Système d'information halieutiques - Campagnes à la mer

Ressources Biologiques et Environnement, département Ecologie et Modèles pour l'Halieutique

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Manual of fisheries survey protocols

PELGAS surveys

(PELagiques GAScogne)

1. ABSTRACT

The PELGAS sea cruises aim at monitoring the Bay of Biscay pelagic ecosystem, in order to provide scientific data for the implementing of an ecosystemic management of Biscay living ressources. The spatial and temporal dynamics of small pelagic fish populations are specifically monitored, with a focus on anchovy populations. The cruise hence takes place in spring, during anchovy spawning, to allow for the assessment of both eggs and adult stages.

The PELGAS ecosystemic cruise aims at collecting data at each level of the Biscay trophic chain. Data are collected continuously along parallel transects covering the whole Bay of Biscay, in order to thoroughly characterize the horizontal and vertical structures of the pelagic ecosystem. Multibeam and multifrequency echosounders provide real time information on the spatial patterns and abundance of pelagic organisms ranging from plankton to fish. Simultaneously, a Continuous Fisg Egg Sampler provide complementary data on small pelagic fish eggs. The presence and abundance of seabirds and marine mammals are also continuously recorded.

Acoustic targets are punctually identified by fishing (pelagic trawling and plankton nets) and/or using video (trawl camera, Remotely Operated Vehicle EROC, plankton video profiler). CTD stations are actually performed over the whole Bay of Biscay to provide hydrological information. In situ measurements are compared to satellite and hydrodynamic models outputs.

This documents describes the sampling protocols in use during the PELGAS survey, as well as the methodology to derive biomasse estimates from acoustics and fishing data.

2. RESUME

L'objectif des campagnes PELGAS est de surveiller l'écosystème pélagique du golfe de Gascogne, soumis aux pressions halieutiques et au variations climatiques, afin de fournir les éléments scientifiques nécessaires à la gestion écosystémique des ressources pélagiques du golfe. Les dynamiques spatio-temporelle des populations de petits poissons pélagiques, notamment d'anchois, sont étudiées particulièrement. La campagne a ainsi lieu au printemps, pendant la ponte des anchois, afin d'observer à la fois les œufs et les adultes.

La campagne écosystémique PELGAS s'attache à récolter un maximum de paramètres à chaque niveau du réseau trophique. Des données sont collectées en continu le long de radiales parallèles couvrant l'ensemble du golfe de Gascogne, afin de caractériser au mieux les structures horizontales et verticales de l'écosystème pélagique. Des échosondeurs multifréquences et multifaisceaux renseignent en temps réel sur les patrons spatiaux et l'abondance des organismes pélagiques, du plancton jusqu'aux poissons. Simultanément, le système de pompage de surface CUFES fournit des informations complémentaires sur la ponte des petits poissons pélagiques. La présence et le nombre d'oiseaux et de mammifères marins sont enfin enregistrés en continu. Ponctuellement, les cibles acoustiques sont identifiées par pêche (chalut et pêches planctoniques) et/ou vidéo (caméra de chalut, engin remorqué EROC, profileur vidéo à plancton). Des stations bathysonde avec prélèvements bouteilles ainsi que des pêches planctoniques (WP2, Multinet) couvrant l'ensemble du golfe renseignent enfin sur le contexte hydro-planctonique. Ces mesures in-situ sont confrontées aux images satellites et aux résultats de modèles hydrodynamiques et biogéochimiques.

Ce document décrit les protocoles utilisés pour collecter et analyser les données collectées lors des campagnes PELGAS.

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3. Sampling strategy

3.1. Survey design

Acoustic data are collected along systematic parallel transects perpendicular to the French coast (Figure 1), from the Northern French coast to Spain, over a linear total distance of about 6 500 nautical miles (NM, 1 NM = 1 852 m). The transects are uniformly spaced every 12 nautical miles (22 km). The mean size of clusters of pelagic fish schools in the Bay of Biscay has been estimated to 8 km (Petitgas, 2003). The inter-transect distance results from a compromise between ship time and cluster mean size.

