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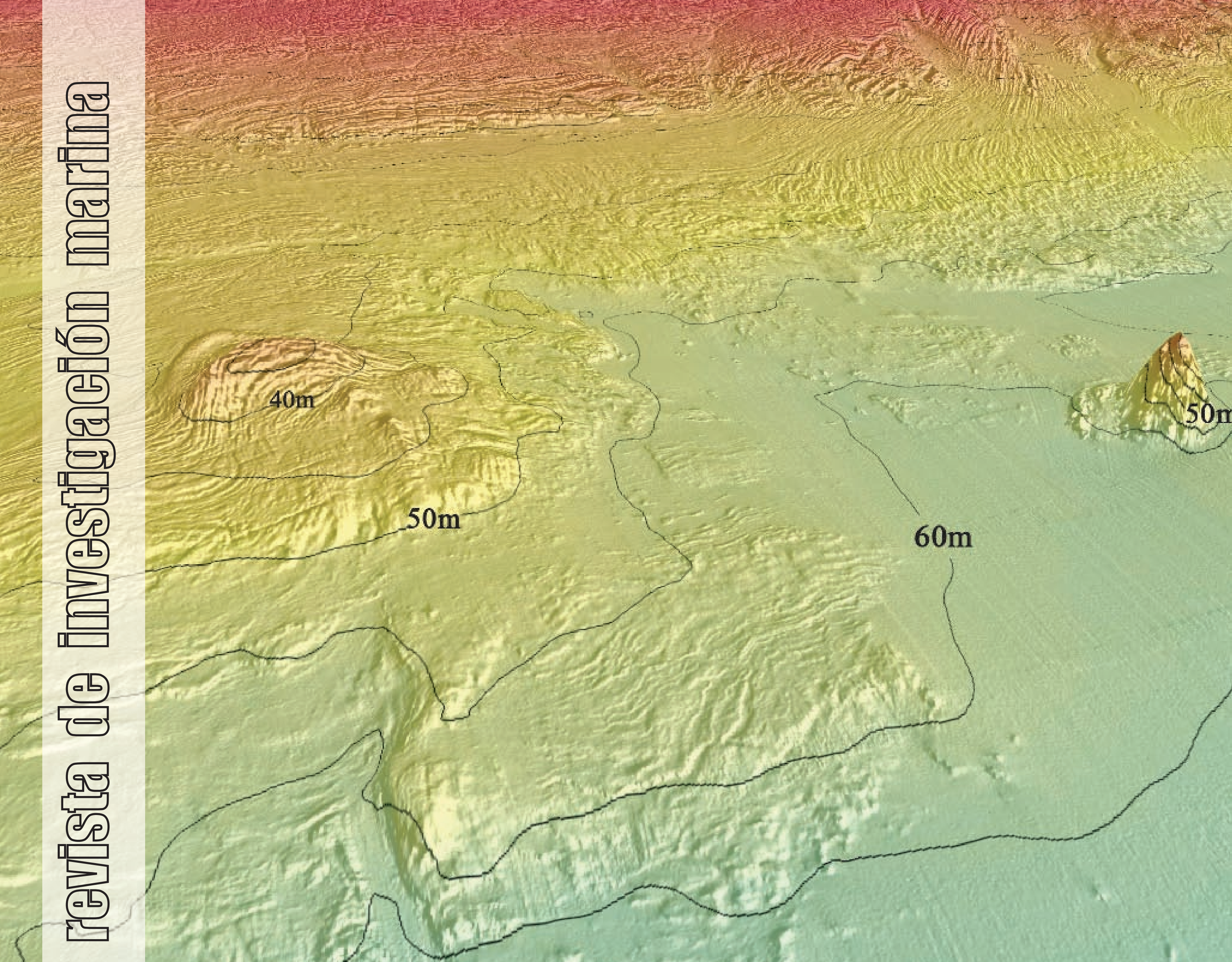

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Spawning Stock Biomass estimates of the Bay of Biscay anchovy (*Engraulis encrasicolus, L.*) in 2010 applying the Daily Egg Production Method

María Santos[1*], Andrés Uriarte[1] and Leire Ibaibarriaga[2]

