition of characteristics and haul composition.
QC biomass estimation	Acoustic data are checked using taylor-made routines before biomass estimation. Biomass per echotype and species, internal consistency checks (mean weight, total abundance vs. sum of at-length abundances, comparison of mean weights calculated with different methodologies).	Tailor-made routines using the same formulation as implemented in StoXs. QC routines to compare global s_A to specific s_A allocated to each species, check total distribution area, length distributions, and total biomass, among other parameters.	EchoR quality checks: bubbleplots of biomass per echotype and species, internal consistency checks (mean weight, total abundance vs. sum of at-length abundances, and comparison of mean weights calculated with different methodologies).	Acoustic data are checked with established internal routines. A second layer of cross checking is carried out during upload to the ICES trawl acoustic database based on established meta-data standards. Biomass estimation is carried on these cleaned data using the StoX programme.

Table A3.1 (continued)

	PELAGO	PELACUS	PELGAS	WESPAS
Biological data				
QC data collection	Sub-sample of catch is weighted and estimated to the total catch. All species are manually measured and weighed on-board	Catch is weighted and sorted by species. Sub-samples from each species are taken for manual length measurements. Standard WLR are used for QC of both total catch for each species and individual measurements.	Catch automatically weighted on-board. Electronic scales connected to "Allegro Campagnes" software for individual length and weight measurements. Training of sorting room supervisor and crew; and observer training before each consort survey.	Biological data are checked with established internal routines to asses WLR and length measurements. A second layer of cross checking is carried out during upload to the ICES trawl acoustic database based on established meta-data standards.
QC data consistency	Tailor made R script checks: WLR, and missing data check.	Checks using WLR; comparing total NASC attributed to a single species vs. mean NASC value multiplied by the number of EDSUs.	EchoR quality checks: WLR plots to spot outliers, and missing data check.	Consistency checks are carried out internally at the point of collection, during upload to the ICES acoustic database, and during the calculation of species-specific, age-stratified abundance
QC metadata	Fishing operations metadata introduced manually in an Microsoft Access database.	Data are validated on-board before transfer to the IEO central database.	Fishing operations metadata recorded in real time on "CASINO+" electronic log. Catch processing metadata stored on "Allegro Campagnes" software.	All trawl-specific data metrics are recorded at the point of collection, validated during upload to local database, then undergo geo-positional and catch composition validation during upload to the ICES acoustic database.
QC biological parameters	Internal and international intercalibration of age readers.	Internal and international intercalibration of age readers, internal workshops for maturity stages allocation, and comparison between microscopic vs. macroscopic stages.	Internal and international intercalibration of age readers.	Continued participation in ICES led age reading/otolith exchange programmes. Internal cross validation by primary and secondary age readers.

Table A3.1 (continued)

	PELAGO	PELACUS	PELGAS	WESPAS
Environmental data				
Calibration	CTD and CT sensors calibration every two years, flowmeters calibration every year.	CTD sensor calibrations every year.	CTD sensors calibration performed every year in summer.	Sensor suite calibrated annually by the manufacturer.
QC data collection	Visual inspection of CTD and thermosalinometer data.	Tailor-made routines and *in situ* scrutiny of each cast.	Visual inspection of CTD data during each cast. Ferrybox data displayed in real time during whole survey.	Visual inspection at the point of collection.
QC data consistency	Comparisons of temperature and salinity between equipment: SBE21, SBE45, and CTD	Taylor-made routines.	Sismer data quality checks. Validation of all zooplankton imagery classification results in Ecotaxa software.	Established internal routines for all sensor data collected prior to upload to the ICES oceanographic database.
Megafauna data				
QC data collection	Data send to SPEA (Portuguese Society for the study of birds) for a check by specialists.	Three observers on shift during daytime. Two people observing for no more than 2 h to limit eye strain. Sea state and weather conditions recorded in real time.	Three observers on shift during daytime. Two people observing for no more than 2 h to limit eye strain. Sea state and weather conditions recorded in real time.	Multiple observers using recognized collection methodology.
QC data consistency	Data check within SPEA database.	Internal data quality checks in dedicated database. Observation efficiency corrected for weather conditions.	Internal data quality checks in dedicated database. Observation efficiency corrected for weather conditions.	Internal data quality checks and cross validation between co-occurring seabirds and marine mammal.
Survey metadata				
QC data collection	Survey metadata recorded in the PNAB (Portuguese National Biological Sampling Programme) Database.	Survey metadata uploaded to own IEO database (SIRENO).	Survey metadata recorded in real time on “CASINO+” electronic log. Standard events definition.	Survey metadata recorded using established and tested host systems.