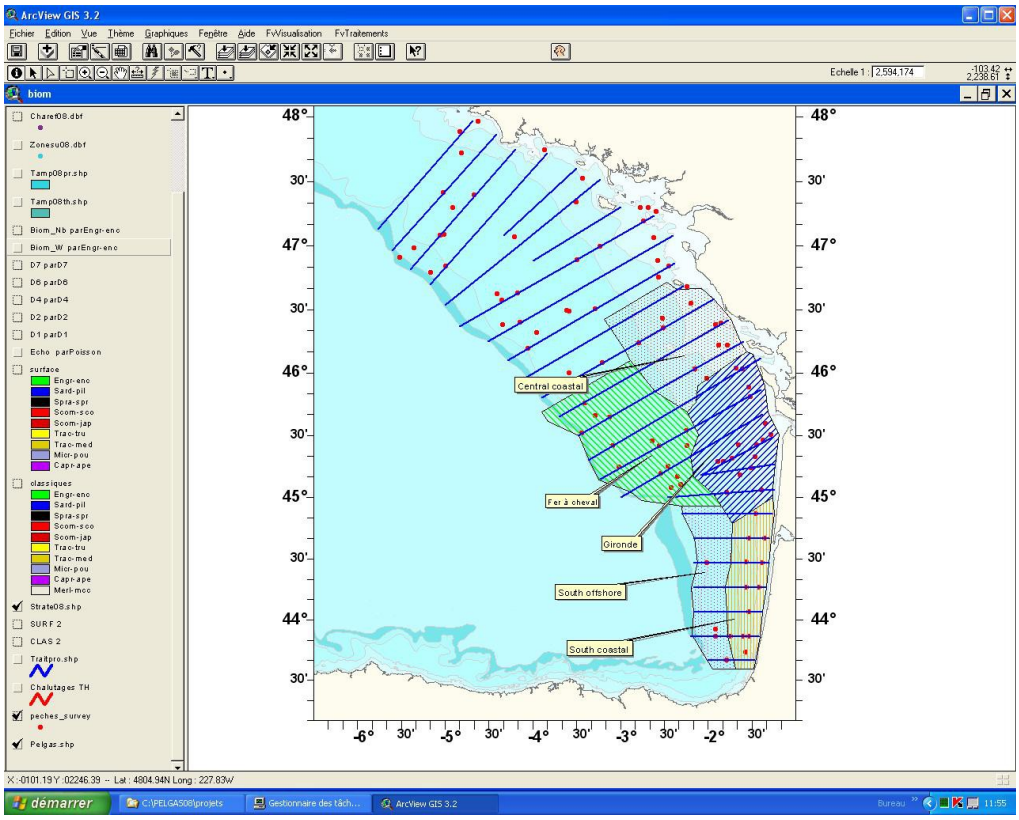


Figure 1. Bay of Biscay map and PELGAS survey design. Blue lines: acoustic transects; red dots: trawl haul locations; colored areas: post-stratification regions.

The survey design allows for the coverage of the whole Biscay continental shelf (about 23 000 NM²), from 25 m depth to the shelf break (200 m depth). The nominal sailing speed is 10 knots (1 knot = 1 852 m.s-1), the speed being reduced to 2 knots on average during fishing operations. This speed allows to sample the whole Biscay shelf in about 30 days.

3.2. Hydro-biological environment sampling

During daytime, the hydrobiology team operates a Continuous Underwater Fish Egg Sampler (CUFES), fitted with a 315 micrometer collector. A CUFES sample is collected every 3 nautical miles along survey transects, during acoustic sampling.

During night-time, 3-4 hydrobiological stations are performed on 1 transect out of 2, yielding a total of about 80 stations per survey. The hydro-stations are ideally performed on a transect that was surveyed during the previous daytime period, to synoptically characterise the fish bio-physical environment, and to allow for the adjustment of the stations locations, according to the hull-mounted thermosalinometer measurements, as well as to the egg counts.

Supplementary hydro stations are generally performed in an adaptative manner during the last week of the Pelgas cruise in front of the Gironde mouth.

The Pelgas hydrobiological environment sampling scheme is summarized in Figure 2.

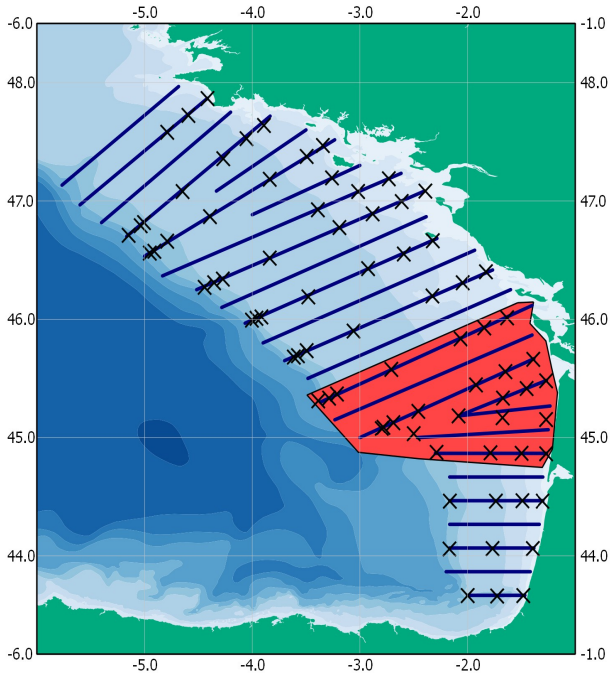


Figure 2. Pelgas hydrobiological environment sampling scheme. Blue lines: daytime CUFES transects; crosses: night-time CTD stations locations; colored area: higher frequency sampling area.

3.3. Acoustic sampling

The pulse length is set to 1.024 ms for all frequencies and echosounders. In situ on-axis calibration of the echosounders is performed before each cruise using a standard methodology (Foote, 1987, Trenkel et al., 2008).

Acoustic data are acquired with the Movies+ (Weill et al., 1993) and Hermes software and archived in the international hydro-acoustic data format (HAC) (ICES, 2005) at a -100 dB threshold.

3.4. Species identification by trawling

The identification of species and size classes comprising fish echotraces (ICES, 2000) heavily depends on identification via trawl hauls performed by R/V Thalassa using a 2 doors, headline: 76 m foot rope: 70 m (or 57 m x 52 m) pelagic trawls. Echograms are scrutinized in real time and trawl hauls are performed as often as possible. Rationale for performing an identification haul include:

- observation of numerous fish echotraces over several elementary sampling units (ESDUs) or of very dense fish echotraces in one ESDU;
- changes in the echotrace characteristics (morphology, density or position in the water column);
- observation of an echotrace type fished on previous transects, but never fished on the current transect.

Acoustic transects are adaptively interrupted to perform the trawl hauls and subsequently resumed. During Pelgas, the trawl stations are then conditioned on the positions of particular acoustic images that are considered to be representative of communities of echo traces during the survey (Petitgas et al., 2003).

Trawl catches do not allow for the identification of single schools but an ensemble of schools over several nautical miles, resulting in identifying groups of schools to species assemblages.

At least one commercial pair trawler have accompanied the R/V Thalassa during the Pelgas cruise since 2007 to increase the effort devoted to echotrace identification.

