Stock Annex: Anchovy (*Engraulis encrasicolus*) in Subarea 8 (Bay of Biscay)

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Anchovy
Working Group:	Working Group on the Assessment of Southern Horse-Mackrel, Anchovy and Sardine (WGHANSA)
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Authors	G. Boyra, E. Duhamel, L. Ibaibarriaga, J. Massé, L. Pawlowski, M. Santos and A. Uriarte.
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A. General

A.1. Stock definition

The Anchovy (*Engraulis encrasicolus*) inhabiting Subarea 8 (Bay of Biscay) is considered to be isolated from a small population in the English Channel and from the populations in western Iberia (Division 9.a) (Magoulas *et al.*, 2006; Zarraonaindia *et al.*, 2012). Morfometrics and meristic studies suggest some heterogeneity at least in morphotipes (Prouzet and Metuzals, 1994; Junquera and Pérez-Gandaras, 1993). Along the North of Spain (in Division 8.c) Junquera and Pérez-Gandaras (1993) had already reported significant morphological differences in anchovies between Galicia, Asturias, and the Basque Country, and recently Borrell *et al*. (2012) have pointed out that there is some genetic isolation of anchovies in the middle west side of this division from the eastern one. In addition, some genetic heterogeneity, based on proteins *allocime loci*, have been found between the Garonne spawning regions and southern regions in the Bay of Biscay (Adour and Cantabrian shores) (Sanz *et al.*, 2008). Despite the evidences for some heterogeneity and perhaps subpopulation in parts of the Bay of Biscay (western Cantabria), there are ample evidences that the major part of the population inhabits the Eastern and northern parts of the Bay of Biscay and show rather homogenous recruitment pulses and have a rather well understood common spatial dynamics throughout the year (Uriarte *et al.*, 1996). This leads ICES to consider that the anchovy in this area should be dealt as a single stock for assessment and management.

A.2. Fishery

The fisheries were closed from July 2005 to December 2009 due to poor condition of the stock. It was reopened in January 2010 with a TAC of 7000t. The fisheries for anchovy are targeted by purse-seiners and pelagic trawlers. The Spanish and French fleets fishing for anchovy in Subarea 8 are spatially and temporally quite well separated. The Spanish fleet (purse-seine fleet) operates mainly in Divisions 8.c and 8.b in spring, while the French fleet (mainly pelagic trawlers) operates in Division 8.a in summer and autumn and in Division 8.b in winter and summer. A small fleet of French purse-seiners operates in the south of the Bay of Biscay (8.b) in spring and in the north

(8.a) during the autumn. An overview of the history of the fishery until the mid-nineties and its spatial behaviour is found in Junquera (1986) and Uriarte *et al.* (1996) and for more recent perspective see ICES (2007, 2008) or STECF (2008) for the international fishery, Uriarte *et al.* (2008); Villamor *et al.* (2008), for the Spanish fishery and Duhamel(2004) and Vermard *et al.* (2008) for the French pelagic trawler. According to information provided by the SWWRAC in 2009 during the closure of the fishery the fleet size operating on anchovy decreased and the fleets redeployed their effort towards other small pelagic species (57%) and tuna (29%).

A.3. Ecosystem aspects

Anchovy is a prey species for other pelagic and demersal species in the Bay of Biscay, and also for cetaceans and birds (Goñi *et al.*, 2011a,b; López-López *et al.*, 2012). In addition to predator interactions on adults, in recent years major attention is being paid to the role that intraguild predation may have in affecting the survival of early life stages (Irigoien and Ross, 2011), and for this anchovy the potential influence of sardine predating on anchovy eggs has been evidenced (Bachiller *et al.*, submitted).

The recruitment depends strongly on environmental factors. Recently ICES WGSPEC (ICES, 2012) has reviewed the role that environmental factors may have on determining the success of recruitment. Two environmental recruitment indices have been considered during the last ten years: i) Borja's *et al.* (1998) index, which is an upwelling index, and ii) Allain's *et al.* (2001) index, which is a combination of upwelling and stratification breakdown. Allain's model was reviewed by Huret and Petitgas (WD 2007, ICES2008) including a) the previous "upwelling" index, plus a new "stratification" index according to a new hydrodynamic model and b) an adult spatial indicator. The role of the Eastern Atlantic pattern in relation to the Upwelling index and the recruitment of anchovy have also been recently pointed out (Borja *et al.*, 2008). Other approaches based on coupling spawning habitat with hydrodynamic and production models are being tried for this anchovy population with promising results (Allain *et al.*, 2007). From the latter studies the issue of much drifting (induced by the Upwelling) of the anchovy eggs and larval out of the shelf is controversial among scientists (Borja *et al.*, 1996; 1998; Uriarte, 2001; Allain *et al.*, 2001; 2007; Irigoien, 2007; 2008).

Recent research for identifying and monitoring limiting factors of anchovy recruitment in the Bay of Biscay was made by Petitgas (2011). Indices of physical features were estimated (river plumes, gyres, stratification, fronts) as well as indices of larval dispersal, primary production and temperature. Indices of spawning aggregations derived from fisheries survey data were also estimated. Results showed that the larval period was where many indices responded, confirming that it is a critical period. The limiting factors changed across the series, confirming the multiple nature of the determinism of recruitment.

Fernandes *et al.* (2010) presents an alternative to attempt to relate environmental indices with recruitment by means of linear models. They use machine-learning techniques to obtain the probability of having a recruitment discretized into low, medium and high classes depending on environmental variables. The proposed methodology consists of performing supervised predictors discretization, carrying out supervised predictors selection and learning a 'naive Bayes' classifier. The approach can be applied to a dataset where the values of the recruitment have been discretized by the end-user, or the recruitment discretization can be part of the proposed model-building process in a bootstrap scheme. Environmental variables seem to explain a significant part of the observed variability of the small pelagics but not more than 50% of it (at least from the

available indicators), so that there is space for looking for other supplementary variables driving recruitment for these species. The significance and reliability of all these indices is considered still insufficient for their consideration alone in the provision of management advice. But they are considered valuable information accompanying the forecasts given from recruitment surveys such as JUVENA. It is certainly useful their consideration for further improvements.

B. Data

B.1. Commercial catches

Annual landings are available since 1940. Discards are not measured and hence not included in the assessment, but nowadays they are considered not relevant for the two fleets. In the past (late eighties and early nineties for the French Pelagic trawlers and sixties and seventies for the Spanish Purse seine fleet) they seemed to be more relevant (according to disputes among fishermen), but were never quantified.

B.2. Biological

- Catches-at-length and catches-at-age are known since 1984 for Spain and since 1987 for France. They are obtained by applying to the monthly Length distributions half year or quarterly ALKs (and when possible monthly ALKs, as for the Spanish fishery in spring). Biological sampling of the catches has been generally sufficient, except for 2000 and 2001, when an increase of the sampling effort seemed useful to have a better knowledge of the age structure of the catches during the second semester in the North of the Bay of Biscay. Complete age composition and mean weight-at-age on half year basis, were reported in ICES.

- Age reading is considered accurate.

  The most recent cross reading exchanges and workshop took place in 2009 WKARA (ICES CM 2009/ACOM:43). The overall level of agreement and precision in anchovy age reading determinations seemed to be satisfactory: Most of the anchovy otoliths were well classified by most of the readers during the exchange (with an average agreement of 88.8% and a CV of 12.9%). CV was minimum at age 0 and increased slightly with age while the percentage of agreement decreased with age (with Percentage of agreement with the modal ages of 100%, 83%, 91% and 63% respective to ages 0, 1, 2 and 3). The most expert readers who are in charge of the largest fraction of the international catches showed higher agreements than the rest of readers.

- In former workshops between Spain and France which took place in 2005 and 2006 respectively (Uriarte *et al.*, 2006 and 2007) the overall level of agreement and precision in anchovy age reading determinations was also satisfactory. Most of the anchovy otoliths were well classified by most of the readers during the 2006 workshop (with an average agreement of 92.7% and a CV of 9.2%). CVs were on average smaller than 15% for any age, although individual CVs for ages or readers might be 30–35%. Anchovies are mature at their 1st year of life.

- Growth in weight and length are well known from surveys and from the monitoring of the fishery (Uriarte *et al.*, 1996).

- Natural mortality is fixed at 0.8 for age 1 and at 1.2 for older individuals. This parameter is considered to vary between years, but it is assumed to be constant for the assessment of the stock.

- In the CBBM assessment model the parameters G_1 and G_{2+} representing the annual intrinsic growth of the population by age class are assumed constant along years and are estimated based on the weight-at-age data.

B.3. Surveys

The population is monitored by the two annual surveys carried out in spring on the spawning stock, namely, the Daily Egg Production Method (since 1987 with a gap in 1993) (Santiago and Sanz, 1992; Motos *et al.*, 2005; Santos *et al.*,2011) and the Acoustics surveys (regularly since 1989, although surveys were also conducted in 1983, 1984 and some in the seventies) (Massé, 1988; 1994; 1996). Both surveys provide spawning bio-mass (this equals total stock biomass since all anchovies are mature in spring) and pop-ulation-at-age estimates. The surveys have shown pronounced interannual variability of biomass according to the pulse of recruitments, since one year old anchovies can conform up to more than 75% of the spawning population. Spawning area and biomass are positive and closely related, revealing expansion of the area occupied by the pop-ulation when SSB increases (Uriarte *et al.*, 1996; Somarakis *et al.*, 2004).

The spring surveys provide population estimates by the middle of the year, when about half of the annual catches have been already taken; and provide very little infor-mation about the anchovy population in the next year, since the bulk of it will consist of one year old anchovies being born at the time the surveys take place. Since 2003 an autumn acoustic survey (JUVENA) is conducted yearly. The main objective of this sur-vey is estimating the anchovy juvenile abundance in order to forecast the strength of the recruitment that will enter the fishery the next year.

B.3.1 Anchovy Daily Egg Production Method

B.3.1.1 The DEPM model

The anchovy spawning–stock biomass estimate is derived according to Parker (1980) and Stauffer and Picquelle (1980) from the ratio between daily production of eggs in the sea and the daily specific fecundity of the adult population:

$$SSB = P_{tot}\Big/DF = \frac{P_0 \cdot A+}{k \cdot R \cdot F \cdot S/W} \qquad \text{Equation B.3.1.1}$$

Where,

   SSB = Spawning–stock biomass in metric tons

   P_{tot} = Total daily egg production in the sampled area

   P_0 = daily egg production per surface unit in the sampled area

   A+   = Spawning area, in sampling units

   DF = Daily specific fecundity. $DF = \dfrac{k \cdot R \cdot F \cdot S}{W_f}$ Equation B.3.1.2

      W_f = Average weight of mature females in grams,

      R = Sex ratio, fraction of population that are mature females, by weight.

F = Batch fecundity, numbers of eggs spawned per mature females per batch

S= Fraction of mature females spawning per day

k = Conversion factor from gram to metric tons (10^6)

An estimate of an approximate variance and bias for the biomass estimator derived using the *delta* method (Seber, 1982, *in* Parker 1985.) was also developed by the latter authors.

Population estimates of numbers-at-age are derived as follows:

$$N_a = N \cdot E_a = \frac{SSB}{W_t} \cdot E_a$$
Equation B.3.1.3

Where,

N_a = Population estimate of numbers-at-age *a*.

N = Total spawning–stock estimate in numbers. $N = \dfrac{SSB}{W_t}$

SSB = spawning–stock biomass estimate.

W_t= average weight of anchovies in the population.

E_a = Relative frequency (in numbers) of age *a* in the population.

W_t and E_a are obtained from the average of the mean weight and the percentages by ages across the anchovy samples from the survey (see the adult parameter section below).

Variance estimate of the anchovy stock in numbers-at-age and total is derived applying the delta method.

B.3.1.2 Collection of plankton samples

Every year the area covered to collect the plankton samples is the southeast of the Bay of Biscay which corresponds to the main spawning area and spawning season of anchovy.