Table A3.1 (continued)

	PELAGO	PELACUS	PELGAS	WESPAS
QC data consistency	Survey metadata consistency checked after the survey with proprietary R routines.	On board and lab checks.	Survey metadata consistency checked every day during survey with EchoR routine.	Established routines utilized.

Annex 4: Data quality check and validations performed during autumn joint acoustic surveys

Table A4.1. Data quality checks and validations on autumn surveys

	JUVENA	ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
Acoustic data					
Calibration	At the beginning of the survey (Demer *et al.*, 2015). Quality criterion: RMS, and consistency with previous calibration results.	Prior to the survey, according to standard procedures (Demer *et al.*, 2015). Quality criterion: RMS, and consistency with previous calibration results.	At the beginning, during or at end of the survey, depending on weather and sea conditions. (Demer *et al.*, 2015) Quality criterion: RMS, and consistency with previous calibrations.	At the beginning of the survey. Quality criterion: RMS, and consistency with previous calibrations. (Demer *et al.*, 2015)	Standard sphere calibration, carried out prior to the survey, using a tungsten sphere for all frequencies. (Demer *et al.*, 2015) Quality criterion: RMS, and consistency with previous calibrations. Additional quality check: raw EK60 data are processed with ESP3 software using the calibration routine.
QC cleaning	Surface (5 m range) and bottom (1 m) exclusion lines definition, and cleaning of big noise (not fish) data. Bottom detection errors corrected manually when necessary.	Echoview surface (3 m) and bottom (0.1 m) lines definition for echo-integration. Bottom detection errors corrected manually when necessary. Cleaning of noise (not fish) data (−70 dB minimum Sv threshold and back-noise removal). Exported echo-integrated values with Sv max > −25 dB are further revised in the echogram.	Manual validation and correction of automated Echoview bottom (+1 m) and surface (13 m) exclusion lines, application of Echoview attenuation filters, application of bespoke multifrequency virtual echograms to remove plankton, manual removal of noise, tuna/dolphin targets and dolphin vocalisation, explore effects of shadowing in schools > 10,000 NASC.	Background noise removal filter (Echoview). Echoview bottom and surface lines. Checking Sv values greater than −20 dB. In bad weather conditions, remove pings with bubbles sweptdown.	Echograms are recorded using Echoview (V10, 2020) and are cleaned within the programme for electrical noise sources (if present), bubble correction, and inclusion of bottom echoes. Echo integration is performed from 12 m subsurface (8.8 m drop keel + nearfield allowance) and to within 0.5 m of the seabed.

Table A4.1 (continued)

	JUVENA	ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
QC scrutiny	Double scrutiny during assignation of strata.	Use of multifrequency virtual echograms (fish vs. plankton). Scrutinisers inter-calibration for two consecutive years to ensure consistent results. Inspection of typical species-specific schools for direct allocation. Changes in the typical species-specific NASC mapping. Quality criterion: s_A per school/region and frequency response analysis, coherence and consistency in NASC mapping.	Application of virtual echograms to separate swimbladder fish and mackerel. Inter-experts validation, and use of multifrequency response, school morphology, trawl, (sardine) egg distribution, and historical data.	Applying virtual echograms together with school processing (Echoview). Two step scrutiny (on-board and in the laboratory), checking school descriptors (energetic, morphometric, and location). The laboratory check is carried out in conjunction by two different experts.	Echograms are clipped to remove transect portions from the analysis, including fishing hauls, inter-transects, and CTD stations. School detection is carried out through processing routines within Echoview, using multifrequency analysis by means of dB differencing to identify schools and aggregations containing swimbladdered fish. Visual checks are then carried out to determine final species allocation, using visual recognition of characteristics and haul composition.
QC biomass estimation	Inspection of the echoes producing the highest NASC values for the survey. Graphic representation of mean NASC per strata. Comparison of biomass estimates using simple and weighted average of hauls.	Taylor-made routines for checking internal consistency of species-specific size- and age-based estimates per post-stratum, country and total area. Check for trends throughout the time-series. Comparison of CUFES-based anchovy eggs vs. acoustic-based adult mapping from the same survey.	Two methods are currently used to compare the biomass estimates and help in the QC process: EchoR and StoX's.	Taylor-made scripts using StoX formulation.	Acoustic data are checked through established internal routines. A second layer of cross checking is carried out during upload to the ICES trawl acoustic database, based on established meta-data standards. Biomass estimation is carried on these cleaned data using the StoX programme.