3.5. Marine mammals and birds sampling

Marine mammals, birds, macro-litters and ship activity are spotted during daytime, along Pelgas transects. Detailed protocols can be found in the dedicated section in this volume.

4. Hydrobiological data collection

4.1. Workspaces and equipments

Located on deck C, the hydrobiology workspace comprices 3 laboratories:

- hydrobiology lab: samples handling, filtrations, binocular observations;
- control room: 1 computer connected to the Conductivity Temperature Depth probe (CTD) and to the vessel GPS (NMEA through local network since 2012) for real time monitoring of CTD profiles, 1 computer for Laser Optical Plankton Counter (LOPC) data upload, 1 computer to define the net closing depths and retrieve Multinet data;

- chemistry lab: density column experiments.

The hydrobiological equipments routinely used during PELGAS surveys include:

- 3 computers to operate the CTD, the multinet and the LOPC;
- 2 binoculars;
- a filtering system;
- pillboxes, formol for CUFES and Multinet sample preservation, 90° alcohol for larvae and otoliths preservation;
- a Continuous Underway Fish Egg Sampler (CUFES);
- a CTD probe fitted with Conductivity-Temperature-Depth, fluorimeter and turbidimeter sensors, a LOPC (with dataLogger) and 9 Niskin bottles;
- three WP2 nets (200 and 50 microns mesh-size);
- a 315 micrometers mesh-size "filet Carré" (Bourriau, 1992), for eggs and larvae sampling;
- a 500 micrometers mesh-size Multinet (Hydrobios) fitted with 5 nets for mesozooplankton sampling.

4.2. Staff

The hydrobiology team comprises 6-7 people working 24h/24, on 8 hours shifts (2 people per shift).

Though the geographic positions of the night hydro stations are pre-defined, the hydrobiology lab responsible may have to adapt them according to hydrological conditions. He/she then needs to have a strong background in ichtyology and biological and physical oceanography to adapt the station positions.

The other hydrobiology team members specific skills include:

- anchovy and sardine eggs and larvae taxonomic identification;

- NISKIN bottles content filtrering, to extract phytoplankton, zooplankton, and suspended matters;

- sample preservation (nutrients, phytoplankton, zooplankton, ichtyoplankton).

4.3. Protocols

4.3.1. Daytime operations

During daytime, the hydrobiology team operates the CUFES, fitted with a 315 micrometer collector. A CUFES sample is collected every 3 nautical miles along survey transects, during acoustic sampling. Sardine and anchovy eggs are sorted, counted and preserved with 4% formol.

4.3.2. Night-time operations

The CTD profiles are first performed from the sea surface to 1-2 m above the seabed, at 2 meters per second. Groups of 3 bottles are subsequently fired near the seabed, well below the pycnocline, in the chlorophyl maximum (generally near the pycnocline), and at the sea surface.

A vertical WP2 net tow is then performed at each station. The WP2 is shooted at 100 m depth maximum, or at 5 m above the seabed depth, if less than 100 m. The first WP2 sample is preserved as CUFES samples, for further mesozooplankton taxonomic analysis. The second WP2 sample is filtered into 4 size classes (2000, 1000, 500 et 200 micrometers) and dried for dry biomass analysis. The third WP2 sample is devoted to other analysis, year-depending.

In case of special hydrographic or meteorological features, or eggs and/or larvae presence in the CUFES samples, supplementary Filet carré and/or Multinet tows are adaptively performed.

The Filet carré is shooted at 100 m depth maximum, or at 5 m above the seabed depth, if less than 100 m. The net is then towed at 1.5-2 knots for 10 (for eggs) to 15 (for larvae) minutes, following an oblique tow profile, from the maximum depth to the surface. The eggs are transferred into the density column to measure their density and calibrate an egg vertical distribution model (Petitgas et al., 2006).

The Multinet is shooted at 100 m depth maximum, or at 5 m above the seabed depth, if less than 100 m. The Multinet is then towed at 1.5-2 knots for 15 minutes, following an oblique tow profile, from the maximum depth to the surface. The 5 nets are automatically closed when reaching the minimum depth limits that were scheduled using the OceanLab software.

4.4. Data pre-processing and storage

The CTD raw data are smoothed, outliers are removed, and pre-processed data are stored in Ocean Data View format (one file per year).

Plankton net tows metadata are recorded in a spreadsheet.

5. Pelagic trawling

5.1. Basic equipments

Located on desk B, the sorting room (130 m2) is by default equipped with:

- a trunk, where the catch is stored;
- an automated sorting system fitted with a conveyor belt and a balance, which allows to weight and deliver the fish to the fish sorters, as well as to record the

catch composition (PUPITRI software interfaced with the balance) and clean the plastic boxes where the sorted fish were stored;

- 3 tables to process fish sub-samples (length measurements, stomach extraction etc...);
- two balances (50 kg and 5 kg max. weights);
- a biology laboratory, equipped with a computer fitted with the "raptri" software to record catch data, a printer, and a small freezer.

5.2. Staff

The agent in charge of the sorting room (or deck master) is an experienced technician, with good knowledge of:

- the PELGAS survey protocol;
- the sorting room functionning;
- the PUPITRI and RAPTRI softwares;
- pelagic species taxonomy.

In addition to this agent, the fish sorter team comprises 4 to 5 extra people, including preferably at least one technician with good experience in small pelagic fish otoliths extraction and catch data checking.

In case of high catch of mixed species, other scientists from other teams are called for help to sort the fish.