Abstract

The research survey BIOMAN2010 for the application of the Daily Egg Production Method (DEPM) for the Bay of Biscay anchovy was conducted in May 2010, from the 5th to the 20th, covering the whole spawning area of the population. Total egg production (P_{tot}) was calculated as the product of the spawning area and the daily egg production rate (P_0), which was obtained from the exponential decay mortality model fitted as a Generalised Linear Model (GLM) to the egg daily cohorts. The adult parameters: sex ratio, batch fecundity and weight of mature females, were estimated from the adult samples obtained during the survey and the spawning frequency was calculated as the mean from the historical series. The spawning biomass estimate resulted in 42,979 t with a coefficient of variation of 15%, which supposes an increase of about 73% over the SSB estimate of 2009 produced in a similar way by the DEPM.

Resumen

La campaña de investigación BIOMAN2010 para la aplicación del Método de Producción diaria de huevos a la anchoa del Golfo de Vizcaya se realizó del 5 al 20 de mayo de 2010 cubriendo el área de puesta de la población. La producción total de huevos se calculó como el producto del área de puesta y la tasa de producción diaria de huevos, que se obtuvo a partir del modelo de mortalidad de decaimiento exponencial ajustando un modelo lineal generalizado a las cohortes diarias de huevos. Los parámetros de adultos: la proporción de sexos, la fecundidad parcial y el peso de las hembras maduras, se estimaron a partir de las muestras de adultos obtenidas durante la campaña y para la frecuencia de puesta se consideró la media de la serie histórica. La estima de la biomasa reproductora dio lugar a 42.979 t, con un coeficiente de variación del 15%, lo que supone un aumento de alrededor del 73% respecto a la estima de 2009 calculada de la misma forma.

Key Words: anchovy, *Engraulis encrasicolus*, DEPM, spawning stock biomass, Bay of Biscay

Introduction

Anchovy (*Engraulis encrasicolus*) is one of the commercial species of high economic importance in the Bay of Biscay. The economy of the Spanish purse seine fleets (primarily from the Basque Country, Cantabria and Galicia) and the French fleet rely greatly on this resource (Uriarte *et al.*, 1996 and Arregi *et al.*, 2004). In order to provide proper advice on the fishery management, it is necessary to conduct annually a monitoring of the population. Thanks to that monitoring, ICES (International Council for the Exploration of the Sea) detected the crisis of the fishery during the last decade due to the poor level of biomass after several failures of recruitments since 2001 (ICES, 2010). In consequence the fishery was closed by the European Council in 2005. In 2010, following the indices of good recruitment detected in September 2009, the fishery was provisionally open by the European Council, with a limited TAC of 7,000 t, conditioned to the confirmation of the recovery of the population above B_{pa} (precautionary approach biomass) levels (33,000 t) from the surveys in May 2010.

Anchovy is a short-lived species, for which the evaluation of its biomass has to be conducted by direct assessment methods as the daily egg production method (DEPM) (Barange *et al*, 2009). This method consists of estimating the spawning stock biomass (*SSB*) as the ratio between the total daily egg production (P_{tot}) and the daily fecundity (*DF*) estimates. In consequence, this method requires a survey to collect anchovy eggs (plankton sampling) for estimating the P_{tot} and to collect

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anchovy adults (adult sampling) for estimating the *DF*. It was developed in the late 1970s by the Coastal Division of the southwest Fisheries Centre, La Jolla, CA, USA (Parker, 1980) as a response to the growing need to devise a suitable direct method for the assessment of northern anchovy (*Engraulis mordax*), an indeterminate spawner with pelagic eggs (Hunter and Goldberg, 1980. Lasker (1985) compiled the work developed in California into the first, and most thorough to date, report defining the underlying principles of the method and describing the parameters, data and techniques required to obtain a DEPM estimate of spawning biomass. Afterwards, Stratoudakis *et al.,* (2006) compiled the recent advances, current applications and future challenge of this method.

