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Ifremer

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Pelagic fish stock assessment by acoustic methods at Ifremer

Contents

1. Context

1.1. Objectives

The main objective of Ifremer's pelagic sea surveys (Pelgas in the Bay of Biscay and Pelmed in the Gulf of Lion) is to assess the biomass of anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) populations, based on fisheries acoustic data.

Complementary data on the whole pelagic ecosystem (hydrology, plankton, fish eggs and larvae, other fish species, seabirds and marine mammals) are also collected during the cruises.

This document describes the procedures used to derive stock abundance estimates from acoustic and fishing data collected during sea cruises, the Pelgas sea survey being used as an example.

1.2. Biscay pelagic ecosystem overview

The Bay of Biscay is a mixed-species ecosystem where gregarious pelagic fish species form numerous small schools (Petitgas2003). Main pelagic species include: sardine, anchovy, sprat (*Sprattus sprattus*), Atlantic mackerel (*Scomber scombrus),* chub mackerel *(Scomber japonicus*), Atlantic horse mackerel (*Trachurus trachurus*), Mediterranean horse mackerel (*Trachurus mediterraneus*), hake (*Merluccius merluccius*) and blue whiting (*Micromesistius poutassou*).

2. Sampling

2.1. Acoustic instrument and platform

The acoustic data are collected onboard R/V Thalassa equipped with a Simrad ER60 echosounder operating at five frequencies: 18, 38, 70, 120 and 200 kHz (beam angles at -3 dB: 7°). The vessel is also equipped with a Simrad ME70 multibeam echosounder operated in fisheries research mode. The echosounder transducers are mounted in the vessel keel, at 6 m below the sea surface.

The ME70 multibeam echosounder is configured with 21 acoustic beams spanning 84° in the athwardship direction. The spread of steering angles through the fan was optimised for side-lobe reduction (mean two way side lobes: -83 dB). Each beam has a unique frequency in the range 70–120 kHz, the highest frequencies being in the centre, and the lowest frequencies in the outer beams to maximize the angular resolution ("Λ" configuration, (Trenkel2008#2). Width and frequency of each beam are detailed in Table 1. Beam emission was in groups of 4 beams, yielding a blind zone extent of 11 m.

2.2. Acoustic measurements

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 (Foote1987#1479)(Trenkel2008#2).

Acoustic data are acquired with the Movies+ (Weill1993) and Hermes software and archived in the international hydro-acoustic data format (HAC) (ICES2005) at a -100 dB threshold.

2.3. Species identification by trawling

The identification of species and size classes comprising fish echotraces (ICES2000) heavily depends on identification via trawl hauls performed by R/V Thalassa using a 2 doors, headline: 57 m, foot rope: 52 m pelagic trawl. 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 (Petitgas2003).

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.

A commercial pair trawler accompanies R/V Thalassa during the Pelgas cruise to increase the effort devoted to echotrace identification.

2.4. Survey design

Acoustic data are collected along systematic parallel transects perpendicular to the French coast (Figure 1), from the Northern French coast to Spain. 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 (Petitgas2003#299). The inter-transect distance results from a compromise between ship time and cluster mean size.