5.3. Setting up the sorting room

Additionnal equipments installed at the beginning of the PELGAS include:

- a binocular;
- a fume cupboard;
- a poster with catch processing protocols plasterd on the wall (including maturity scales);
- an additional light;
- a 5 kg balance;
- dissection and otolith extraction tools;
- taxonomic reference books.

At the beginning of the cruise, the raptri software and biological files are initialized. The species list is checked, as well as the availibility of all fish processing protocols (genetic, stomacal content, energy...).

5.4. Protocols

The actions performed in the sorting room are summarized below:

5.4.1. Catch visual inspection, rescue of live robust species

The deck master evaluates the volume and degree of mixing of the catch and eventually ask for extra-manpower.

Look for living "robust" species (sunfish, mammal, pelagic shark) that might survive if returned to the sea. If some are present, they are quickly identified, measured, weighted, pictured and thrown back to the sea.

5.4.2. Choice of sampling scheme and conveyor start-up

The deck master determines the sampling scheme, based on the catch amount and composition. He/she decides wether to sort the whole catch or a subset, whether to use 40 kilograms subsamples or less if fishes are very small, and which are the main and secondary species in the catch.

The deck master starts the Pupitri software operating the conveyor.

5.4.3. Split, weight and deliver the catch

The deck master operates the conveyor system. The catch is automatically split into subsamples which are weighted. Each subsample is then either send to the sorting belt, or thrown overboard.

5.4.4. Catch sorting

5.4.4.1. Pre-sorting of large species

To precisely assess the contribution of large species (mackerels, hake etc...) to the catch, the deck master, eventually aided by a fish sorter, visually detect and sort out large fish before they pass through the pupitri system.

5.4.4.2. Catch sorting on conveyor belts

A minimum of 4 people sort the catch around the conveyor belts. The main species is left on the conveyor, whereas secondary species are sorted out in plastic boxes. If some species display a clear bimodal length distribution, they are sorted by size category, to improve the precision of length distributions.

The deck master operates the PUPITRI workstation which records the amounts of catch sorted and/or discarded.

If the sorting process is long, a second line of belts is openned.

Macroscopic litter and highly damaged fish are sorted out in the same box.

5.4.5. Sorted catch data input

The fish sorters around the conveyor belts send the boxes containing sorted species on the weighing belt.

The deckmaster inputs in the Pupitri software:

- the scientific name of the species comprised in each the box passing on the weighing belt,
- the type of box for removing the box weight from the subsample weight. The actual species weight is automatically recorded by Pupitri.

Boxes with sorted species are then send to the biological measurements area.

5.4.6. Biological measurements on sub-samples

The following biological measurements are conducted by 2 to 3 fish sorters on each species (and eventually size class). One or two fish sorter perform the measurements while one other record the size or weight distributions on a sheet of paper.

If the catch of one species is too abundant, measurements are conducted on a subsample. Eitherway, all fish are measured.

About 100 fish are usually measured to assess the length distributions of species with short size distribution ranges (*Capros aper* and *Sprattus sprattus*), and around 150 to 200 species for other species.

5.4.6.1. Size measurements

Size data are recorded in a table with 1 row per size class on a measurement sheet.

Fish lengths are rounded to the nearest inferior ½ cm for clupeids, or to the nearest inferior cm for all other species.

Each time a fish length is recorded, a tick is drawn in the table row corresponding to its size class on the measurement sheet. This allow for the real-time visual control of the length distribution aspect.

Fish are sized until sample exhaustion or until the fish sorter decides that a robust length distribution graphically appeared on the sheet.

5.4.6.2. Mean weight measurements

The total weight of sub-samples used for defining size distributions are measured and used to derive a global mean weight for the sub-sample.

5.4.7. Weight-length keys

Based on the level of completion of the fish sampling scheme, the deckmaster determines when a weight-length key must be defined for *Engraulis encrasicolus, Sardina pilchardus, Scomber scombrus, Scomber japonicus, Trachurus trachurus, Capros aper* and *Sprattus sprattus*.

A total of one to three length-weight equations are derived at each trawl stations. Anchovy and sardine length-weight equations are derived everytime the catch is sufficient. Length-weight equations of other species are adaptatively derived, time permitting, and to ensure a good spatial coverage.

To define a weight-length key, individual fish used to derive the length distribution are split by size class in small boxes. The box weight and the number of fish in each box are recorded on a sheet.

5.4.8. Biometric measurements and otolith extraction

5.4.8.1. Fish selection

Based on the level of completion of the fish sampling scheme, the deckmaster determines when specific biometries and otolith extraction are to be conducted, for anchovy and sardine only.

For biometry and otolith reading purposes, a total of about 40 (sardine) or 50 (anchovy) individuals are selected over the length classes of the subsample used to derive the length distribution, and stored in small boxes in the laboratory.

5.4.8.2. Biometric measurements

The following individual biological data are written on biometry cards by 2 fish sorters (1 trained reader and 1 possibly novice writer) for each individual in every sardine and anchovy sub-sample:

- weight (in grams);
- sex (male/female/undetermined);
- maturity stage

The following extra data are recorded for sardine:

- level of fatiness;
- infestation level by Anisakis spp. parasite.

5.4.8.3. Otoliths extraction

Different types of trays, each containing 10 pairs of otoliths, are used for anchovy and sardine.

A trained fish sorter extract pairs of otoliths from fish whose biometrical parameters had been precedently recorded. Otoliths are cleaned with a wet sponge and dried for 24h on a tray. Pictures of completed trays are actually taken.

After 24 hours of drying, the otoliths are placed on the right side, with the concave face looking downwards, and the point to the top of the tray. « EUKITT » resin is put in each of the tray holes, with a plastic pipette, in a fume cupboard. The resin dries for 1 or 2 days.