In 1987 exploratory surveys were conducted to improve the knowledge on the Bay of Biscay anchovy, the reproductive biology and to check the suitability of this population to be assessed by this method (Santiago and Eltink, 1988; Sanz and Uriarte, 1989). Since then, AZTI-Tecnalia (Marine and Food Technological Centre, Basque country, Spain), either alone or in collaboration with other institutes, has conducted annually specific surveys to obtain anchovy biomass indices by the DEPM (Somarakis *et al.*, 2004; Motos *et al.*, 2005). In addition, the Basque fishery on anchovy has been continuously monitored. This information has been submitted annually to ICES, to advice on the exploitation of the fishery (ICES, 2010).

The survey for the application of the DEPM to estimate the Bay of Biscay anchovy biomass is one of the two surveys which give information about the anchovy population. The other one carried out at the same time in May is the acoustic French survey. The biomass indices provided by the acoustic and DEPM surveys together with the information supplied by the fleet are used as input variables for a two stage biomass model used to assess the Bay of Biscay anchovy population (Ibaibarriaga *et al.*, 2008). Apart from the anchovy SSB estimates the DEPM survey in the Bay of Biscay gives information on distribution and abundance of sardine eggs and environmental conditions due to the recollection of different parameters in the area surveyed such as sea surface temperature, sea surface salinity, temperature and salinity in the water column, currents and winds.

This paper describes the BIOMAN2010 survey for the application of the DEPM for the Bay of Biscay anchovy in 2010. First, the data collection, the estimation of the total egg production and the reproductive parameters are described in detail. Then, the SSB and the age structure indices obtained from the survey are given as they were used for the assessment and posterior management of this stock. Finally the historical trajectory of the population is reviewed.

Material and Methods

Survey description

The BIOMAN2010 survey was carried out in May, at the spawning peak covering the whole spawning area of anchovy in the Bay of Biscay. During the survey, ichthyoplankton and adult samples were obtained for the estimation of total daily egg production and total daily fecundity respectively. Moreover, the age structure of the population was also estimated.

The collection of plankton samples was carried out on board R/V Investigador from the 5th to the 20th May. The sampling was conducted in two phases. During the first phase, from the 5th to the 14th May, the western limit of the spawning was found, surveying the Cantabrian Coast from 4º35’W to the east until the coast and up to 45º30’N. Afterwards, the vessel ported in Le Verdon to change the scientific crew. The second phase, from the 14th to the 20th May, covered the remainder French platform, up to 47ºN and 4º30’W, looking for the northern limit of the spawning, getting back to the Pasajes port (43º36’N,-1º80’W) where the survey finished (Figure 1).

The strategy of egg sampling was identical to that used in previous years, i.e. a systematic central sampling scheme with random origin and sampling intensity depending on the egg abundance found (Motos, 1994). Stations were situated at intervals of 3 nmi along 15 nmi apart transects perpendicular to the coast. When the egg abundances found were relatively high, additional transects separated by 7.5 nmi were completed. This occurred in the area of Cap Breton until Arcachon and the area of influence of the Gironde estuary (Figure 1).

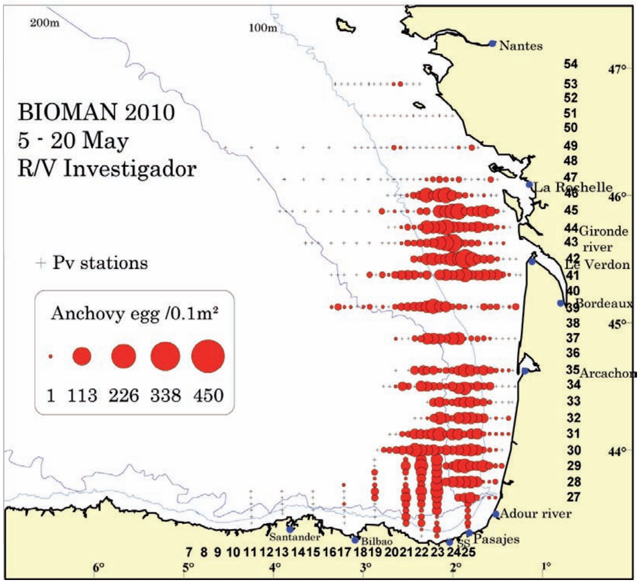


Figure 1. Distribution of plankton stations and egg abundances (eggs per 0.1m2) from the daily egg production method survey BIOMAN2010 obtained with PairoVET (Pair of Vertical Egg Tow).