Table A4.1 (continued)

	JUVENA	ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
Biological data					
QC data collection	Data Capture with automatic checks.	Electronic scales, software applications and icrOS digital measuring board connected to the OSB-PELAKAMP open source-open hardware paperless sampling system (relational database management system) for haul metadata and catches, length distributions, and individual biological samplings. Skilled sorting room supervisor and crew. Skilled personnel for species-specific biological sampling.	Bespoke Electronic Data Capture System (EDC) involving electronic measuring boards, scales, and subsample prompts, with internal checks and external R scripts.	Manual quality control checks. Catch is weighed and sorted by species. A sub-sample from each species is taken for manual length measurements. Standard WLR are used for QC of both total catch for each species and individual measurements.	Biological data are checked with established internal routines to asses WLR and length measurements. A second layer of cross checking is carried out during upload to the ICES trawl acoustic database, based on established metadata standards.
QC data consistency	Comparison to previous years to check for consistency/patterns.	OSB-PELAKAMP internal quality checks (haul, catch, length distribution, and biological sampling)	Comparison to previous years to check for consistency/patterns	Comparison to previous years to check for consistency/patterns	Consistency checks are carried out internally at the point of collection, during upload to the ICES acoustic database, and during the calculation of species-specific age-stratified abundance.
QC metadata	Manual checks.	Fishing operations metadata recorded manually in specific forms and in OSB-PELAKAMP's Lancero software (direct acquisition in real time of fishing haul metadata from vessel's instrumentation).	Internal check of the EDC system and manual checks using R routines.	Manual checks.	All trawl specific data metrics are recorded at the point of collection, validated during upload to local databases, then undergo geo-positional and catch composition validation during upload the ICES acoustic database

Table A4.1 (continued)

	JUVENA	ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
QC biological parameters	WLR, age–length tables and otolith reading.	Internal and international intercalibration of age readers and maturity scales. Assessment of age readers.	WLR, age–length tables, maturity checks, and double check on otolith readings.	Internal and international intercalibration of age readers, internal workshops for maturity stages allocation, and comparison between microscopic vs. macroscopic stages. Checking outliers, WLR, age–length tables, and otolith readings.	Continued participation in ICES led age reading/otolith exchange programmes. Internal cross validation by primary and secondary age readers.
Environmental data					
Calibration	All Seabird sensors (temperature, conductivity, and pressure) are calibrated by the external manufacturer every three years. Occasional in-survey and intervessel salinity, pH, oxigen, and transmitance calibrations	All Seabird sensors are calibrated by the external manufacturer.	SeaPoint Fluorometer, SeaPoint OBS, Aanderaa Optode and RINKO optode are calibrated every three months in house by either comparing to master sensor (which is calibrated by the external manufacturer) or using a standard or series of standards. All Seabird sensors are calibrated annualy by the external manufacturer.	Periodic calibration	Sensor suite is calibrated annually by the external manufacturer.
QC data collection	Visual inspection of CTD data during each cast.	Visual inspection of CTD-LADCP data during each cast.	Discrete samples are taken, alongside data collected from sensors and instruments, and analysed by specific instruments in the laboratory. Results are constantly compared, and coefficients are applied to collected data.	Taylor made scripts for checking outliers	Visual inspection at the point of collection. Established internal QC routines for all sensor data collected prior to upload to the ICES oceanographic database

Table A4.1 (continued)