Otoliths seasonal growth rings are read using a binocular by a technician certified for anchovy and sardine otolith reading.

The age of the fish is determined based on the number of growth rings. The age is expressed in years, assuming that the birthday was January, 1st. The age and the nature of the otolith edge are added to the fish biometry card, and input into a standard spreadsheet.

On average, a total of 1200 and 1400 anchovy and sardine otoliths, respectively, are collected during a cruise.

Anchovy otoliths readings are a posteriori double-checked by another certified technician who also precise the growth rings patterns.

5.4.8.4. Sub-samples and biometry data input

The deckmaster and a fish sorter input sub-samples and biometry data in the Raptri database and in a spreadsheet, respectively.

5.4.8.5. Catch data check

Sub-samples and biometry data input are checked against the original values on paper sheets by 2 fish sorters familiar with the Raptri software. Eventual input errors are corrected in the databases.

6. Pelagic fish biomass assessment by acoustic method

Biscay fish population biomass is assessed during Pelgas cruise using an 'expert' methodology to combine acoustic and fishing data.

6.1. Acoustic data pre-processing

Only 38 kHz backscatters are used for biomass assessment. However, echograms recorded at the 120 kHz frequency are also scrutinized to help isolating fish echotraces from sound scattering layers (SSLs).

Pelagic fish are frequently scattered close to the sea surface and within the surface acoustic blind zone (0-10 m depth) at night. SSLs are also denser during night-time

than at day, making fish echotrace partitioning less reliable. Only daytime acoustic data are then used for stock assessment purposes.

Echograms are first scrutinized and bottom detection errors are manually corrected. Daytime 38 kHz volume backscattering coefficients (Sv) higher than -60 dB (Petitgas et al., 1998) and recorded from 10 m depth to 150 m depth along acoustic transects are then echo-integrated in each beam over standard depth channel of 10 m thickness and averaged over 1 NM long Elementary Sampling Distance Units (ESDUs). Resulting values of Nautical area backscattering coefficients (NASC) are used in subsequent analysis.

6.2. Classification of echo-integrals

Expert echogram scrutinizing is then performed to allocate echo-integrals (S_A) thought to correspond to fish targets to several echotrace categories in each ESDU, based on echotraces shape, density and position. Echotrace categories correspond to species or group of species found in midwater identification trawls. At least 4 categories are generally considered during a survey:

- D1: diffuse shoals or layers close to the bottom or small 'drops' extending up to 10 m above the sea floor. These echotypes are allocated to horse mackerel and gadoids;
- D2: schools displaying sharp edges and often high density, generally distributed up to 50 m above seafloor in coastal areas and sometimes offshore. These echotypes are allocated to anchovy, sprat, sardine and mackerel;
- D3: diffuse echo-traces often observed offshore all along the shelf break, allocated to a mixture of blue whiting and myctophids;
- D4: small, dense and very superficial (0-30 m depth) schools attributed to sardine, mackerel or anchovy.

Other echotype categories are adaptively defined every year to accommodate new temporary aggregation patterns or species mixtures (e.g. when sardine forms large schools very close to the coast, or dense small superficial schools offshore).

When fish echotraces cannot be visually allocated to species, especially in the case of diffuse, multi-species layers, echo-integrals are partitioned according to the catch composition in the area.

6.3. Association of acoustic and fishing data

6.3.1. Selection of homogeneous regions

At large scale, acoustic ESDUs are allocated to homogeneous regions visually defined based on trawl haul composition (species and size) (Figure 1). Regions are further partitioned in two depth layers for depths higher than 50 m. Fish backscatter classified

into the D4 category are then allocated to the surface layer, whereas other categories are pooled in the bottom layer.

Region-averages of the trawl haul compositions are computed, by weighing the species/size compositions of the hauls performed in a region by the mean fish backscatter recorded in a 10 NM square centered around the haul position (Massé et al., 1995).

6.3.2. Reference hauls

A 'reference haul ' is manually allocated to each ESDU, according to:

- the haul depth: surface hauls are exclusively applied to D4 (surface echo traces) and bottom hauls to other echo-traces categories (D1, D2, Dn...) ;
- in the case of bottom hauls, the resemblance between echotraces observed in the ESDU and echotraces of nearby ESDUs where a trawl haul was performed.

Size composition distributions derived from reference haul catches are generally used to compute biomass at length in the associated ESDU. Catches from another haul are alternatively used if the the reference haul sample size is too small.

6.4. Pelagic fish biomass assessment

6.4.1. General methodology

The methodology described below is adapted from Simmonds and MacLennan (2005).

6.4.1.1. Partitioning of the total echo-integrals between species.

As two or more species are commonly found in mixed concentrations and their marks cannot be distinguished on the echogram during PELGAS surveys, further partitioning to species level is possible by including the composition of trawl catches (Nakken1977). Echo-integrals Ei allocated to species i then writes (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:

w_i are expressed as the proportional number or weight of each species in the trawl catches (eventually weighted by total haul catches or mean acoustic backscatter in the vicinity of the haul(s));

$<\sigma_i>$ is the mean backscattering cross-section of the species *i*.

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

$$TS_1 = b_i + m_i \log(L) \qquad (2)$$

where b_i and m_i are species-specific coefficients, assumed to be known from experimental evidence. A formula for the mean backscattering cross-section (expressed in m² of backscattering surface) is:

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

where <L> is species i mean length.

b_i et m_i coefficients used for Pelgas surveys are presented in table 1.