Predetermined distribution of stations is shown in Figure B.3.1.2.1.The strategy of egg sampling is as follow: a systematic central sampling scheme with random origin and sampling intensity depending on the egg abundance found (Motos, 1994). Stations are located every three miles along 15-mile-apart transects perpendicular to the coast. The sampling strategy is adaptive. When the egg abundances found are relatively high, additional transects separated by 7.5 nm are completed.
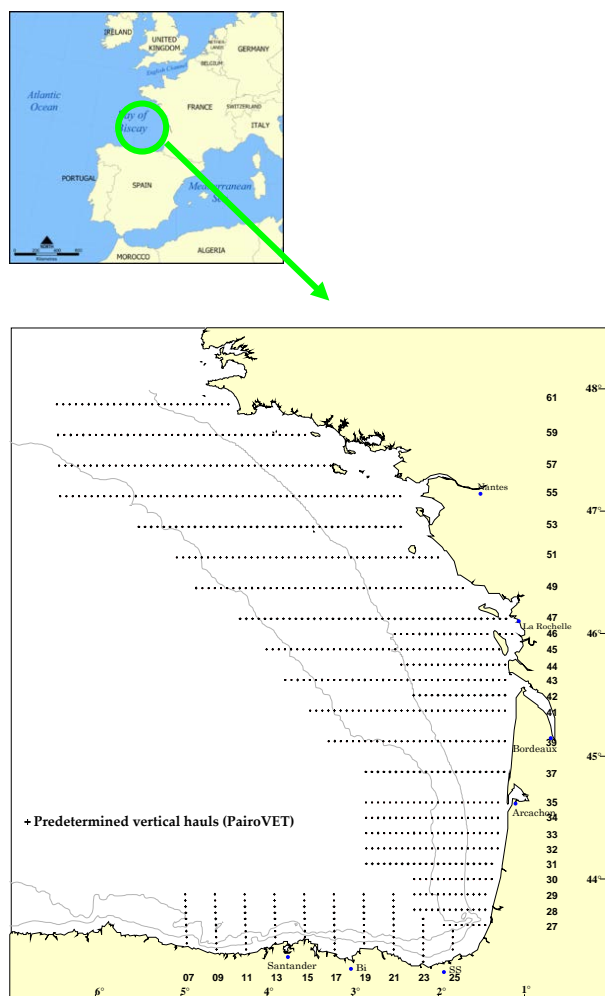
Figure B.3.1.2.1. Predetermined stations of the vertical hauls (PairoVET) that could be performed during the survey.

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

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

The Continuous Underway Fish Egg Sampler (CUFES, Checkley *et al*., 1997) is used to record the eggs found at 3m depth with a net mesh size of 350μm. The samples obtained are immediately checked under the microscope so that the presence/absence of anchovy eggs is detected in real time. When anchovy eggs are not found in six consecutive CUFES samples in the oceanic area transect is abandoned. The CUFES system has

a CTD to record simultaneously temperature and salinity at 3 m depth, a flowmeter to measure the volume of the filtered water, a fluorimeter and a GPS (Geographical Position System) to provide sampling position and time. All these data are registered at real time using the integrated EDAS (Environmental Data Acquisition System) with custom software.

During the survey, the anchovy, sardine and other eggs are recorded per PairoVET station and the area where anchovy eggs occurred is quantified. The spawning area is delimited with the outer zero anchovy egg stations. It contains some inner zero egg stations embedded on it (Picquelle and Stauffer, 1985). Following the systematic central sampling scheme (Cochran, 1977) each station is located in the centre of a rectangle. Egg abundance found at a particular station is assumed to represent the abundance in the whole rectangle. The area represented by each station is measured. A standard station has a surface of 45 squared nautical miles (154 km^2) = 3 (distance between two consecutive stations) x 15 (distance between two consecutive transects) nautical miles. Since sampling is adaptive, station area changed according to sampling intensity and the cut of the coast.

Sample depth, temperature, salinity and fluorescence profiles are obtained in every station using a CTD RBR-XR420 coupled to the PairoVET. In addition, surface temperature and salinity are recorded in each station with a manual termosalinometer WTW LF197. Moreover current data are obtained all along the survey with an ADCP (Acoustic Doppler Current Profiles). In some point determinate previously to the survey, water is filtered from the surface to obtain chlorophyll samples to calibrate the chlorophyll data.

The historical maps of anchovy egg distribution obtained with PairoVET are shown in Figure B.3.1.2.2.

B.3.1.3 Collection of adult samples

In 1987 and 1988 the samples were obtained from commercial purse-seines and the adult sampling was opportunistic. From years 1989 to 2005 the adult samples were obtained both from commercial purse-seines and a research vessel with pelagic trawl so the adult sampling was both opportunistic and directed. Since 2006 the samples are obtained from a research vessel with pelagic trawl. Samples from the purse-seines were not available due to the closure of the fishery. Since the reopening of the fisheries in March 2010 the commercial purse-seines are providing again samples for the analysis apart from the ones obtained from the research vessel.

The research vessel pelagic trawler covers the same area as the plankton vessel. When the plankton vessel encountered areas with anchovy eggs, the pelagic trawler is directed to those areas to fish. In each haul 100 individuals of each species are measured. Immediately after fishing, anchovy is sorted from the bulk of the catch and a sample of two Kg is selected at random. A minimum of one kg or 60 anchovies are weighted, measured and sexed and from the mature females the gonads of 25 non-hydrated females (NHF) are preserved. If the target of 25 NHF is not completed ten more anchovies are taken at random and process in the same manner. Sampling is stopped when 120 anchovies have to be sexed to achieve the target of 25 NHF. Otoliths are extracted on board and read in the laboratory to obtain the age composition per sample. In case samples are obtained from the purse-seines, a sample of two kg is selected from the fishing and is directly kept in 4% formaldehyde. Afterwards, in the laboratory the samples are process in the same manner as explained above.

B.3.1.4 Total daily egg production estimates

When all the anchovy eggs are sorted and staged, it is possible to estimate the total daily egg production (P$_{tot}$). This is calculated as the product between the daily egg production (P$_0$) and the spawning area (SA):

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

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

The daily egg production per area unit (P$_0$) was estimated together with the daily mortality rate (Z) from a general exponential decay mortality model of the form:

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

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

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

where the number of eggs of daily cohort *j* in station *i* (N$_{ij}$) was assumed to follow a negative binomial distribution. The logarithm of the effective sea surface area sampled (log(R$_i$)) was an offset accounting for differences in the sea surface area sampled and the logarithm of the daily egg production log(P$_0$) and the daily mortality Z rates were the parameters to be estimated.

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

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

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

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

The pdf of spawning time f(spawn=τ - age) allows refining the ageing process for species with spawning synchronicity that spawn at approximately certain times of the

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

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

> Step 1. Assume an initial mortality rate value;
>
> Step 2. Using the current estimates of mortality calculate the daily cohort frequencies and their mean age;
>
> Step 3. Fit the GLM and estimate the daily egg production and mortality rates. Update the mortality rate estimate;
>
> Step 4. Repeat steps 1–3 until the estimate of mortality converged (i.e. the difference between the old and updated mortality estimates was smaller than 0.0001).

Incomplete cohorts, either because the bulk of spawning for the day was not over at the time of sampling, or because the cohort was so old that its constituent eggs had started to hatch in substantial numbers, were removed in order to avoid any possible bias. At each station, younger cohorts were dropped if they were sampled before twice the spawning peak width after the spawning peak and older cohorts were dropped if their mean age plus twice the spawning peak width was over the critical age at which less than 99% eggs were expected to be still unhatched. In addition, cohorts in which hatching has started are excluded: Upper limit is set at the age in which 99% of the eggs are unhatched, having developed at the 50 quantile of the incubation temperature.

Once the final model estimates were obtained the coefficient of variation of P_0 was calculated from the standard error of the model intercept (log(P0)) (Seber, 1982) and the coefficient of variation of Z was obtained directly from the model estimates.

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

B.3.1.5 Adult parameters and daily fecundity estimates

The daily fecundity (DF) estimate for the WGHANSA in June is obtained following the equation B.3.1.2. The adult parameters sex ratio (R), Batch fecundity (F) and average weight of mature female (W_f) are estimate in June from the adults obtained during the survey as explained below. The Spawning frequency (S) is taken in June as the mean of the historical series because histologic processing is required for this parameter and this takes longer than 15 days (time lapsed from the end of the survey until the evaluation meeting in June).Afterwards in the ICES WGACEGG in November the complete DEPM with all the adult parameters, including S estimates, is presented and approved. This occurred since 2005 when the advice started demanding SSB estimates in June.

In case of not having time enough after the survey in a particular year as to process the adult parameters for the June assessment then the mean of past Daly Fecundity estimates would be preliminarily borrowed from the historical series.

Ordinary processing of the adult parameters: From the whole set of adult samples gathered during the survey, a subset is chosen for final processing with the criterion of collection within ±5 days of the egg sampling in the same particular area. In the last years the samples were collected within the same day as the egg sampling. Batch fecundity (F), spawning fraction (S), average female weight (W) and sex ratio (R) are estimated as follows:

Sex Ratio (R): Given the large variability among samples of the sex ratio and taking into account that for most of the years when the DEPM has been applied to this population the final estimate has come out to be not significantly different from 50% for each sex (in numbers), since 1994 the proportion of mature females per sample is being assumed to be equal to 1:1 in numbers. This leads to adopt as R the value of the average sample ratio between the average female weight and the sum of the average female and male weights of the anchovies in each of the samples.

Total weight of hydrated females is corrected for the increase of weight due to hydration. Data on gonad-free-weight (Wgf) and correspondent total weight (W) of non-hydrated females is fitted by a linear regression model. Gonad-free-weight of hydrated anchovies is then transformed to total weight by applying the following equation:

$$W = -a + b * W_{gf}$$

For the **Batch fecundity (F)** estimates i.e. number of eggs laid per batch and female, the hydrated egg method was followed (Hunter *et al.*, 1985). The number of hydrated oocytes in gonads of a set of hydrated females is counted. This number is deduced from a subsampling of the hydrated ovary: Three pieces of approximately 50 mg are removed from different parts of each ovary, weighted with precision of 0.1 mg and the number of hydrated oocytes counted. Sanz and Uriarte (1989) showed that three tissue samples per ovary are adequate to get good precision in the final batch fecundity estimate and the location of subsamples within the ovary do not affect it. Finally the number of hydrated oocytes in the subsample is raised to the total gonad of the female according to the ratio between the weights of the gonad and the weight subsampled.

A linear regression between female weight and batch fecundity is established for the subset of hydrated females and used to calculate the batch fecundity of all mature females. The average of the batch fecundity estimates for the females of each sample as derived from the gonad free weight; eggs per batch relationship is then used as the sample estimate of batch fecundity.

Moreover, an analysis is conducted to verify if there are differences in the batch fecundity between different strata if strata are defined to estimate SSB.

To estimate **Spawning Frequency (S)**, i.e. the proportion of females spawning per day:Spawning frequency estimates are obtained applying the new classification for oocyte and POFs stage of Alday *et al*. (2008) and the procedures described in Uriarte *et al*. (2012). The degeneration of postovulatory follicles (POFs) in time at different temperatures was studied for the Bay of Biscay anchovy by Alday *et al*. (2008). For this purpose a key of seven POF stages, solely defined on the basis of their histological degeneration characteristics, was applied (Alday *et al*., 2008; 2010). The novelty of this procedure is that it separates staging of POFs from their ageing process. The ovaries, taken from several captivity experiments and field samples, were classified in this way. There was

close agreement in the succession of POF stages after spawning between the experiment and the field samples. The first four stages of POF occurred in less than 24 h, and by the end of the first day the POFs were mainly in Stage V. Stages VI and VII showed their highest occurrence during the first and second half of the second day after spawning, respectively. Full reabsorption of POFs was achieved in 55–60 h. For the range of temperatures examined (13–19°C), little effect of temperature on the degeneration of POF was noticed.

The procedure to assign mature females to spawning classes was improved by incorporating all the knowledge on oocyte maturation and degeneration of POFs in a matrix system which defines the probabilities of females with those histological indicators belonging to pre- or post-spawning cohort according to the time of capture (Uriarte *et al.*, 2012).

Finally, the selected estimator is the mean of S (day 0) and S (day 1). Corrections of sample estimates +/-five hours around peak spawning time (23:00 hours) were applied according to the formulas in Uriarte *et al.* (op. cit.) for an average S of 0.39.

For the years with S estimates which could not be reviewed by the time of WKPELA 2013 (2006, 1989, 1988 and 1987), but have their own estimates of the other reproductive parameters, the average of the historical series (1990–2012) of new S was considered. For the years which did not have any adult reproductive parameters, 1996, 1999 and 2000, the average Daily Fecundity (DF) estimate across the historical series (1990–20012) was adopted (of about 98.5 eggs gram-1 day-1).

Mean and variance of the adult parameters are estimated following equations for cluster sampling (as suggested by Picquelle and Stauffer, 1985):

$$Y = \frac{\sum_{i=1}^{n} M_i \, y_i}{\sum_{i=1}^{n} M_i} \qquad\qquad \text{Equation 6}$$

$$Var(Y) = \frac{\sum_{i=1}^{n} M_i^2 \, (y_i - Y)^2}{\overline{M}^2 \, n \, (n-1)} \qquad\qquad \text{Equation 7}$$

Where,

Y_i is an estimate of whatever adult parameter from sample i and M_i is the size of the cluster corresponding to sample i. occasionally a station produced a very small catch, resulting in a small subsample size. To reflect the actual size of the station and its lower reliability, small samples were given less weight in the estimate. For the estimation of W, F and S, a weighting factor was used, which equalled to one when the number of mature females in station i (M_i) was 20 or greater and it equalled to $M_i/20$ otherwise. In the case of R when the total weight of the sample was less than 800 g then the weighting factor was equal to total weight of the sample divided by 800 g, otherwise it was set equal to one. In summary for the estimation of the parameters of the Daily Fecundity we are using a threshold-weighting factor (TWF) under the assumption of homogeneous fecundity parameters within each stratum.