	JUVENA	ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
QC data consistency	CTD data from both vessels are compared when possible to check for consistency. Data quality checks during data post-processing, following CTD manufacturer recommendations. Occasionally, satellite imagery (SST, SLA) is used to confirm mesoscale frontal structures and eddies in the spatially interpolated fields.	Use of real time satellite imagery to confirm processes/events. Data quality check during daily post-processing.	All data are collected following SOPs (standard operational procedures) and undergo a series of QA (quality analysis) steps.	Taylor made scripts checking for outliers.	Established internal routines for all sensor data collected prior to upload to the ICES oceanographic database.
Megafauna data					
QC data collection	Distance sampling methodology. Two observers on shift during daytime. Two people observing for no more than 1 h to limit eye strain. Conditions which could influence sightings recorded at the beginning of each sampling period. GPS position recorded every 1 min.	Use of standard methods and protocols.	Use of standard methods and protocols (Evans and Hammond, 2004)	Two observers on shift during daytime. Two people observing for no more than 2 h to limit eye strain. Sea state and weather conditions recorded in real time.	Two observers on shift during daytime, with 2 h shifts to limit eye strain. Sea state and weather conditions recorded in real time.
QC data consistency	Sightings are checked when entered in the relational database. Observation efficiency corrected for weather conditions.	Sightings are checked when entered in the relational database.	Internal data quality checks in dedicated database. Observation efficiency corrected for weather conditions and cross validated with ships automatic weather station data	Internal data quality checks in dedicated database. Observation efficiency corrected for weather conditions	Internal data quality checks in dedicated database. Observation efficiency corrected for weather conditions and cross validated with ships automatic weather station data

Table A4.1 (continued)

	JUVENA	ECOCADIZ-RECLUTAS	PELTIC	IBERAS	CSHAS
Survey metadata					
QC data collection	Metadata are stored in internal AZTI databases. Acoustic metadata are also stored in the ICES acoustic database.	Metadata from all the operations (acoustic transects, fishing hauls, CUFES and CTD-LADCP stations, and microplastic hauls) are uploaded to IEO databases.	Metadata from all the operations (including acoustic transects, fishing hauls, plankton, and CTD-LADCP stations) are uploaded to Cefas databases.	Standard check carried out when uploading to IEO/IPMA databases.	Biological data are checked with established internal routines to asses WLR, and length measurements. A second layer of cross checking is carried out during upload to the ICES trawl acoustic database based on established metadata standards.
QC data consistency	Consistency checks are carried out during upload to the ICES acoustic database.	OSB-PELAKAMP internal quality checks for fishing hauls metadata. Internal checks for CUFES, megafauna, hydrographic, and environmental metadata.	EDC internal quality checks for fishing hauls metadata. Internal checks for plankton, megafauna, hydrographic, and environmental metadata.	Standard check carried out when uploading to IEO/IPMA databases	Consistency checks are carried out internally at the point of collection, during upload to the ICES acoustic database, and during the calculation of species-specific age-stratified abundance.

Annex 5: Data quality check and validations performed during ECOCADIZ summer acoustic surveys

Table A5.1. Gulf of Cadiz summer acoustic survey ECOCADIZ data quality checks.

Type of data	Qualitiy checks	ECOCADIZ
Acoustic data	**Calibration**	Prior to the survey, and according to the standard procedures (Demer *et al*., 2015). Quality criterion: RMS, and consistency with previous calibration results.
	QC cleaning	Echoview surface and bottom lines definition for echointegration (3 m surface threshold and 0.1 m bottom threshold). Bottom detection errors corrected manually when necessary. Cleaning of noise (not fish) data (−70 dB minimum Sv threshold and back-noise removal). Exported echo-integrated values with Sv max > −25 dB are further revised in the echogram.
	QC scrutiny	Use of multifrequency virtual echograms (fish vs. plankton). Scrutinisers inter-calibration for two consecutive years to ensure consistent results. Inspection of typical species-specific schools for direct allocation. Changes in the typical species-specific NASC mapping. Quality criterion: s_A per school/region and frequency response analysis, coherence, and consistence in NASC mapping.
	QC biomass estimation	Taylor-made routines for checking internal consistency of species-specific, size- and age-based estimates per post-stratum, country, and total area. Checking for trends throughout the time-series. Comparison of CUFES-based anchovy eggs vs. acoustic-based adult mapping from the same survey.
Biological data	**QC data collection**	Electronic scales, software applications and icrOS digital measuring board connected to the OSB-PELAKAMP open source-open hardware paperless sampling system (relational database management system) for haul metadata and catches, length distributions, and individual biological samplings. Skilled sorting room supervisor and crew. Skilled personnel for species-specific biological sampling and CUFES.
	QC data consistency	OSB-PELAKAMP internal quality checks (haul, catch, length distribution, and biological sampling).
	QC metadata	Fishing operations metadata recorded manually in specific form and in OSB-PELAKAMP Lancero software (fishing haul metadata directly acquired in real time from vessel instrumentation).
	QC biological parameters	Internal and international intercalibration of age readers and maturity scales. Assessment of age readers.
Environmental data	**Calibration**	All CTD-LADCP sensors callibrated annually by the external manufacturer.
	QC data collection	Visual inspection of CTD-LADCP data during each cast.
	QC data consistency	Use of real time satellite imagery to confirm processes/events. Data are automatically (Matlab routines) checked before submission to IEO central database.