Species	Frequency (kHz)	b20 in use at Ifremer	Closest b20 value in the literature	Reference	Literature species
Engraulis encrasicolus	38	71.2	71.2	ICES, 1982. Report of the 1982 Planning Group on ICES-Coordinated Herring and Sprat Acoustic Surveys. *ICES Document CM*, **1982/H: 04**.	*Clupea harengus & Sprattus sprattus*
Sardina pilchardus	38	71.2	71.2	ICES, 1982. Report of the 1982 Planning Group on ICES-Coordinated Herring and Sprat Acoustic Surveys. *ICES Document CM*, **1982/H: 04**.	*Clupea harengus & Sprattus sprattus*
Scomber japonicus	38	70	70.9	Guttierez M. & MacLennan D., 1998. Preliminary results of determination of in situ target strength of main pelagic species: Cruise of RV Humboldt 9803-05 from Tumbes to Tacna. *Inf. Inst. Mar. Peru*, **135**: pp. 16-19.	*Scomber japonicus*
Scomber scombrus	38	86	86.4	Misund O. & Betelstad A., 1996. Target strength estimates of schooling herring and mackerel using the comparison method. *ICES J. Mar. Sci.*, **53**: pp. 281-284.	*Scomber scombrus*
Sprattus sprattus	38	71.2	71.2	ICES, 1982. Report of the 1982 Planning Group on ICES-Coordinated Herring and Sprat Acoustic Surveys. *ICES Document CM*, **1982/H: 04**.	*Clupea harengus*
Trachurus mediterraneus	38	68.7	68.9	Lillo S., Cordova J. & Paillaman A., 1996. Target-strength measurements of hake and jack mackerel. *ICES J. Mar. Sci.*, **53**: pp. 267-272.	*Trachurus symetricus*
Trachurus trachurus	38	68.7	68.9	Lillo S., Cordova J. & Paillaman A., 1996. Target-strength measurements of hake and jack mackerel. *ICES J. Mar. Sci.*, **53**: pp. 267-272.	*Trachurus symetricus*
Micromesistius poutassou	38	67	67.4	Foote K.G., 1987. Fish target strengths for use in echo integrator surveys. *J. Acoust. Soc. Am.*, **82**: pp. 981-987.	*Physoclystii (gadoids)*
Gadoids	38	67	67.4	Foote K.G., 1987. Fish target strengths for use in echo integrator surveys. *J. Acoust. Soc. Am.*, **82**: pp. 981-987.	*Physoclystii (gadoids)*

Table 1. TS coefficients used at Ifremer for acoustic fish biomass assessment.

If echo-integrals Ei are expressed as nautical area-scattering coeffcients, SA (in m².n.mi.-²), backscattering cross-sections must be expressed in (1) as spherical backscattering cross-sections: $\sigma_{sp-i} = 4\pi\sigma_{bs-i}$, to derive fish density estimates (MacLennan et al., 2002).

6.4.2. Estimation of the density of targets of species *i*

The density of targets of species *i* can be estimated using the generic formula (Simmonds and MacLennan, 2005):

$$F_i = \frac{C_E}{\langle \sigma_i \rangle} E_i \qquad (4)$$

where:

F_i is the areal density of target of species *i*

E_i is the mean acoustic backscatter of species *i*

C_E is the equipment calibration factor which is the same for all species

$<\sigma_i>$ is the mean backscattering cross-section of the species *i*

6.4.2.1. 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, one can use a weight-based TS function i.e. the target strength of 1 kg of fish to compute F_i. If the mean relationship between the length L of a fish and its weight W is expressed as:

$$W = a_f L^{b_f} \qquad (5)$$

Since the number of individuals of mean weight <W> per unit weight of fish is 1/<W>, the weight-based TS function writes (Simmonds and MacLennan, 2005):

$$TS_w = b_w + m_w \log(L) \qquad (6)$$

where:

$$b_w = b_i - 10\log(a_f) \text{ and } m_w = m_i - 10\log(b_f) \qquad (7)$$

From (3) and assuming that m_i = 20, the weight-based spherical scattering cross-section hence writes:

$$\langle \sigma_{sp-w} \rangle = \frac{\langle \sigma_{sp-1} \rangle}{\langle W \rangle} = \frac{4\pi}{\langle W \rangle} \times \langle L^2 \rangle \times 10^{b_i/10} \qquad (8)$$

6.4.2.2. Abundance estimation

Areal densities of target of species *i* per ESDU must then be raised to the total surface of the surveyed area. This implies to make some assumptions on the density of fish in areas that have not been sampled. The abundance is calculated independently for each species or category of target defined during echo-partitioning.

In the case of Pelgas surveys, total abundance estimates in previously defined homogeneous regions are computed by multiplying the mean fish density per ESDU by the total surface of the region.

From (1) and (4), the total abundance in number Qi of species i in an homogeneous region of surface A then writes :

$$Q_i = F_i \times A = \frac{C_E}{\sigma_i} \frac{z_i \sigma_i}{\sum_j z_j \sigma_j} E_m \times A = C_E \frac{}{\sum_j} \quad (9)$$

Zi is a region-specific weighting factor depending only on trawl catches and TS equations (Diner and Le Men, 1983).

In the same way, the total abundance in weight Qw-i of species i in an homogeneous region of surface A then writes :

$$Q_{w-i} = \langle W_i \rangle \times F_i \times A = \langle W_i \rangle \times C_E \frac{z_i}{\sum_j z_j \sigma} \quad (10)$$

Where:

<*Wi*> is the mean weight of species i in the region (kg)

Xi is a region-specific weighting factor depending only on trawl catches and TS equations (Diner and Le Men 1983), expressed in kg.m-2.