B.3.1.6 SSB estimates

In WGHANSA during June the spawning–stock biomass (SSB) is preliminary esti-
mated, following equation B.3.1.1, as the ratio between the total egg production (P_{tot})
and Daily Fecundity (DF) (the latter estimated as the equation 2 with the exception of
the S parameter that is obtained as the mean of the historical series).The SSB variance
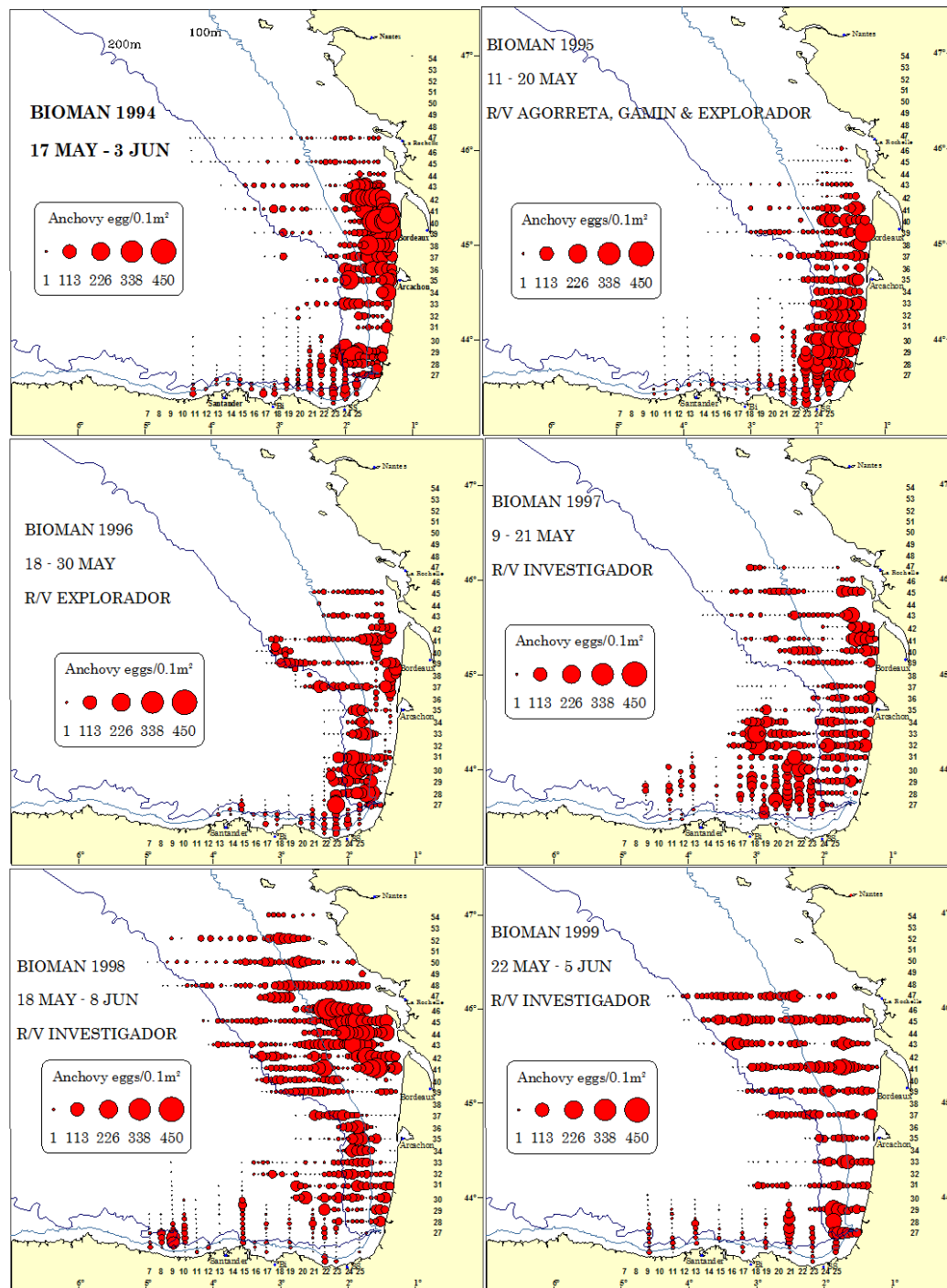is computed using the Delta method (Seber, 1982):

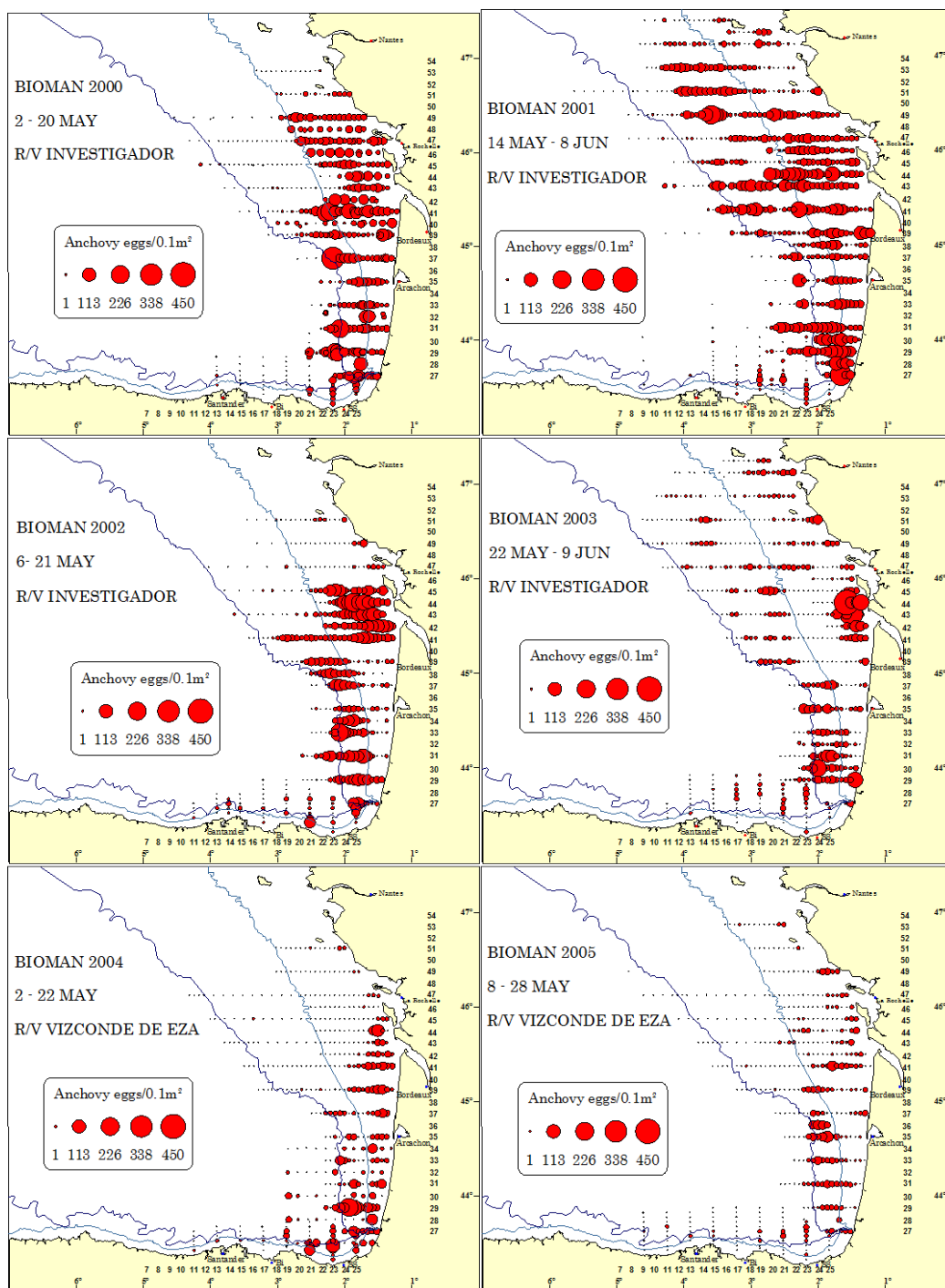$$Vâr[SSB] = \frac{Vâr[Ptot]}{DF^2} + \frac{P_{tot}^2 Vâr[DF]}{DF^4}$$

The definitive SSB estimate, following B.3.1.1, with all the adult parameters including
the S estimate is presented and approved at WGACEGG during November.

B.3.1.7 Numbers–at–age

For the purposes of producing population-at-age estimates, the age readings based on
otoliths from the adult samples collected are available. Estimates of anchovy mean
weights and proportions-at-age in the adult population are computed as a weighted
average of the mean weight and age composition per samples where the weights are
proportional to the population (in numbers) in each stratum considered. These
weighting factors are proportional to the egg abundance per stratum divided by the
numbers of samples in the stratum and the mean weight of anchovy per sample.
Weighting factors were allocated according to the relative egg abundance and to the
amount of samples in the strata defined for the proposed of the estimation of the num-
bers-at-age. These strata are defined each year depending on the distribution of the
adult samples i.e. size, weight, age and the distribution of the anchovy eggs.

Mean and variance of the adult parameters of the population in numbers-at-age and
the population length distribution (total weight, proportion by ages and length distri-
bution) are estimated following equations 6 and 7 for cluster sampling.

BIOMAN 1994
17 MAY - 3 JUN

BIOMAN 1995
11 - 20 MAY
R/V AGORRETA, GAMIN & EXPLORADOR

BIOMAN 1996
18 - 30 MAY
R/V EXPLORADOR

BIOMAN 1997
9 - 21 MAY
R/V INVESTIGADOR

BIOMAN 1998
18 MAY - 8 JUN
R/V INVESTIGADOR

BIOMAN 1999
22 MAY - 5 JUN
R/V INVESTIGADOR

BIOMAN 2006
4 - 24 MAY
R/V VIZCONDE DE EZA

Anchovy eggs/0.1m²
1 113 226 338 450

BIOMAN 2007
3 - 23 May
R/V Investigador

anchovy eggs/0.1m²
1 113 226 338 450

+ Plankton stations (n = 420)
Total area surveyed = 56,079Km²
Spawning area = 34,449Km²