Table A5.1 (continued)		
Megafauna data	**QC data collection**	Use of standard methods and protocols.
	QC data consistency	Sightings are checked when entered in the relational database.
Survey metadata	**QC data collection**	Metadata from all the operations (acoustic transects, fishing hauls, CUFES and CTD-LADCP stations, and microplastic hauls) are uploaded in SeaDataNet MIKADO tool.
	QC data consistency	OSB-PELAKAMP internal quality checks for fishing haul metadata. Internal checks for CUFES, megafauna, hydrographic, and environmental metadata.

Annex 6: Survey summary sheet example

Survey Summary Table WGACEGG XXXX	
Name of the survey (abbreviation):	
Target Species:	
Survey dates:	
Summary:	
	Description
Survey design	
Index Calculation method	
Random/systematic error issues	
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective ICES Survey Protocol should outline how these are evaluated:*
Bubble sweep down	
Extinction (shadowing)	
Blind zone	*Time-series:* *Survey Year specific*:
Dead zone	
Allocation of backscatter to species	
Target strength	
Calibration	
Specific survey error issues (biological)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective ICES Survey protocol should outline how these are evaluated:*
Stock containment	*Time-series:* *Survey Year specific*:
Stock ID and mixing issues	*Time-series:* *Survey Year specific*:.
Measures of uncertainty (CV)	

Biological sampling	*Time-series:* *Survey Year specific*:
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole time-series or for individual years? (please specify)	*To be answered by Assessment Working Group*
Did the Survey Summary Table contain adequate information to allow for evaluation of the quality of the survey for use in assessment? Please identify shortfalls	*To be answered by Assessment Working Group*

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Annex 8: List of abbreviations

AZTI	Technological center for marine and food research in the Basque Country
Cefas	Centre for Environment, Fisheries and Aquaculture Science, UK
DCF	Data Collection Framework
DEPM	Daily egg production method
EDSU	Elementary distance sampling unit
HAWG	ICES Herring Assessment Working Group for the Area South of 62° N
IEO	Instituto Español de Oceanografia (Spanish Institute of Oceanography)
Ifremer	Institut Français de Recherche pour l'Exploitation durable de la Mer (French research institute for sustainable exploitation of the Sea)
IPMA	Instituto Português do Mar e da Atmosfera (Portuguese Institute of the Sea and Atmosphere)
JUVENA	Acoustic survey for JUVENile Anchovy
LFD	Length-frequency distribution
NASC	Nautical area-scattering coefficient
PELGAS	Pélagiques GAScogne
PELTIC	Pelagic ecosystem survey in the Western Channel and Celtic Sea
QA	Quality analysis
QC	Quality control
RMS	Square root of the mean of the squares
s_A	Nautical area-scattering coefficient
S_V	Volume backscattering strength
SAHMAS	Sardine, Anchovy and Horse Mackerel Acoustic Survey
SOP	Standard operational procedure
SSS	Sea surface salinity
SST	Sea surface temperature
TS	Target strength
WGACEGG	ICES Working Group on Acoustic and Egg Surveys for small pelagic fish in the Northeast Atlantic
WGHANSA	ICES Working Group on Southern Horse Mackerel, Anchovy, and Sardine
WGWIDE	ICES Working Group on Widely Distributed Stocks
WLR	Weight to length relationship