Using the weight-based spherical scattering cross-section equation (8), X_{i-k} is expressed as:

$$X_{i-k} = C_E z_i / \left(\sum_j z_j \langle \sigma_{w-j} \rangle \right) \quad (11)$$

Where $\langle \sigma_{w-j} \rangle$ is the weight-based mean spherical scattering cross-section of species j in the region. To express the abundance in no. of fish, one shall use the weighting factor Xi-1 which writes:

$$X_{i-1} = X_{i-k} \langle W \rangle \quad (12)$$

6.4.2.3. Abundance and biomass at size per species and ESDU

Fish densities per species and size class are computed for each echotype category and ESDU based on:

- fish backscatters allocated to the echotype category in ESDU x;
- the species composition and the size distribution in the reference haul associated with the ESDU.

Acoustic backscatter Eild(x) of species i of mean length l in echotype category d and ESDU x, associated with reference haul r writes (Diner and Le Men, 1983):

$$E_{ild}(x) = \frac{q_{ild}(r) \sigma_{il}(r)}{\sum_{j=1}^{N} q_{jld}(r) \sigma_{jl}(r)} E_d(x) \quad (13)$$

where:

- $q_{ild}(r)$ is the ratio of the catches of species *i* of size *l* over the total catches of the *N* species of echotype *d* in reference haul *r* ;
- $E_d(x)$ is the average fish backscatter allocated to echotype category *d* in ESDU *x*, expressed as a nautical area backscattering coefficient (NASC) ;

– $\sigma_{il}(r)$ is the backscattering cross-section of species i of size l in the reference haul *r*.

Replacing $E_{ild}(x)$ in (4) by its expression in (13), the density of fish of size *l* and species *i* in echotype category *d* and ESDU *x* associated with reference haul *r* writes:

$$F_{ild}(x) = \frac{C_E}{\sigma_{il}(r)} \frac{q_{ild}(r)\sigma_{il}(r)}{\sum_j q_{jld}(r)\sigma_{jl}(r)} E_d(x) = C \quad \text{(14)}$$

Further replacing $q_{ild}(r)$ by $c_{ild}(r)/c_d(r)$, where $c_{ild}(r)$ are the catches of species *i* of size *l* in reference haul *r,* and $c_d(r)$ the total catches of the *N* species of echotype *d* found in haul *r*, one gets:

$$F_{ild}(x) = C_E \frac{\frac{c_{ild}(r)}{c_d(r)}}{\sum_j \frac{c_{jld}(r)}{c_d(r)}\sigma_{jl}(r)} E_d(x) = C_E \quad \text{(15)}$$

Where $X_{E\text{-}ild(r)}$ is a scaling factor depending only on trawl catches, echotype species composition and TS equations.

The total density of targets of species i and size l for each ESDU is then computed as the sum of the fish densities at size l over all echotype categories comprising species i:

$$F_{il}(x) = \sum_d F_{ild}(x) \quad \text{(16)}$$

Total abundance in number and weight of fish of species i and class size l per square nautical mile are actually computed for each ESDU using (7) and (8), with A equal to 1:

$$Q_{il}(x) = F_{il}(x) \quad \text{and} \quad Q_{w-il}(x) = F_{il}(x) \times \langle W_{il} \rangle (r) \quad \text{(17)}$$

Where <Wil>(r) is the mean weight of species i of size l in haul r.

6.4.2.4. Abundance and biomass at age per species and ESDU

Size-age keys are derived from biological samples by otolith reading.

The density of fish of age *a* and species *i*, in echotype category *d* and ESDU *x*, associated with reference haul *r*, then writes:

$$F_{ila}(x) = q_{ila} F_{il}(x) \quad \text{(18)}$$

where:

– q_{ila} is the proportion of fish of species *i* and age *a* in the size class *l*, according to the size-age key;

– $F_{il}(x)$ is the density of fish of species *i* and size *l* in ESDU *x*.

The total density of fish of age *a* and species *i* in ESDU *x* is computed as the sum of $F_{ila}(x)$ over *l*.

Total abundance and biomass estimates per square nautical miles are actually computed in each ESDU for each species and age class using (7) and (8), with *A* equal to 1.

6.4.2.5. Biomass estimates per species and region

Echo-integrals allocated to each echotype category in each ESDU are averaged over each homogeneous region. Mean echo-integrals are then partitioned to species level, relative to the species composition in the region's mean haul.

In each region, the estimated areal fish density *Fi,d* of species *i* in echotype category *d* comprising *N* species is computed as (Diner and Le Men, 1983):

$$F_{id} = C_E \frac{w_{id}}{\sum_{j=1}^{N} w_{jd} \langle \sigma_{sp-j} \rangle} E_d \qquad (19)$$

where:

- C_E is an equipment calibration factor;
- E_d is the mean nautical area fish scattering coefficient (NASC) per ESDU for echotype category d in the region;
- w_{id} is the weight of species *i* in the computation of the mean species composition of echotype category *d* in the region (Diner and Le Men, 1983):

$$w_{id} = \frac{\sum_{k=1}^{M} E_{kd} q_{ik} / q_{dk}}{\sum_{k=1}^{M} E_{kd}} \qquad (20)$$

- $\langle \sigma_{sp-i} \rangle = 4\pi 10^{b_i + m_i \log(\bar{L}_i)/10}$ is the mean backscattering cross-section of species i, derived from the species mean length, $\bar{L}_i$, in the region's mean haul and from coefficients bi et mi (Table 1);

where :

- qik are the catches of species i recorded in the M hauls k performed in the region;
- qdk are the total catches of the species comprised in the echotype category d in a haul k;
- Ekd is the average fish backscatter allocated to echotype d recorded in a 6 NM square centered around the position of haul k (Massé et al., 1995).