BIOMAN 2008
6 - 26 May
R/V Investigador

Anchovy eggs/0.1m2
1 113 226 338 450

+ Stations with 0 anchovy eggs

BIOMAN 2009
5 - 25 May
R/V Investigador

Anchovy egg/0.1m²
1 113 226 338 450

BIOMAN 2010
5 - 20 May
R/V Investigador

Anchovy eggs/0.1m2
1 113 226 338 450

BIOMAN 2011
6 - 27 May
R/V Investigador

Anchovy egg/m²
1 113 226 338 450

BIOMAN 2012
10 - 30 May
R/V Ramón Margalef

Anchovy eggs(eggs/0.1m^2)
1 113 226 338 450

BIOMAN 2013
9 - 28 May
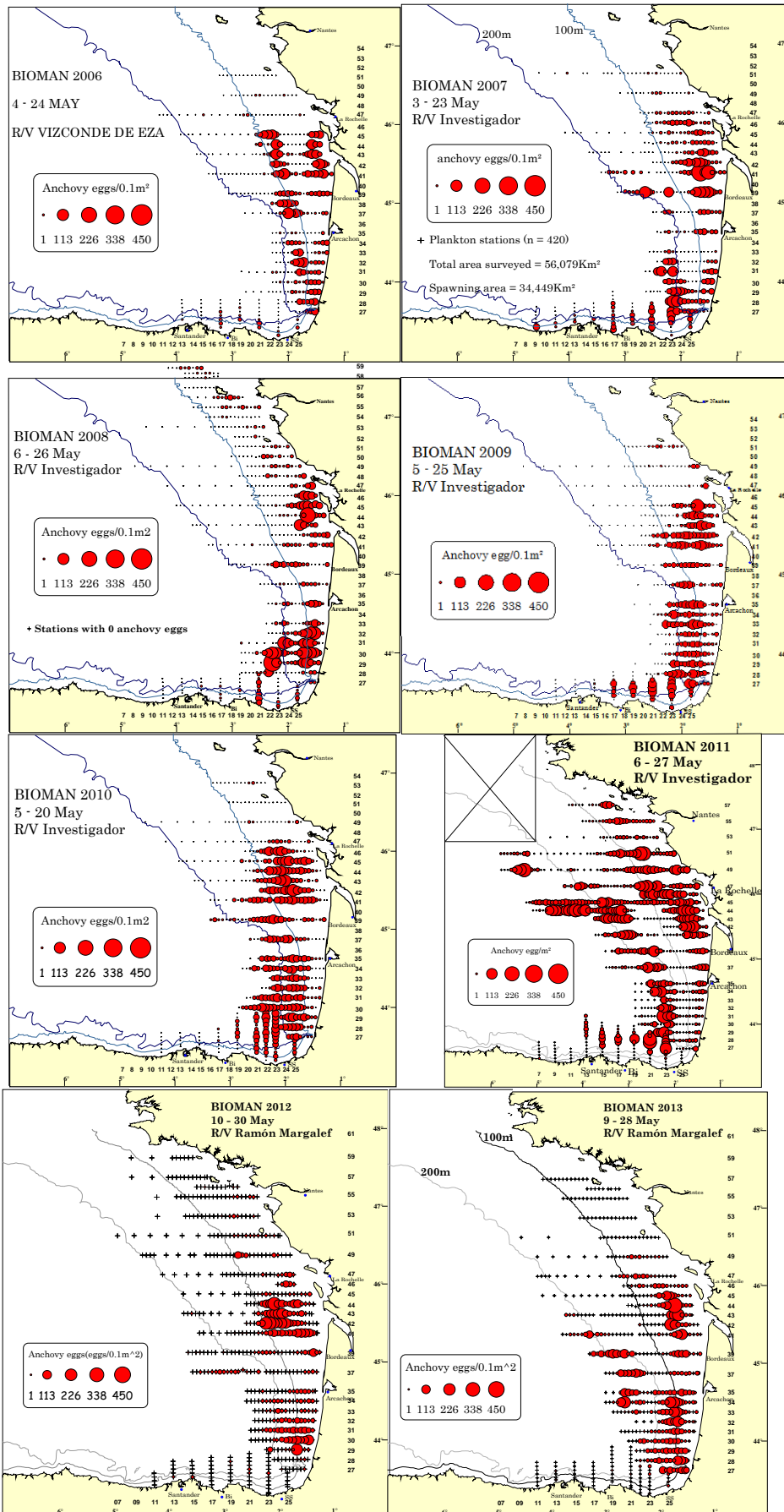R/V Ramón Margalef

Anchovy eggs/0.1m^2
1 113 226 338 450

Figure B.3.1.2.2. Anchovy egg distribution from 1998 to 2013.The circles represent the anchovy egg abundance /0.1m² encountered in each plankton station.

B.3.2. Anchovy acoustic indices

Acoustic surveys are carried out every year in the Bay of Biscay in spring on board the French research vessel Thalassa. The objective of PELGAS surveys is to study the abundance and distribution of pelagic fish in the Bay of Biscay. The main target species is anchovy but it will be considered in a multispecific context as species located in the centre of ecosystem.

These surveys are connected with Ifremer programmes on data collection for monitoring and management of fisheries and ecosystemic approach for fisheries. This task is formally included in the first priorities defined by the Commission regulation EU N° 199/2008 of 06 November 2008 establishing the minimum and extended Community programmes for the collection of data in the fisheries sector and laying down detailed rules for the application of Council Regulation (EC) No 1543/2000. These surveys must be considered in the frame of the Ifremer fisheries ecology action "resources variability" which is the French contribution to the international Globec programme. It is planned with Spain (PELACUS) and Portugal (PELAGO) in order to have most of the potential area to be covered from Gibraltar to Brest with the same protocol for sampling strategy. Data are available for the ICES working groups WGHANSA, WGWIDE and WGACEGG.

B.3.2.1. Method and sampling strategy

In the frame of an ecosystemic approach, the pelagic ecosystem is characterized at each trophic level. In this objective, to assess an optimum horizontal and vertical description of the area, two types of actions are combined:

- Continuous acquisition by storing acoustic data from five different frequencies and pumping seawater under the surface in order to evaluate the number of fish eggs using a CUFES system (Continuous Under-water Fish Eggs Sampler); and

- Discrete sampling at stations (by trawls, plankton nets, CTD). Satellite imagery (temperature and sea colour) and modelisation are also used before and during the cruise to recognise the main physical and biological structures and to improve the sampling strategy.

Concurrently, a visual counting and identification of cetaceans and of birds (from board) is carried out in order to characterise the top predators of the pelagic ecosystem.

The strategy was the identical to previous surveys (2000 to 2009):

- Acoustic data were collected along systematic parallel transects perpendicular to the French coast (Figure B3.2.1.1). The length of the ESDU (Elementary Sampling Distance Unit) was one mile and the transects were uniformly spaced by 12 nautical miles covering the continental shelf from 20 m depth to the shelf break.

- Acoustic data were collected only during the day because of pelagic fish behaviour in this area. These species are usually dispersed very close to the surface during the night and so "disappear" in the blind layer for the echosounder between the surface and 8 m depth.
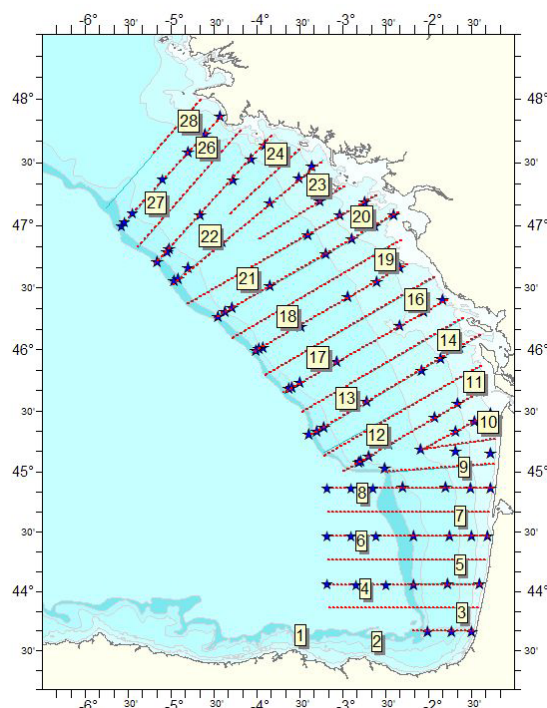
Figure B 3.2.1.1. Acoustic transects and stations during PELGAS surveys since 2000.

Two echosounders are usually used during surveys (SIMRAD EK60 for vertical echo-sounding and SIMRAD ME70 multibeam echosounder for a 3D approach since 2009). Energies and samples provided by split beam transducers (six frequencies EK60, 18, 38, 70, 120, 200 and 333 kHz), and multibeam echosounder were simultaneously visualised, stored using the MOVIES+ software and at the same standard HAC format.

The calibration method is the same that the one described for the previous years (see WD 2001) with a tungsten sphere hanged up 20 m below the transducer and is generally performed at anchorage in front of Machichaco Cap or in the Douarnenez Bay, at the west side of Brittany, in optimum meteorological conditions.

Acoustic data are collected by Thalassa along the totality of the daylight route from which about 2000 nautical miles on one way transect are usable for assessment. Fish are measured on board (for all species) and otoliths (for anchovy and sardine) are collected for age determinations.

B.3.2.2. Echoes scrutinizing

Most of the acoustic data along the transects are processed and scrutinised during the survey and are generally available one week after the end of the survey (Figure 2.2.1). Acoustic energies (Sa) are cleaned by sorting only fish energies (excluding bottom echoes, parasites, plankton, etc.) and classified into several categories of echotraces according to the year fish (species) structures.

Some categories are standard such as:

D1 – energies attributed to mackerel, horse mackerel, blue whiting, divers demersal fish, corresponding to cloudy schools or layers (sometimes small dispersed points) close to the bottom or of small drops in a 10m height layer close to the bottom.

D2 –energies attributed to anchovy, sprat, sardine corresponding to the usual echotraces observed in this area since more than 15 years, constituted by schools well

designed, mainly situated between the bottom and 50 meters above. These echoes are typical of clupeids in coastal areas and sometime more offshore.

D3 – energies attributed to blue whiting and myctophids offshore, just closed to the shelfbreak.

D4 – energies attributed to sardine, mackerel or anchovy corresponding to small and dense echoes, very close to the surface.

D6 – energies attributed to a mix, usually between 50 and 100 m depth when D1 and D2 were not separable.

Some particular categories are usually specifically designed according to several iden-tifications during the survey (when Thalassa and/or commercial vessels hauls are avail-able), such as:

D7 – energies attributed exclusively to sardine (big and very dense schools).

D5 – energies attributed to small horse mackerel only when they are gathered in very dense schools; this category is usually used for typical echoes which occur along par-ticular surveys. In the case of 2010, it was used to gather energies which occurred all along the transects in the northern platform where a continuous cover of mainly blue whiting was observed.

B.3.2.3. Data processing

The global area is split into several strata where coherent communities are observed (species associations) in order to minimise the variability due to the variable mixing of species. For each stratum, a mean energy is calculated for each type of echoes and the area measured. A mean haul for the strata is calculated to get the proportion of species into the strata. This is obtained by estimating the average of species proportions weighted by the energy surrounding haul positions. Energies are therefore converted into biomass by applying catch ratio, length distributions and TS relationships. The calculation procedure for biomass estimate and variance is described in Petitgas *et al.*, 2003.

The TS relationships used since 2000 are still the same and as following:

Sardine, anchovy and sprat:	TS = 20 Log L – 71.2
Horse mackerel:	TS = 20 Log L – 68.7
Blue whiting:	TS = 20 Log L – 67.0
Mackerel:	TS = 20 Log L – 86.0

The mean abundance per species in a stratum (tons m.n.$^{-2}$) is calculated as:

$$M_e(k) = \sum_D \overline{s}_A(D,k)\overline{X}_e(D,k)$$

and total biomass(tons) by: $B_e = \sum_k A(k)M_e(k)$

where,

k: strata index

D: echo type

e: species

S$_A$: Average S$_A$ (NASC) in the strata (m2/n.mi.2)

X$_e$: species proportion coefficient (weighted by energy around each haul) (tons m^{-2})

A: area of the strata (m.n.^{2})

Then variance estimate is:

$$Var.M_e(k)=\sum_D \bar{s}_A^2(D,k)Var[X_e(D,k)]/n.cha(k)+\bar{X}_e^2\,var[s_A(D,k)]/n.esu(D,k)$$

$$Var.B_e=\sum_k A^2(k)Var.Me(k)$$

$$cv=\sqrt{Var.Be}/Be$$

At the end, density in numbers and biomass by length and age are calculated for each species in each ESDU according to the nearest haul length composition. These numbers and biomass are weighted by the biomass in each stratum and data are used for spatial distributions by length and age.