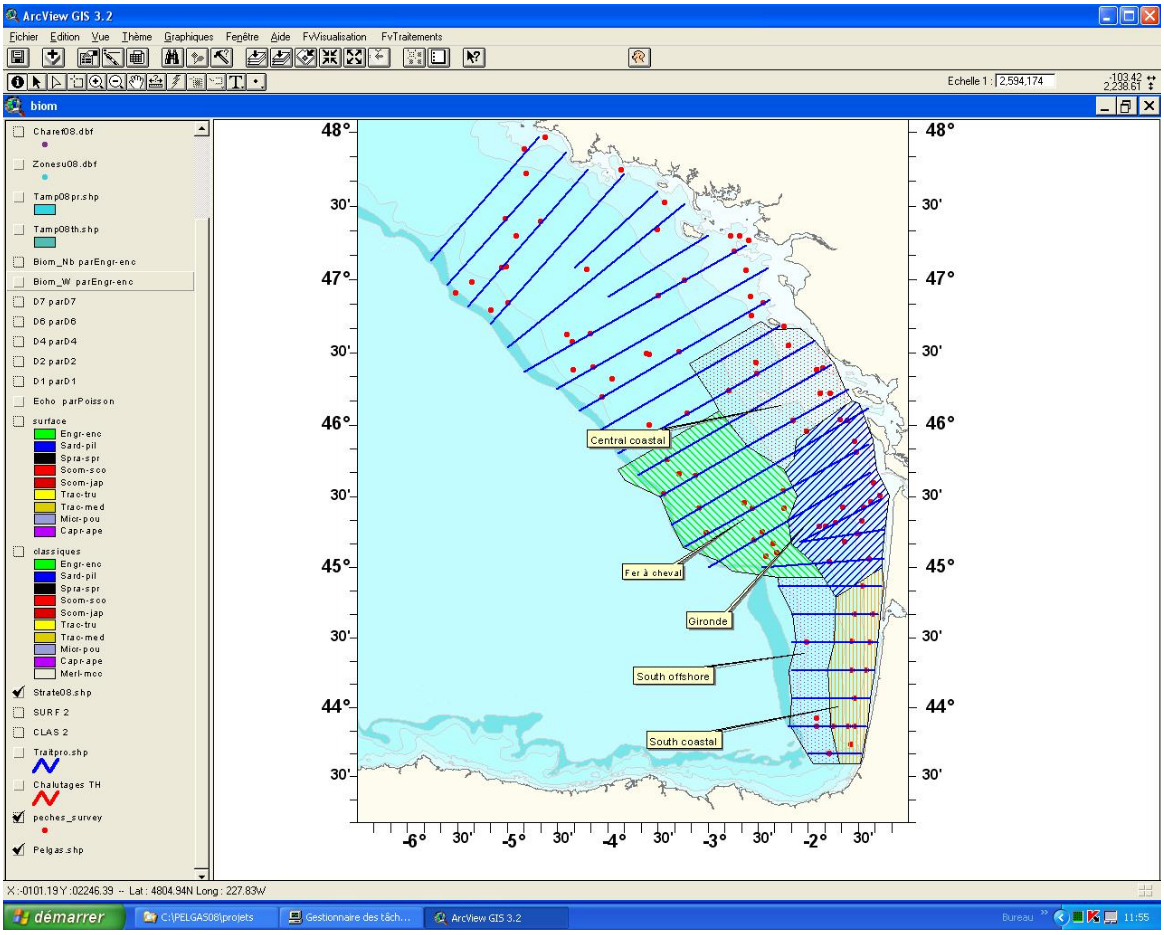

Figure 1. Bay of Biscay map and PELGAS survey design. Blue lines: acoustic transects; red dots: trawl haul station; colored areas: post-stratification regions.

The survey design allows for the coverage of the whole Biscay continental shelf, from 25 m depth to the shelf break (200 m depth). The nominal sailing speed is 10 knots (1 knot = 1852 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. Acoustic fish stock biomass assessment

3.1. General framework

Acoustic biomass estimation requires the combination of data from various origin collected along the cruise track (Woillez2009#1482). This can be viewed as the combination of three data fields: total acoustic backscatter, proportions by species and/or size class and mean length (Figure 2).