For each region, abundance Qid and biomass Qw-id of species i in echotype category d are computed as:

$$Q_{id} = F_{id} \times A \quad \text{and} \quad Q_{w-id} = Q_{id} \times \bar{w}_i \qquad (21)$$

where:

- A is the region area;
- $\bar{w}_i$ is the mean weight of species i, derived from biological samples.

Total density estimates for species i in the region is actually computed as the average of density estimates of species i in all echotype categories. In the same way, total abundance and biomass estimates for species i are computed as the sum of abundance/biomass estimates of species i in all echotype categories in the region.

6.4.2.6. Estimation error

An estimation variance $\sigma^2_{E\text{-}i}$ taking into account the catches and acoustic backscatter variability is computed for each species i in echotype d and region j, based on the product variance:

$$Var\left(\overline{s_A}\,\overline{X_e}\right) = var\left(\overline{s_A}\right)\overline{X_e}^2 + var\left(\overline{X_e}\right)\overline{s_A}^2 \quad (22)$$

Assuming that :

$var\left(\overline{s_A}\right) = var\left(s_A\right)/N_{esdu} = var\left(s_A\right)w_{sA}$, with $w_{sA} = \frac{1}{N_{sA(d,j)}}$, and:

$var\left(\overline{X_e}\right) = var\left(X_e\right)w_{Xe} = var\left(X_e\right)\sum\left[s_A(n\right.$

the estimation variance hence writes:

$$\sigma^2_{E-i} = A^2 \times \sum_d \sum_j \left(w_{Aj} \cdot \left[\overline{s_{A-d,j}}^2 var\left(X_{E-d}\right.\right.\right. \quad (23)$$

where:

- A is the surface of the estimation zone;
- $\overline{s_{A-d,j}}$ and $var\left(s_{A-d,j}\right)$ are the average and the variance of acoustic backscatters allocated to echotype d in region j, respectively.
- $\overline{X_{E-d,i,j}}$ and $var\left(X_{E-d,i,j}\right)$ are the average and the variance of the XE scaling factors of species i in region j and echotype d.
- $w_{Aj} = \frac{A_j}{\sum_j A_j}$ is the weighting factor of the region j of area Aj.
- $w_{X_E-d,i,j} = \sum_k \left(\frac{s_{A-neigh,k,d,i}}{\sum_k s_{A-neigh,k,d,i}}\right)^2$ is the weight of the XE factor of species i in region j and deviation d, computed over trawl hauls k, as the mean fish sA value $s_{A-neigh,k,d,i}$ around the hauls.

6.4.2.7. Software

The fish biomass acoustic computations described above are performed at Ifremer using the EchoR R package (Doray, 2013).

7. TOP PREDATOR sighting protocol (UMS PELAGIS)

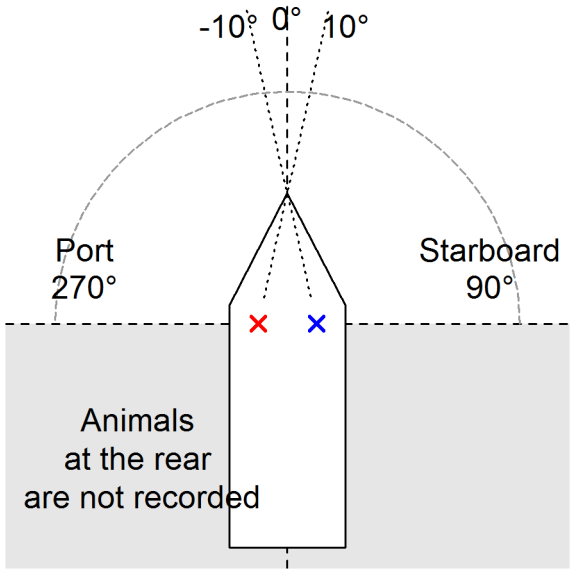
7.1. General method

Data on top predator (seabirds and cetaceans) are collected along transects, achieved over the continental shelf of bay of Biscay by ship-based surveys conducted between 2003 and 2012. These ship-based surveys involved the use of the research vessel THALASSA during PELGAS, PELACUS and EVHOE surveys. The general method used is a single platform lines transect survey.

7.2. Method of data acquisition:

Top predator sightings were recorded all the day during observation leg. An observation leg is a segment with same sighting conditions, observers, bearing and speed. If one of these parameters changes, the observation leg changes. All sightings collected are linked to the observation leg concerned. During the observation leg data on weather and sighting conditions are recorded included sea state, wind speed and direction, swell, glare severity, cloud cover and an indice of subjective condition (good, moderate, poor estimated to detect a small cetacean).

Two observers were placed at 16 m above sea level (upper bridge of the ship, see Figure below). Ship speed was maintained at 10-12 knots during the observation leg. Two observers searched for cetaceans and seabirds within an angle of 180° ahead of the bow and were renewed every two hours.



They searched with naked yes close to the ship (out of 1000m and less if sighting conditions are moderate or poor). For each sighting, number, species, time UTC were recorded, and the distance and angle was estimated by eye and with a stick and an angleboard. Additional data collected from each detected group of cetaceans or birds: included age for birds (adult, juvenile, immature), behaviour (attracting, flying, sitting, feeding for bird and swimming, logging, attracting, feeding,… for cetacean). Data on litters (macro size more than 30 cm), large pelagic fishes (shark, sunfish, swordfish, tuna,…), turtle, and boats (fishing, sailing, and commercial) are collected during the observation leg.

The GPS positions are provided by CASINO, and each day the link with the data location are performed with the UTC time.

Every change of observation leg or activity of the research vessel (trawling), the following birds (scavenger) are recorded (number and species composition)

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