The detailed protocol for these surveys (strategy and processing) is described in Annex 6 of the WGACEGG Report in 2009.
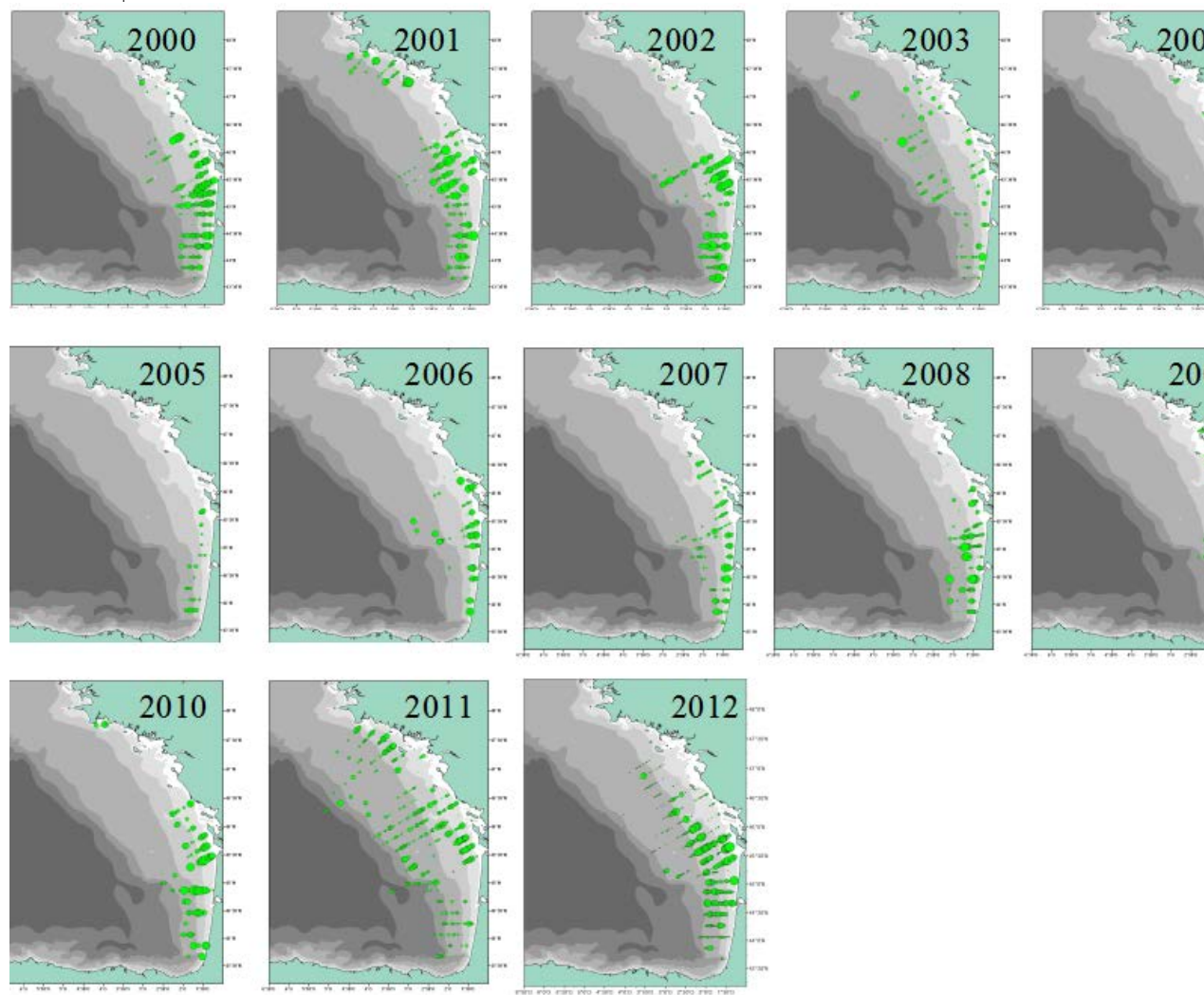
Figure B 3.2.1. Back-scattered energies (SA) registered for anchovy during PELGAS surveys since 2000.
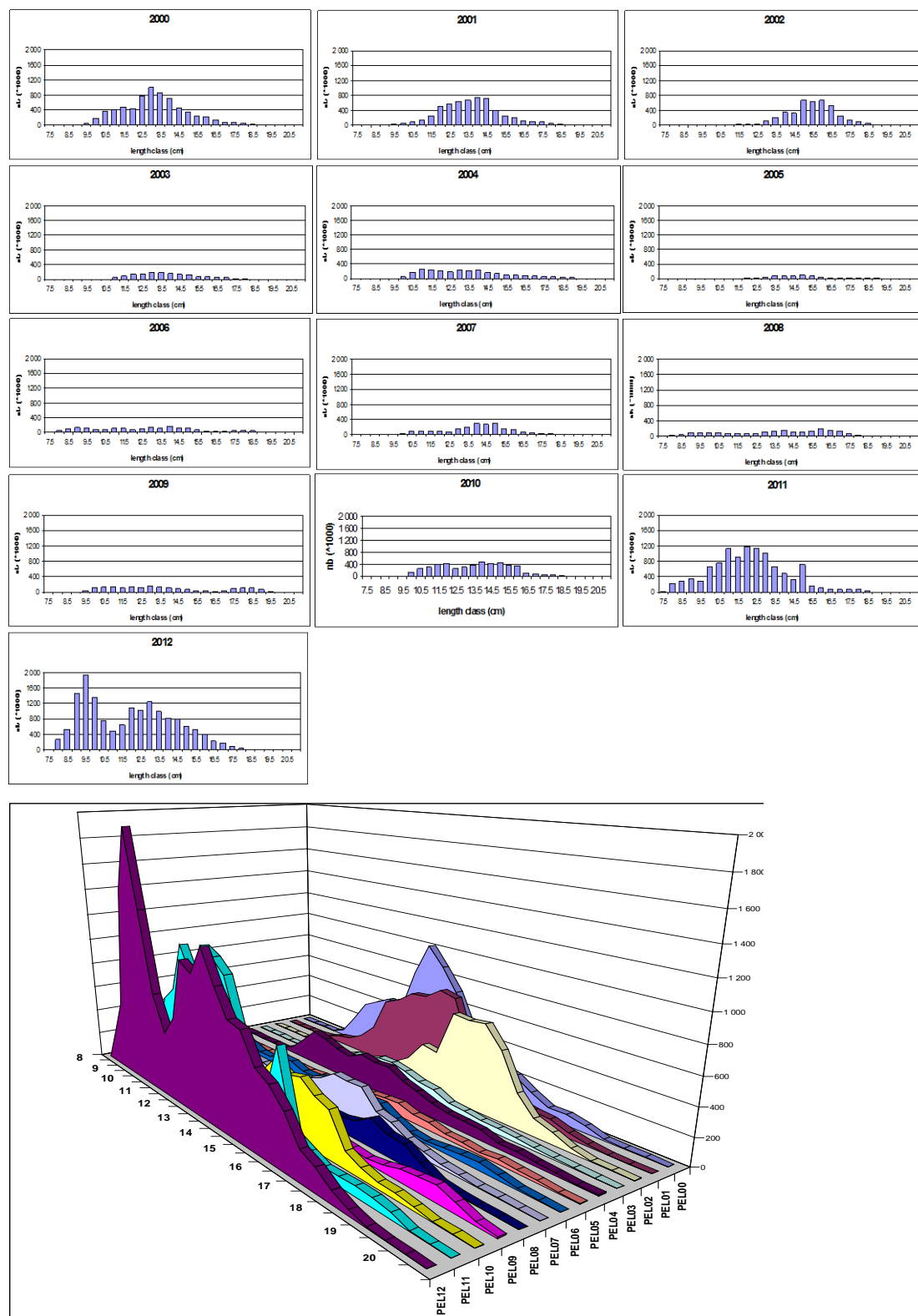
Figure B 3.2.2. Length composition of adults of anchovy as estimated by acoustics since 2000 during PELGAS surveys.
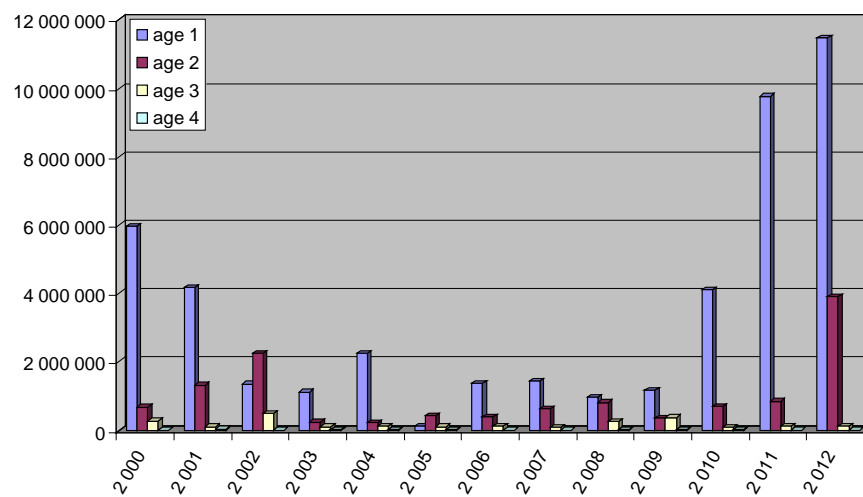
Figure B 3.2.3. Age composition of adults of anchovy as estimated by acoustics since 2000 during PELGAS surveys.
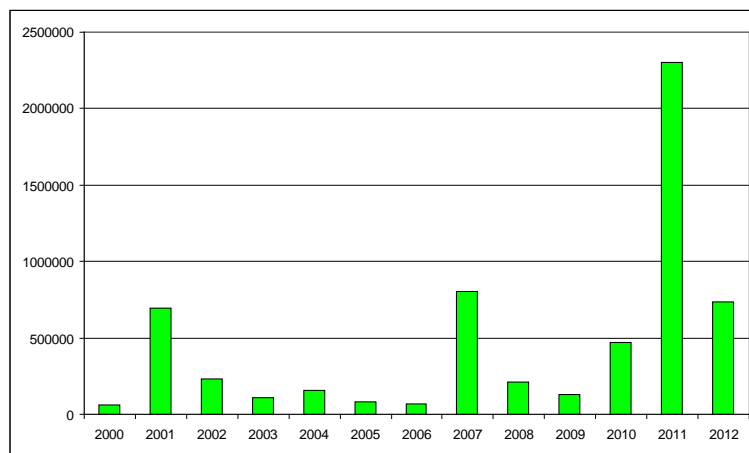

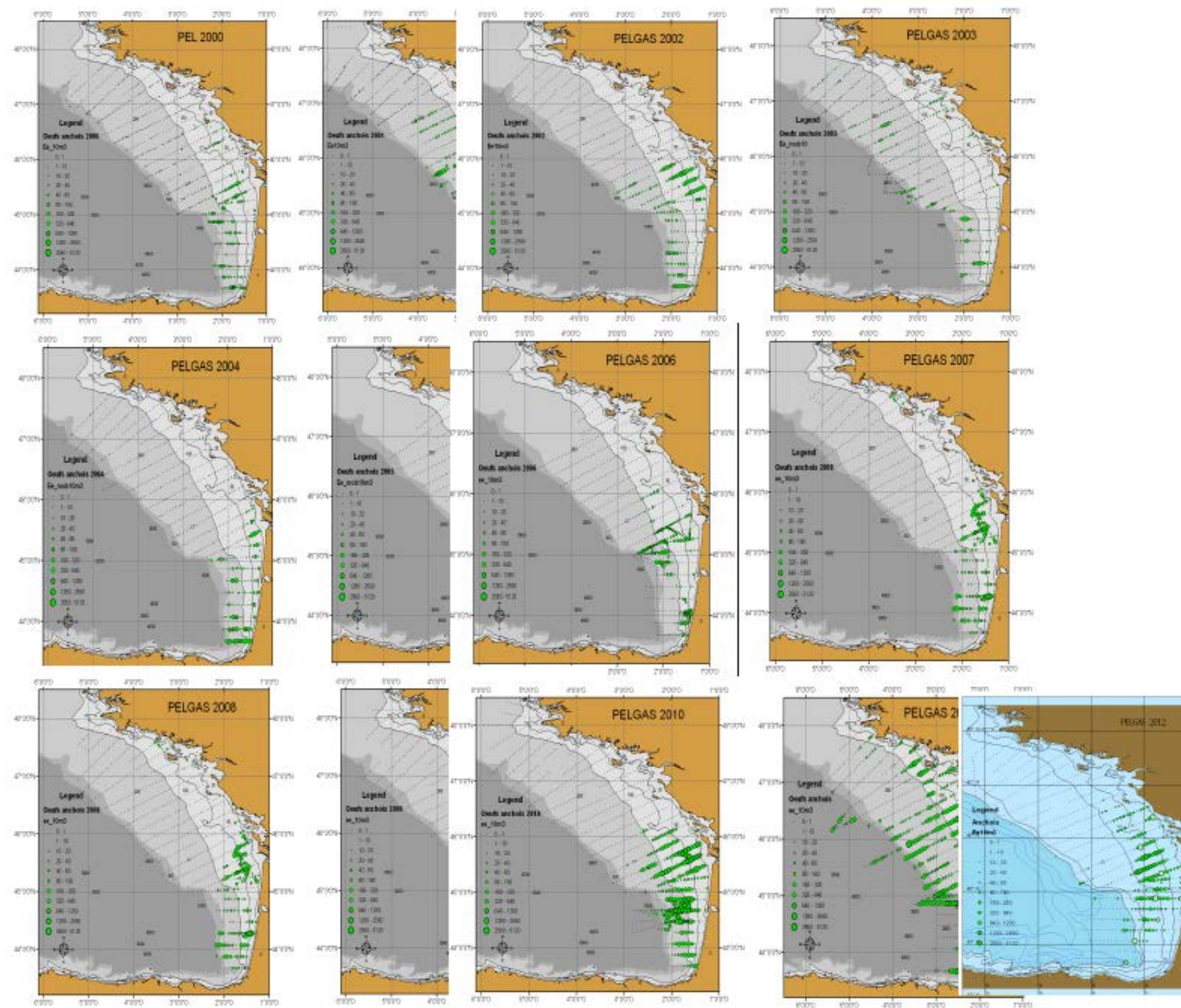**Figure B 3.2.4. Number of eggs observed during PELGAS surveys with CUFES from 2000 to 2010.**

Figure B 3.2.5. Distribution of anchovy eggs observed with CUFES during PELGAS surveys from 2000 to 2012 (number for 10m³).

B.3.4 Autumn survey JUVENA on juvenile anchovy

Since year 2003, there is an acoustic survey to estimate abundance of juvenile anchovy (JUVENA) every September–October, with the long-term objective of forecasting the strength of the anchovy recruitment which will enter the fishery the next year (ICES 2008–2011 WGACEGG reports, Boyra*et al.*2013). The survey was conducted by AZTI from 2003 to 2009, and is coordinated between AZTI and IEO since year 2010. The IEO conducted a parallel acoustic survey on anchovy, PELACUS10, from 2006 to 2009. Both surveys were merged in year 2010 in a joint JUVENA AZTI-IEO survey coordinated in ICES WGACEGG. This survey is expected to provide further insights on the recruitment process and additional knowledge on the biology and ecology of the juveniles.