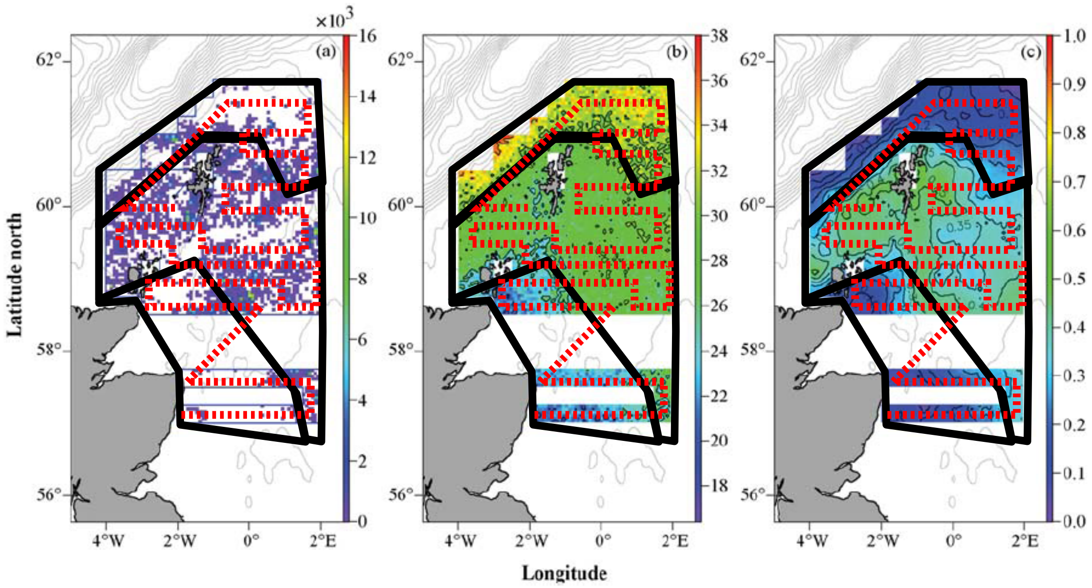

Figure 2. Data fields required for acoustic biomass assessment of a given species: a) total fish acoustic backscatter; b) species mean length; c) proportion by species and/or size class. Red dotted line: ship track; black lines: homogeneous regions boundaries. (Adapted from Woillez et al., 2009).

First, the mean density of insonified fish is usually computed for each ESDU of the cruise track, and for each species and depth channel considered. This involves five main steps: (Simmonds2005):

– <u>definition of the proportions by species from fishing data</u>.

This can be done by: i) allocating to each ESDU the proportions by species recorded in a specific 'reference haul'; ii) defining regions where species/size compositions are homogeneous. Mean species/size compositions computed for each region are then applied to the ESDUs comprised in the regions (Simmonds2005); iii) computing estimates of species proportions at the nodes of a grid overlain on the survey area, using a geostatistical model (kriging, geostatistical simulation) (Gimona2003)(Walline2007)(Woillez2009#1482). Modelled species proportions are then allocated to the closest ESDUs.

– <u>Partitioning of the total echo-integrals between species.</u>

When acoustic marks can be visually allocated with good confidence to a single species, no further echo-integrals partitioning is needed after the scrutinizing process.

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 (Nakken1977). Echo-integrals E_i allocated to species i then writes (Simmonds2005):

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

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_1, as a function of its length L (usually expressed in cm):

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

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:

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

where $<L>$ is species i mean length.

b_i et m_i coefficients used for Pelgas surveys are presented in table 2.

If echo-integrals E_i are expressed as nautical area-scattering coeffcients, S_A (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 (MacLennan2002).

– Estimation of the density of targets of species i, using the generic formula:

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

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

– 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:

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

Since the number of individuals of mean weight <*W*> per unit weight of fish is *1/<W>*, the weight-based TS function writes (Simmonds2005):

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

where:

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

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

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

– <u>Abundance estimation</u>

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.

If geostatistical interpolation procedures (kriging, conditional simulations) have been used to estimate the total fish abundance in the surveyed area from fish densities per ESDU (Rivoirard2000)(Gimona2003)(Walline2007)(Woillez2009#1482), total abundance estimates in previously defined homogeneous regions are most of the time 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 Q_i of species *i* in an homogeneous region of surface *A* then writes :

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

Z_i is a region-specific weighting factor depending only on trawl catches and TS equations (Diner1983).

In the same way, the total abundance in weight Q_{w-i} of species *i* in an homogeneous region of surface *A* then writes :

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

Where:

$\langle W_i \rangle$ is the mean weight of species *i* in the region (kg)

X_i is a region-specific weighting factor depending only on trawl catches and TS equations (Diner1983), expressed in kg.m^{-2}.

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

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

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, ones shall use the weighting factor $X_{i-1\,w}$ which writes:

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

3.2. Pelagic fish stock assessment by acoustic methods at Ifremer

Biscay fish population biomass is assessed during Pelgas cruise using an 'expert' methodology to combine acoustic and fishing data. This methodology is summarized in Figure 3.

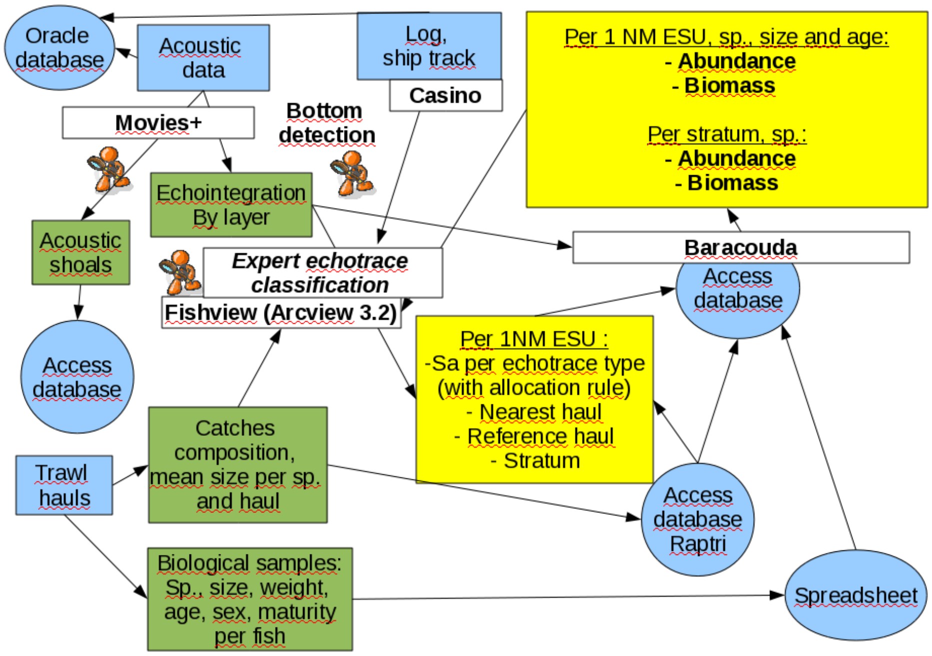

Figure 3. Flow diagram summarizing the expert methodology used to assess fish population biomass during Pelgas. Blue rectangles: raw data; blue circles: data storage; green rectangles: pre-processed data, white rectangles: softwares; yellow rectangles: assessment results.

3.2.1. Acoustic data pre-processing

Only 38 kHz backscatters are used for biomass assessment. However, echograms recorded at other frequencies are often 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 (S_v) higher than -60 dB

(Petitgas1998) 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 (S_A) are used in subsequent analysis.

3.2.2. 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.

3.2.3. Association of acoustic and fishing data

3.2.3.1. 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 (Massé1995).

3.2.3.2. Reference hauls

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

– 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.

3.2.4. Acoustic biomass estimates

3.2.4.1. 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 $E_{ild}(x)$ of species i of mean length l in echotype category d and ESDU x, associated with reference haul r writes (Diner1983) :

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

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:

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

– 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:

$$F_{ild}(x)=C_E\frac{\frac{c_{ild}(r)}{c_d(r)}}{\sum_j \frac{c_{jld}(r)}{c_d(r)}\sigma_{jl}(r)}E_d(x)=C_E\frac{c_{ild}(r)}{\sum_j c_{jld}(r)\sigma_{jl}(r)}E_d(x)=X_{E-ild}(r)E_d(x \qquad (15)$$

Where $X_{E-ild}(r)$ 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:

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

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 (9) and (10), with A equal to 1:

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

Where $\langle W_{il}\rangle(r)$ is the mean weight of species i of size l in haul r.