The recruitment prediction capability of the survey has been tested by comparing the biomass estimates of juveniles and the next year's age-1 recruits for a wide range of recruitment values, and has been confirmed by the significant ($p<0.001$) positive correlations between them.

B.3.4.1 Sampling strategy

The JUVENA surveys were carried out annually between September and October in the Bay of Biscay. In these months the juveniles have grown enough to be visible to the echosounders (allowing the tuna fishing fleet to target them as live bait) and normally occupy large outer and off shelf areas in front of the Cantabric and west French coasts (Uriarte *et al.*, 2001; Cort *et al.*, 1976; Martin, 1976). Acoustic sampling was performed during the day because at this time of year juveniles usually aggregate in schools in the upper layers of the water column during the day, and can be distinguished from plankton structures (Uriarte *et al.*, 2001; Cort *et al.*, 1976). The sampling was carried out following a regular grid formed by transects arranged perpendicular to the coast (Figure B.3.4.1), spaced at 17.5 n.mi. (from 2003 to 2005) or 15 n.mi. (2006 onwards) to ensure their independence (Carrera *et al.*, 2006). Sampling started in the Cantabrian Sea, going from west to east, and then moved to the north to cover the waters in front of the French coast. It is important to conduct the survey in the precise temporal window that extends from mid-August to mid-October, which is not too early, so juveniles have sufficiently grown and hence can be detected and caught, and not too late, so they have not yet abandoned the offshore grounds towards the coasts.

The survey covered the entire expected spatial distribution of juvenile anchovy in these months of the year, from offshore areas well beyond the continental shelf to very coastal waters, because the spatial process of anchovy juvenile recruitment occurs from offshore areas towards the coast during autumn (Uriarte *et al.*, 2001). This exploration area can vary from year to year and is potentially large. Consequently, considerable effort was made to achieve the broadest possible coverage of the area by using an adaptive sampling strategy. In this strategy, the boundaries of the sampling area were defined according to the findings of each survey and the parallel information obtained from the commercial fishing fleet, which uses juvenile anchovy as live bait for tuna fishing. Along the Spanish and French coastlines, the minimum limits of the sampling area were set at 5°W and 46°N respectively. According to previous information on juvenile distribution, this area was expected to contain the vast majority of the juvenile anchovy abundance (Uriarte *et al.*, 2001; Carrera *et al.*, 2006; Cort *et al.*, 1976). For practical reasons, a maximum surveying area was set within the limits 6°W and 48°N. Between these limits, the actual along-coastline boundaries were set each year at the points where there was a clear decrease in abundance or, if possible, a transect in which juvenile anchovy were not detected. The length of the transects extended from about

the 20 m to at least the 1000 m isobaths, and, according to the adaptive scheme of the survey, if the detections continued they were enlarged offshore to 4 n.mi. beyond the last detection of an anchovy school. In addition, the information from the commercial live bait tuna fishery collected before and during each survey was taken into account when decisions about the sampling strategy were made during the surveys. As a result of this sampling scheme, the years with a larger abundance of anchovy required a larger sampling coverage.

In the period from 2003 to 2004, the area was sampled with a single commercial purse-seiner subcontracted for the survey and equipped with scientific echosounders. In 2005 a second purse-seiner was added to the survey to provide extra fishing operations, and in 2006 a pelagic trawler with complete acoustic equipment, the R/V Emma Bardán, replaced the second purse-seiner.

B.3.4.2 Data acquisition

The acoustic equipment included Simrad EK60 split-beam echosounders (Kongsberg Simrad AS, Kongsberg, Norway) of 38 and 120 kHz from 2003 to 2006, plus a 200 kHz transducer from 2007 (Table 2). The transducers were installed looking vertically downwards, at about 2.5 m depth, at the end of a tube attached to the side of the vessel in the case of the commercial fishing vessels and on the vessel hull in the case of the research vessel. The transducers were calibrated using standard procedures (Foote, 1987).

The water column was sampled acoustically to a depth of 200 m. Catches from the fishing hauls and echotrace characteristics were used to identify fish species and determine the population size structure. Purse-seining was used to collect samples up to 2005 and then this was combined with pelagic trawls from 2006 onwards. To improve species identification in the first three surveys when only purse-seiners were available, additional night fishing operations were performed by focusing bright light on the water to attract the fish from surrounding waters. In 2006 pelagic trawling was included in the surveys, which made it possible to fish at greater depths than the purse-seine range (50 m maximum). The purse-seiners generally covered the coastal areas and the waters off the shelf where juveniles occupy the surface waters and are accessible to the purse-seine fishing range. The pelagic trawler covered the intermediate shelf regions where it may be necessary to sample at all depth layers. In addition, when deep, anchovy like aggregations were detected by the purse-seiners, the pelagic trawler temporally left its coverage area to carry out additional fishing operations in these areas.

For the years when pelagic trawling was carried out in the surveys (2006 onwards) we have assessed the fraction of juvenile biomass observed deeper than 45 m below the surface. This assessment was restricted to the areas over the shelf because pure aggregations of juveniles off the shelf were all above 45 m depth. This was done in order to determine by how much the limited vertical fishing range of purse-seines could have affected the detection and estimates of juvenile biomass in the years 2003–2005, when only this fishing gear was available, and to eventually correct the potential underestimation of the juvenile biomass detected over the shelf in those years.

B.3.4.3 Intercalibration of acoustic data between vessels

Since the 2006 survey, when the acoustic sampling was split between two vessels, intercalibration exercises between the two vessels were routinely carried out each year based on the intercalibration methodology described by Simmonds and MacLennan (2005). The intercalibration process consisted in comparing the echointegration of the

bottom echo in areas with a smoothly variable bottom (visible as overlapping transects in Figure B.3.4.1). A minimum distance of 30 n.mi. was covered simultaneously by the two vessels for these exercises (Figure B.3.4.1). The NASC values (Maclennan *et al.*, 2002) obtained by the layer echointegration of both the water column and bottom echos obtained by the two vessels were compared to detect recording biases or other potential problems.

B.3.4.4 Abundance estimates

Echograms were examined visually with the aid of the catch species composition to identify positive anchovy layers. Noise from bubbles, double echoes, and, when necessary, plankton were removed from the echograms. Acoustic data were processed in the positive strata by layer echo integration using an ESDU (Echo integration Sampling Distance Unit) of 0.1 n.mi. with the Movies+ software (Ifremer, France). Echoes were thresholded to -60 dB and integrated into six depth channels: 7.5–15 m, 15–25 m, 25–35 m, 35–45 m, 45–70 m and 70–120 m (no anchovies were found below 120 m depth).

Generally, only the 38 kHz data were echo integrated using the TS-length relationships agreed in ICES WGACEGG for the main species (ICES, 2006; Table B.3.4.1). Each fishing haul was classified into species. A random sample of each species was measured to determine the length–frequency distribution of the different species in 0.5 cm classes for the smaller species (anchovy and sardine) and one cm classes for the rest. Complete biological sampling of anchovy was performed to analyse age, size and the size–weight ratio. The hauls were grouped by strata of homogeneous species and size composition. The species and size composition of each homogeneous stratum were obtained by averaging the composition (in numbers) of the individual hauls contained in the stratum weighted to the acoustic density in the vicinity (2 n.mi. diameter). This species and size composition of each stratum was used to obtain the mixed species echointegrator conversion factor (Simmonds and Maclennan, 2005) for converting the NASC values of each ESDU into numbers of each species. However, although the methodology involved estimating multiple species, the survey strategy was focused strongly on juvenile anchovy and only the positive areas for anchovy were processed. Therefore, only estimates of this species were considered reliable and thus produced.

The procedure is as follows:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Anchovy juveniles (age=0) and adults (age ≥ 1) were separated and treated as different species. To separate juveniles from adults, the length frequency distribution of anchovy by haul was multiplied by a corresponding age-length key. The key was determined every year for three broad areas: the pure juvenile area, the mixed juvenile area (with a mix of juveniles and adults), and the Garonne area (also a mixed area but here adult anchovy were usually smaller than in the other areas).

B.3.4.5 Recruitment predictive capability

The annual biomass estimates for anchovy juveniles were compared with the estimates of anchovy recruitment the following year. The recruitment is the biomass of age-1 anchovy in January of the following year, estimated according to the ICES assessment using a Bayesian model with inputs from catches and biomass estimates of two spring surveys: an acoustic one (PELGAS), conducted by Ifremer, and a survey based on DEPM (BIOMAN), conducted by AZTI (ICES, 2011). Up to 2012, The Spearman rank correlation between the JUVENA series and the assessment estimates of recruitment at age 1 is 0.81, which is statistically significant with p-value=0.01, and the Pearson correlation is 0.94, which is statistically significant with p-value=0.000163. In addition, JUVENA's juvenile abundance index shows also statistically significant (Pearson's) correlations with the series of recruit estimates provided independently by each of the spring surveys (R=0.94 P(R=0)=0.000 for DEPM and R=0.89 P(R=0)=0.001 for Acoustics). WGHANSA (2012), like Boyra *et al.* (2013), concluded that the JUVENA acoustic index of juveniles is a valid indicator of the strength of the incoming recruitment and hence useful for improving the forecast of the population and potentially its assessment.
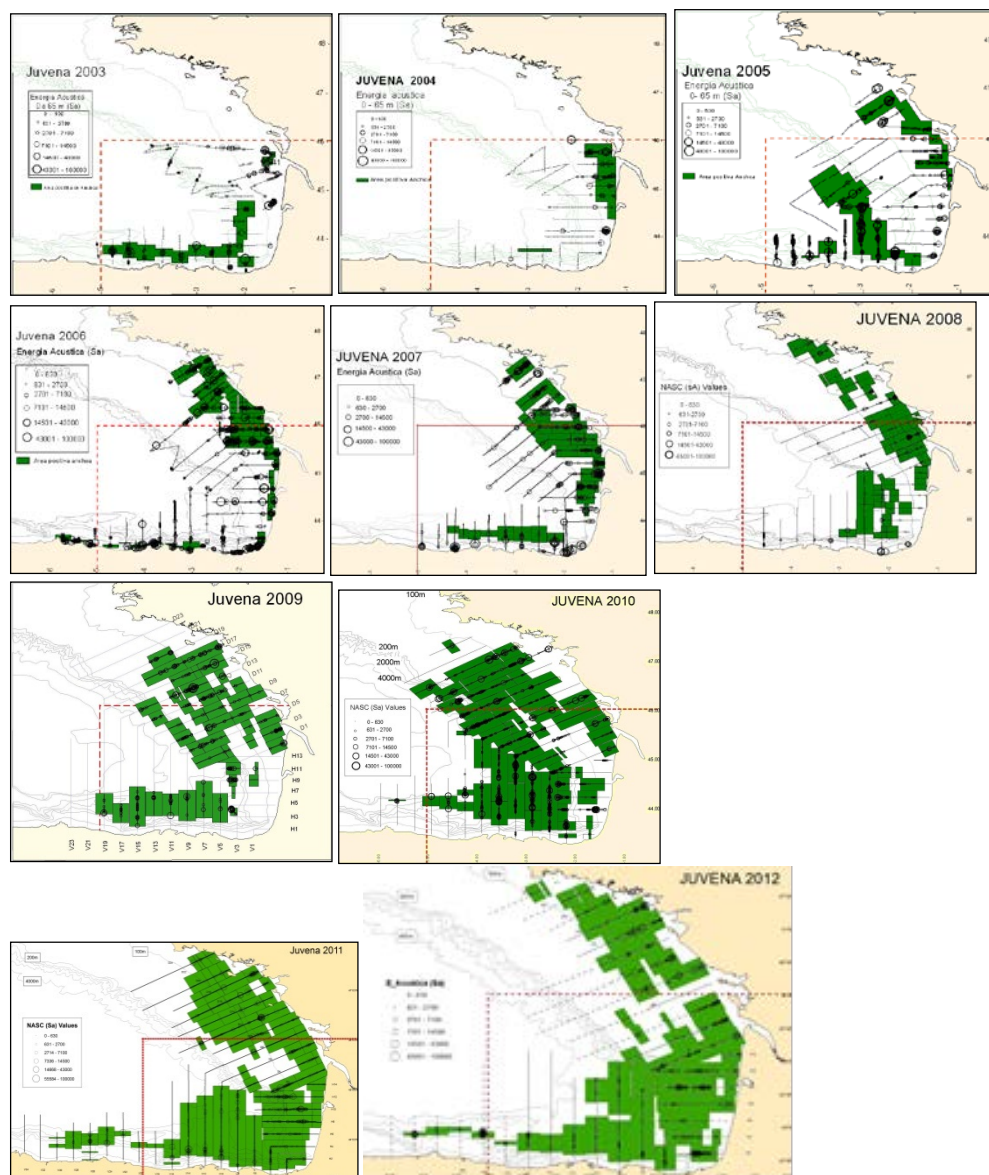
Figure B.3.4.1. Positive area of presence of anchovy and total acoustic energy echo-integrated (from all the species) for the ten years of surveys. The area delimited by the dashed line is the minimum or standard area used for inter annual comparison.

Table B.3.4.1. Vessels and equipment.

		Vessel 1	Vessel 2
Vessel	Name	Variable*	Emma Bardán
	Length (m)	30–35	27
	Side (m)	8	7
	Draft (m)	3.5–4	3.5
	Acoustic installation	side perch	hull
Acoustic Equipment	Transducer frequencies (kHz)	38,120, (200)**	38,120,200
	Power (for 38, 120, 200 kHz) (W)	1200, 250, (210)**	1200, 250, 210
	Pulse duration (10-6s)	1024	1024 (except in 2006: 256)
	Ping interval (s)	0.25–0.5	
Target Strength (b20)***	Engraulis encrasicolus Sardina pilchardurs Sprattus sprattus	-72.6 dB	Degnbol et al. (1985)
	Trachurus trachurus Trachurus mediterraneus Scomber japonicas	-68.7 dB	ICES (2006)
	Scomber scombrus	-88 dB	Clay and Castonway (1996)
	Jellyfish (mean TS)	-81.7 dB	Average TS for jellyfish species in Simmonds and Maclennan (2005)
Fishing gear****	Pelagic trawl	nº of doors	2
		vert opening	15
		Mesh size (mm)	4
	Purse-seine	Depth	75
		Perimeter	400
		Mesh size	4

(*Vessel names: Divino Jesus de Praga (2003), Nuevo Erreñezubi (2004), Mater Bi (2005), Gure Aita Joxe (2005, 2008), Itsas Lagunak (2006, 2007, 2009, 2010, 2011, Ramón Margalef (2012)). **The 200 kHz transducer has been available onboard purse-seiners since 2007. ***TS of the mean pelagic species. The TS is obtained according to the relationship TS = b20 - 20log(L), where L is the standard length of the fish in cm. ****The fishing gear of RV Ramon Margalef in 2012 was a pelagic trawl identical to the Emma Bardan one.

B.4 Commercial cpue

According to literature, cpue indices have been considered as not reliable indicators of abundance for small pelagic fishes (Ulltang, 1980, Csirke 1988, Pitcher 1995, Mackinson *et al.* 1997). Current series of cpue available for the Spanish Purse seine are not considered of utility for the monitoring of the fishery (Uriarte *et al.*, 2008).

B.5 Other relevant data

Members of the South Western Waters Regional Advisory Council (SWWRAC) participated in the benchmark workshop process for the Bay of Biscay anchovy stock. They provided their opinion relative to the anchovy assessment (SWW RAC Opinion 69, 22 November 2012) and participated to WKPELA, their input being reflected in the report.

C. Stock assessment method

There are two points in time where an assessment can be given for this stock: in June when SSB is estimated based on the most recent spring surveys information and in

December when the assessment can incorporate the most recent juvenile abundance index from JUVENA, the catches in the second semester and any other updated data. In the former the assessment goes up to June, whereas in the latter the assessment covers the whole year up to December.

C.1 June assessment

<u>Model used:</u>

The assessment for the Bay of Biscay anchovy population is a Bayesian two-stage biomass-based model (CBBM) (Ibaibarriaga *et al.*, 2011), where the population dynamics are described in terms of biomass with two distinct age groups, recruits or fish aged 1 year, and fish that are 2 or more years old. The biomass changes exponentially with time according to intrinsic growth, natural mortality and fishing mortality rates. Growth and natural mortality are separated processes that are assumed constant along time but distinct across age groups (recruits and older individuals). Fishing is treated as a continuous process in time separated by semester. The first semester fishery consists mainly of the Spanish purse-seine fishery operating in spring, and the second semester fishery primarily relates to the French fleet. Furthermore, fishing mortality by semester is separable into age and year effects.

The observation equations consist of:

- log-normally distributed spawning–stock biomass from the acoustics and DEPM surveys, where the biomass observed is scaled to the true population biomass by the catchability coefficient of each of the surveys. The variance of the SSB observation equations from the surveys are split as the sum of the variances obtained from the surveys (sampling error changing from year to year and fixed according to the survey results) and the residual variance (constant parameter across years estimated from the model).

- the beta distributed age 1 biomass proportion from the acoustics and DEPM surveys, with mean given by the true age 1 biomass proportion in the population.

- log-normally distributed juvenile abundance index from the JUVENA surveys, where the abundance index observed in year (y-1) is related to the true recruitment (age 1 biomass in January of year y) by a power model:

$$\log\big(R_{\mathrm{juv}}(y)\big) \sim \mathrm{Normal}\left(\log(q_{\mathrm{juv}}) + k_{\mathrm{juv}}\log(R_y), \frac{1}{\psi_{\mathrm{juv}}}\right),$$

  where q_{juv}, k_{juv} and ψ_{juv} are respectively the catchability, the power and the precision of the JUVENA surveys that need to be estimated.

- log-normally distributed total catch by semester.

- beta distributed age 1 biomass proportion in the catch by semester.

- normally distributed growth rates by ages.

The unknown parameters are the initial biomass, the mean and the precision of the recruitment process in log scale, the acoustic and DEPM surveys catchabilities, the catchability and the power parameters of the JUVENA index, the parameters affecting the precision of the survey and catch observation equations, the year and age components of the fishing mortality by semester, the annual intrinsic growth rates by age, the precision of the observation equations for growth and the annual natural mortality

rates by age, though in the standard assessment the natural mortality will be fixed at the values agreed by the WG (see below).

Inference on the unknowns is made using Markov Chain Monte Carlo (MCMC).

Software used:

The model is implemented in BUGS (www.mrc-bsu.cam.ac.uk/bugs/). The WinBUGS development interface was used to reduce run times. The assessment is run from R (www.r-project.org) using the package R2WinBUGS.

Model Options chosen:

- Catchability of the DEPM and acoustic SSB estimates and of the juvenile abundance indices are estimated. DEPM and acoustic surveys are assumed to provide unbiased proportion of age 1 biomass estimates in the stock.

- Natural mortality rates are fixed at M_1=0.8 and M_{2+}=1.2.

The set of priors as defined in Ibaibarriaga *et al.*, 2011 are used. The logarithm of the power parameter of the JUVENA index was assumed to have a normal prior distribution with median at 0 and precision 0.5. The prior distribution of the catchability parameter of the JUVENA index was considered wider than that assumed for the acoustic and DEPM surveys. A normal distribution with median at 0 and precision 0.1 was selected for the logarithm of the JUVENA index catchability. The prior distribution of the precision of the JUVENA index observation equation was the same as for the acoustic and DEPM surveys.

The length of the MCMC run, the burn-in period (removal of the first draws to avoid dependency on the initial values) and the thinning to diminish autocorrelation should be enough to ensure convergence and obtain a representative joint posterior distribution of the parameters.

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year. Yes/No
Caton	Catch in tonnes by semesters	1987–latest year	1 to 2+	Yes
Canum	Catch-at-age in numbers by semesters	1987–latest year	1 & 2+	Yes
Weca	Weight-at-age in the commercial catch by semesters	1987–latest year	1 to 2+	Yes
Mprop	Proportion of natural mortality before spawning	Not applicable		
Fprop	Proportion of fishing mortality before spawning	Not applicable		
Matprop	Proportion mature-at-age	Not applicable		
Natmor	Natural mortality M1=0.8 and M2+=1.2	1987–latest year	1 to 2+	No
G	Intrinsic growth rate	1987–latest year	1 to 2+	Yes

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	DEPM SSB spring series	1987–latest year (with gap in 1993)	
Tuning fleet 2	Acoustic SSB spring series	1989–latest year (with gaps)	
Tuning fleet 3	DEPM P1 (B1/SSB) spring series	1987–latest year (with gaps)	
Tuning fleet 4	Acoustic P1 (B1/SSB) spring series	1989–latest year (with gaps)	
Tuning fleet 5	Juvenile abundance index from JUVENA autumn survey	2003–latest year	Recruitment

Prior distributions of the parameters:

The current prior distributions (see table below) are described and justified in Ibaibarriaga *et al.* (2011) and in Ibaibarriaga and Uriarte (2013, WD to WGHANSA-ICES CM 2013/ACOM:16).

Parameter	Hyperparameter	Median (90% probability interval)
q_{surv}	$\mu_{q_{\text{surv}}} = 0 \quad \psi_{q_{\text{surv}}} = 2$	1(0.3, 3.2)
q_{juv}	$\mu_{q_{\text{juv}}} = 0 \quad \psi_{q_{\text{juv}}} = 0.1$	1(0.005, 181.5)
k_{juv}	$\mu_{k_{\text{juv}}} = 0 \quad \psi_{k_{\text{juv}}} = 0.5$	1(0.098, 10.2)
ψ_{surv}	$a_{\psi_{\text{surv}}} = 0.9 \quad b_{\psi_{\text{surv}}} = 0.02$	29.8(1.7, 139.9)
ψ_{juv}	$a_{\psi_{\text{juv}}} = 0.9 \quad b_{\psi_{\text{juv}}} = 0.02$	29.8(1.7, 139.9)
ξ_{surv}	$\mu_{\xi_{\text{surv}}} = 5 \quad \psi_{\xi_{\text{surv}}} = 0.2$	5(1.3, 8.7)
ξ_{catch}	$\mu_{\xi_{\text{catch}}} = 5 \quad \psi_{\xi_{\text{catch}}} = 0.2$	5(1.3, 8.7)
B_0	$\mu_{B_0} = 10.3 \quad \psi_{B_0} = 1.0$	29 733(5 740, 154 022)
μ_R	$\mu_{\mu_R} = 9.8 \quad \psi_{\mu_R} = 1.0$	9.8(8.2, 11.4)
ψ_R	$a_{\psi_R} = 2 \quad b_{\psi_R} = 3$	0.6(0.1, 1.6)
$s(\text{sem}_j, 1)$	$a_s = 0 \quad b_s = 2$	1.0(0.1, 1.9)
$f(\text{sem}_j, y)$	$\mu_f = -0.9 \quad \psi_f = 1$	0.4(0.1, 2.1)
G_a	$\mu_{\log(G)} = -0.7 \quad \psi_{\log(G)} = 2$	0.5(0.2, 1.6)
ψ_G	$a_{\psi_G} = 1.5 \quad b_{\psi_G} = 0.1$	11.8(1.8, 39.1)

Note: Sufix surv refers to either acoustic or DEPM spring surveys

C.2 December assessment:

The assessment conducted in June can be updated using the same settings in December once the results from the JUVENA survey and the catch levels during the second semester are available. The definitive DEPM estimates which are obtained after the full processing of the adult samples are completed by November and should be incorporated in this update. It must be taken into account that only preliminary estimates of

the total catch in the first and the second semesters and of the age structure of the catch during the first semester of the interim year Y would be available in December.

D. Short-term projection

The forecast can be given either based on the June or on the December assessment. In June, there is no indication on next year recruitment, so the forecast is based on an assumed scenario constructed from past recruitments. In December the forecast can be based on the next year recruitment distribution derived from the December assessment (which will be informed ultimately by the JUVENA anchovy juvenile index).

D.1 June forecast:

Model used:

The CBBM model (Ibaibarriaga *et al.* 2011) used for the assessment of the stock is used to project the population one year forward from the current state and to analyse the probability of the population in the next year of being below the biological reference point B_{lim} under a recruitment scenario based on the past recruitment-series and under alternative exploitation levels for the second half of the current year and the first half of next year. Exploitation can be given either in terms of fishing mortality or in terms of catches.

The predictive distribution of recruitment at age 1 (in mass) in January next year is defined as a mixture of the past series of posterior distributions of recruitments as follows:

$$R_{2008} = \sum_{y=1987}^{2007} w_y \; p(R_y/\cdot \;)$$

,

where $p(R_y \mid \cdot)$ denotes the posterior distribution of recruitment in year y and w_y are the weights of the mixture distribution, such that $\sum w_y = 1$. When no information about incoming recruitment is available all the years are equally weighted, resulting in an undetermined recruitment scenario. This is the typical situation in June.

Software used:

The projections are implemented in R (www.r-project.org), using ad hoc script for the anchovy model.

Projection period:

One year ahead from the spawning period (15th of May) in the last assessment year.

Initial stock size:

Posterior distribution of SSB in the last assessment year

Maturity: NA

F and M before spawning: NA

Weight-at-age in the stock: NA

Weight-at-age in the catch: NA

Intrinsic growth rate (G):

Intrinsic growth rates are assumed distinct by age groups and their posterior distribution from the assessment is used.

Natural mortality rate (M):

Assumed constant same as in the assessment (M_1=0.8 and M_{2+}=1.2)

Exploitation pattern:

Alternative options for the year effect of fishing mortality by semester are tested. The age effects of the fishing mortality by semester are taken from the posterior distribution from the assessment.