3.2.4.2. 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:

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

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 (9) and (10), with A equal to 1.

3.2.4.3. Biomass estimates per species and region

Echo-integrals allocated to each echotype category in each ESDU are averaged for each homogeneous region and partitioned to species level relative to the species composition in the region's mean haul.

In each region, the estimated areal fish density $F_{i,d}$ of species i in echotype category d comprising N species is computed as (1)(4)(Diner1983):

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

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;
- $\langle\sigma_{sp-i}\rangle=4\pi\,10^{b_i+m_i\log(\bar{L}_i)/10}$ 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 b_i et m_i (Table 2);
- w_{id} is the weight of species i in the computation of the mean species composition of echotype category d in the region (Diner1983):

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

where :

- q_{ik} are the catches of species i recorded in the M hauls k performed in the region;
- q_{dk} are the total catches of the species comprised in the echotype category d in a haul k ;
- E_{kd} is the average fish backscatter allocated to echotype d recorded in a 10 NM square centered around the position of haul k (Massé1995).

For each region, abundance Q_{id} and biomass Q_{w-id} of species i in echotype category d are computed as:

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

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.

3.3. Estimation error

An estimation variance σ^2_{E-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:

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

Assuming that :

$var(\overline{s_A})=var(s_A)/N_{esdu}=var(s_A)w_{sA}$, with $w_{sA}=\frac{1}{N_j}$, N_j being the numbre of acoustic ESDUs in region *j*, and:

$$var(\overline{X_e})=var(X_e)w_{Xe}=var(X_e)\sum_k[s_A(nei_k)/\sum_k s_A(nei_k)]^2$$

the estimation variance hence writes:

$$\sigma^2_{E-i}=A^2\times\sum_d\sum_j(w_{Aj}\cdot[\overline{s_{A-d,j}}^2 var(X_{E-d,i,j})w_E+\overline{X_{E-d,i,j}}^2 var(S_{A-d,j})w_{sA}]) \tag{23}$$

where:

- A is the surface of the estimation zone;
- $\overline{s_{A-d,j}}$ and $var(s_{A-d,j})$ are the average and the variance of acoustic backscatters allocated to echotype *d* in region *j,* respectively.
- $\overline{X_{E-d,i,j}}$ and $var(X_{E-d,i,j})$ are the average and the variance of the X_E scaling factors of species *i* in region j and echotype *d*.
- $w_{Aj}=\frac{A_j^2}{(\sum_j A_j)^2}$ is the weighting factor of the region *j* of area A_j.

– $w_{X_E-d,i,j}=\sum_k \left(\frac{s_{A-neigh,k,d,i}}{\sum_k s_{A-neigh,k,d,i}}\right)^2$ is the weight of the X_E 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.

4. Tables

Table 1. Characteristics of ME70 acoustic beams. Steering angles are given from port (negative values) to starboard (positive values).

0	0	0	0	0
1	-39	79	9.4	-82
2	-30	85	7.9	-82
3	-23	91	6.9	-83
4	-16	97	6.2	-83
5	-10	104	5.7	-84
6	-4	110	5.4	-84
7	1	117	5	-85
8	6	113	5.2	-84
9	11	107	5.6	-84
10	17	100	6.1	-83
11	24	94	6.7	-83
12	30	88	7.7	-82
13	39	82	9.2	-81

Beam number	Steering angle (°)	Frequency (kHz)	Beam width (°)	Side lobe level (dB)
1	-39	79	9.4	-82
2	-30	85	7.9	-82
3	-23	91	6.9	-83
4	-16	97	6.2	-83
5	-10	104	5.7	-84
6	-4	110	5.4	-84
7	1	117	5	-85
8	6	113	5.2	-84
9	11	107	5.6	-84
10	17	100	6.1	-83
11	24	94	6.7	-83
12	30	88	7.7	-82
13	39	82	9.2	-81

Table 2. TS coefficients used for acoustic fish biomass assessment.

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)*

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