Intermediate year assumptions: NA

Stock–recruitment model used:

No implicit S/R model is used. Recruitment is sampled from the posterior distributions of past series recruitments. The default recruitment scenario in June is the undetermined case, where all past years are equally likely. However, if there are other reliable indications available, different recruitment scenarios could be constructed by giving different weights to the past series recruitments.

Procedures used for splitting projected catches: NA

D.2 December forecast

The method for the short-term projections based on the December assessment is the same as the ones based on the June assessment, the main difference being that the next year recuitment distribution is obtained directly from the assessment. This recruitment distribution is mainly obtained by the latest JUVENA juvenile abundance index and the parameters of the JUVENA observation equations estimated from the model. Therefore, if the latest juvenile abundance index is high/low, the recruitment distribution are centered around high/low values. The December assessment provides estimates of the fishing mortality in the second semester in the interim year and the December short-term projections allow for exploring catch options for the first semester of the following year. For the current management calendar, where the TAC is set from July to June next year, the December short-term projections could be used to adjust the TAC accordingly for the first semester until a new assessment in June. At request, the December forecast can be extended for the whole year subject to a range of annual catches and the apportioning between the two halves of the year.

E. Medium-term projections

No medium-term projections are applied to this fishery for the provision of advice by ICES.

F. Long-term projections

No long-term projections are applied to this fishery for the provision of advice by ICES. Long-term projections (ten years ahead) were run by STECF in 2008 to set the basis of a management plan on anchovy to the EC. This work was based in other assessment models and assumptions. Thus, the biomass estimates obtained with the new methods are not valid to inform the harvest control rules in the draft management plan proposal of this stock. The long-term management plan proposal should be revised accordingly.

G. Biological reference points

The results of applying the CBBM according to this stock annex in June 2013 are shown in Annex 1 and they are used here as the basis for the definition of Biological reference points.

A stock–recruitment relationship is not explicitly used, given that no clear pattern arises from the scatter plot of SSB and Recruits (Figure G.1):
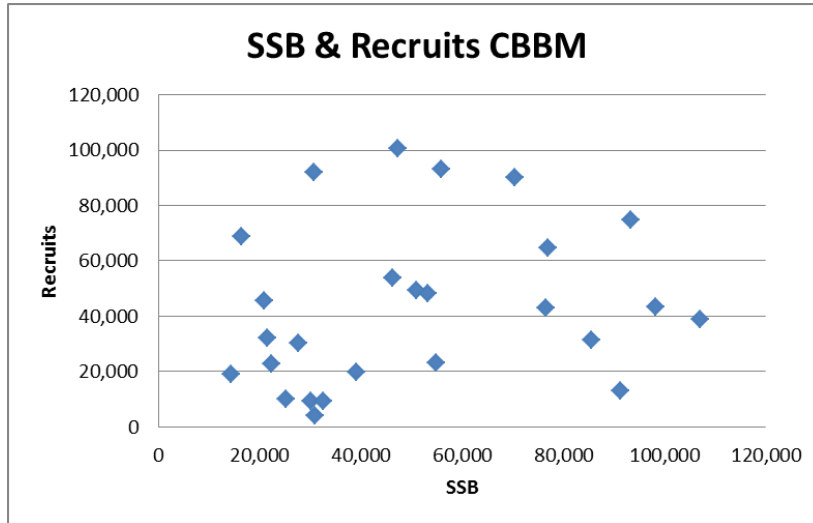

Figure G.1: Plots of Recruits vs parental Spawning Biomass (SSB) from the CBBM assessment in June 2013 see data in Annex1).

Fitting a segmented regression resulted in an inflection point at 48 362 t. (just around the historical median SSB of 46 715 t.) and was not statistically significant (P= 0.24). Such fitting would lead to admit that B_{lim} could be at the median biomass since 1987, and therefore the fishery would have been operating on a population below Blim half of the years. This is hard to believe for a fishery leading to harvest rate around 0.54 (between 1987-2004) and with more than 50% of the catches being taken after mid spawning time. So it was considered better searching for a Blim somewhere in the lower range of historical SSB values.

B_{lim} is defined as B_{loss} (minimum estimated biomass which still produced a substantial recruitment) based on the posterior median of the 1987 and 2009 SSB estimates (of 21425t and 20776 t respectively in the 2013 CBBM assessment), which are the third and fourth lowest values in the series. This results in B_{lim} at 21000 t. Notice that 2009 is the year afterwhich a series of weak SSB abundances (since 2005 accompanying a repeated failure of the fishery and its closure) produced a significant recruitment restoring the population to medium levels. The Biomass in 1987, which was very similar to the 2005 one, did also produce a significant recruitment (close to geometric mean R). The two lowest SSB values arose in years 1989 and 2005 (assessed at 16 404 t and 14 291 t respectively) with a mean of 15 348 t. These two values were omitted when calculating Bloss for the following two reasons: The 2005 SSB value was the lowest in the series and correspond with the failure and closure of the fishery. The stock did not recover the next year (in 2006) and took 5 years (until 2010) to get a substantial recovery of biomasses as to reopen the fishery. The 1989 level is likely to be an underestimate in the current assessment. The 1989 SSB (at 16404 t) which was used in the former stock annex as the year of reference for definition of B_{lim}, is not considered any longer a proper reference point. The 1989 DEPM SSB input value used to be corrected upward by 1 SD in the past assessments because of presumed underestimation, However now

a days that input value is not corrected as the underestimation is considered likely but of uncertain magnitude and the former correction would be too strong. . As such, the SSB estimate may suffer some uncertain underestimate and it is preferable avoiding taking the 1989 SSB biomass as the reference value for the Blim.

This B_{lim}value (21000t) is also approximately the median of the seven lowest SSB levels in the series, (years: 1987/1989/2003/2005/2006/2008/2009), a range of SSB where low recruitments occurred more often (in 71.5%) than medium or high recruitments. This median SSB is 21435 t. Therefore, the probability of suffering impaired recruitment under these levels is presumed in accordance with the B_{lim} definition.

	TYPE	VALUE	TECHNICAL BASIS
MSY	MSY Btrigger	Not defined	
Approach	FMSY	Not defined	
	Blim	21 000 t	Bloss (median of SSB estimates in years 1987 and 2009, minimum estimated biomasses which still produced a substantial recruitment)
Precautionary	Bpa	Not defined	
Approach	Flim	Not defined	
	Fpa	Not defined	

H. Other issues

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Annex 1

Results of applying the June assessment in June 2013

These results were obtained after WKPELA2013 and after WGHANSA 2013 as required to close properly the stock annex and the definition of the biological reference points. It includes the latest inputs from surveys in the spring 2013.

Table A.1: Summary output of the CBBM assessment of the Bay of Biscay anchovy, following the stock annex of WKPELA but with Power catchability for the JUVENA series and Variance setting of the Spring Survey biomasses as Case 2 (Var.Estimated as in Annex 3 of WKPELA).

|	Recruitment			SSB			F.sem1			F.sem1		
	5%	50%	95%	5%	50%	95%	5%	50%	95%	5%	50%	95%
1987	12,076	16,147	22,026	16,502	21,435	28,658	0.91	1.19	1.52	0.21	0.31	0.43
1988	26,357	32,209	40,135	24,311	30,034	38,405	0.76	0.98	1.23	0.23	0.31	0.41
1989	6,667	9,377	13,333	11,376	16,406	23,173	0.65	0.91	1.26	0.11	0.16	0.24
1990	59,874	68,872	80,017	47,056	54,869	64,470	0.95	1.18	1.43	0.44	0.58	0.77
1991	17,694	23,156	30,946	22,918	30,675	40,371	0.85	1.11	1.44	0.17	0.24	0.34
1992	72,403	92,042	117,008	57,908	77,009	100,542	0.83	1.11	1.48	0.19	0.29	0.43
1993	51,534	64,861	80,822	64,002	76,479	91,251	0.64	0.81	1.01	0.35	0.47	0.62
1994	35,242	43,045	53,130	41,706	50,932	62,686	0.87	1.09	1.35	0.37	0.50	0.69
1995	38,561	49,513	66,171	34,185	46,253	62,666	1.01	1.36	1.81	0.18	0.27	0.41
1996	42,617	53,637	66,836	43,263	53,167	66,407	0.83	1.08	1.39	0.37	0.52	0.72
1997	37,049	48,050	61,698	42,708	55,793	71,423	0.41	0.53	0.70	0.28	0.39	0.56
1998	71,682	92,967	120,572	76,029	98,194	125,454	0.31	0.41	0.54	0.27	0.39	0.57
1999	30,638	43,478	60,476	54,213	70,369	90,608	0.38	0.51	0.68	0.26	0.36	0.52
2000	73,865	90,219	110,194	76,534	93,280	112,433	0.56	0.70	0.89	0.24	0.33	0.44
2001	62,318	74,608	89,322	78,671	91,202	107,170	0.54	0.65	0.79	0.33	0.43	0.54
2002	9,127	13,030	18,564	31,747	39,140	49,225	0.43	0.55	0.67	0.35	0.46	0.61
2003	15,553	19,634	24,835	22,514	27,703	34,913	0.29	0.38	0.47	0.41	0.56	0.74
2004	24,588	30,333	38,561	24,414	30,871	40,026	0.64	0.84	1.09	0.36	0.52	0.72
2005	2,636	3,942	5,866	10,265	14,291	20,122	0.11	0.16	0.22	NA	NA	NA
2006	13,440	18,864	26,370	16,221	22,222	30,027	0.16	0.22	0.30	0.01	0.01	0.01
2007	16,465	22,697	30,638	24,197	32,421	42,245	0.01	0.01	0.02	NA	NA	NA
2008	6,464	9,173	13,083	19,333	25,169	32,478	NA	NA	NA	NA	NA	NA
2009	7,347	10,199	14,273	16,190	20,776	26,782	NA	NA	NA	NA	NA	NA
2010	35,596	45,707	61,084	37,423	47,177	62,060	0.31	0.41	0.52	0.11	0.16	0.23
2011	79,221	100,710	130,679	84,720	107,123	138,804	0.24	0.32	0.41	0.05	0.06	0.09
2012	28,854	38,949	52,575	66,548	85,539	111,661	0.17	0.22	0.29	0.12	0.16	0.21
2013	21,829	31,257	44,356	42,813	58,475	80,380	0.24	0.33	0.45	NA	NA	NA
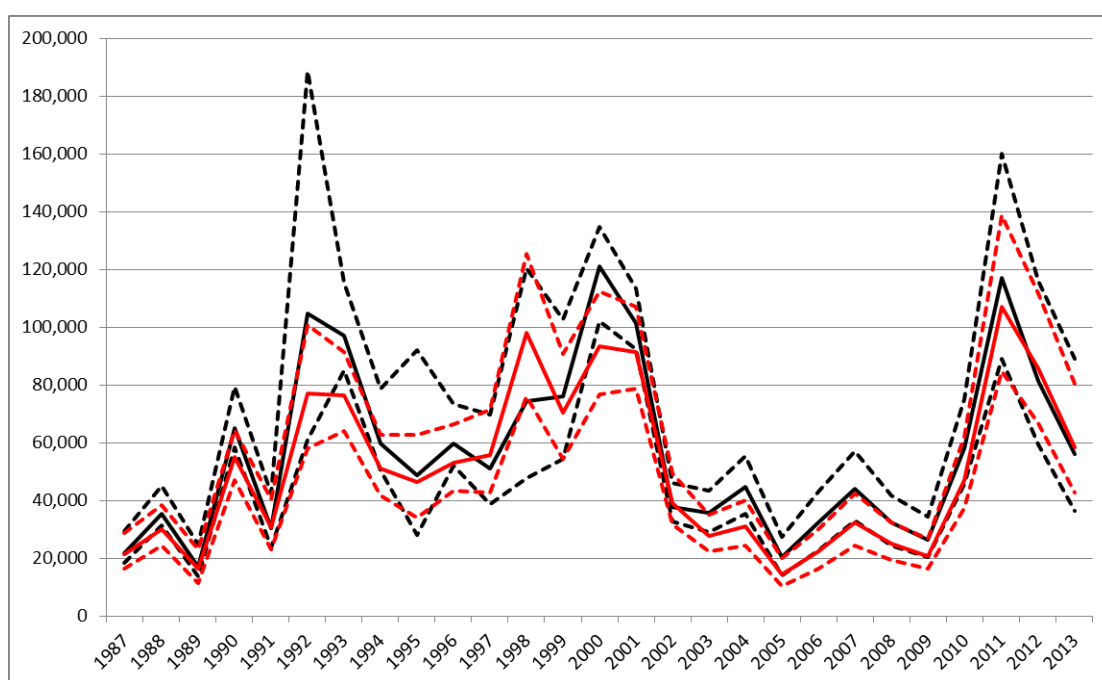
Figure A.1: Comparison of the Anchovy Spawning Biomass series from the old BBM model (from the June 2013 WGHANSA assessment- ICES 2013) (in black) and the CBBM with the new settings in the current Stock Annex (in red).