At each station a vertical plankton haul was performed using a PairoVET net (Pair of Vertical Egg Tow, Smith *et al*., 1985 in Lasker, 1985) with a net mesh size of 0.150mm for a total retention of the anchovy eggs under all likely conditions. The net was lowered to a maximum depth of 100 m or 5 m above the bottom in shallower waters. After allowing 10 seconds at the maximum depth for stabilisation, the net was retrieved to the surface at a speed of 1 m s^{-1}. A 45 kg depressor was used to allow for correctly deploying the net. “G.O. 2030” flowmeters were used to detect sequential clogging of the net during a series of tows.

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

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

The Continuous Underway Fish Egg Sampler (CUFES, Checkley *et al*., 1997) was used to record the eggs found at 3m depth with a net mesh size of 350µm. The samples obtained were immediately checked under the microscope so that the presence/absence of anchovy eggs was detected in real time. When anchovy eggs were not found in six consecutive CUFES samples in the oceanic area transect was abandoned. The CUFES system had 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 were registered at real time using the integrated EDAS (Environmental Data Acquisition System) with custom software.

The adult samples were obtained mainly on board R/V Emma Bardán (pelagic trawler) from the 5^{th} to the 25^{th} May coinciding in space and time with the plankton sampling. In each haul, immediately after fishing, anchovy were sorted from the bulk of the catch and a sample of two kg was selected at random. A minimum of one kg or 60 anchovies were weighted, measured and sexed and from the mature females the gonads of 25 non-hydrated females (NHF) were preserved. If the target of 25 NHF was not completed 10 more anchovies were taken at random and processed repeatedly in the same manner. Sampling was stopped when more than 120 anchovies had to be sexed to achieve the target of 25 NHF. Otoliths were extracted onboard and read in the laboratory to obtain the age composition per sample. In addition, a piece of each anchovy was frozen to do genetic analysis afterwards on land. In each haul 100 individuals of each species were measured. Extra samples were frozen to analyse the gut content of anchovy, sardine, mackerel and horse mackerel in the laboratory to study the predation on anchovy eggs.

Nine additional adult samples were obtained from the commercial Spanish purse seine fleet. Three of these samples did not have date and position data and therefore could not be used for the analysis. Onboard the purse seines a sample of two kg was selected from the bulk of the catch and was directly kept in 4% formaldehyde in a container. Afterwards, in the laboratory the samples were processed in the same way as explained above. As the otoliths were not valid after keeping them in formaldehide the age structure of these samples were deduced from an Age Length Key derived from the anchovies fished with the pelagic trawler.

Total egg production

Total daily egg production (P_{tot}) was calculated as the product between the spawning area (SA) and the daily egg production (P_0) estimates:

$$(1) \quad P_{tot} = P_0 \, SA \, .$$

.

A standard PairoVET sampling station represented a surface of 45 nmi^2 (i.e. 154 km^2). Since the sampling was adaptive, the area represented by each station was corrected according to the sampling intensity and the cut of the coast. The total area was calculated as the sum of the area represented by each station. The spawning area (SA) was delimited with the outer zero anchovy egg stations although it could contain some inner zero anchovy egg stations embedded. The spawning area was 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:

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

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:

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

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:

(4) $$f(age \mid stage, temp) \propto f(stage \mid age, temp) f(age) .$$

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 *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)*):

(5) $$f(age) \propto f(spawn = \tau - age) \exp(-Z\ age) .$$

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, 1985; 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 down.

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 (2)-(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, eggs younger than 4 hours and older than 90% of the survey incubation time (Motos, 1994) were removed.

Once the final model estimates were obtained the coefficient of variation of P_0 was given by the standard error of the model intercept (log(P_0)) (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 .

Daily fecundity

The daily fecundity (DF) was estimated as follows:

(6) $$DF = \frac{R \cdot F \cdot S}{W_f} ,$$

where *R* is the sex ratio in weight, *F* is the batch fecundity (eggs per batch per female weight), *S* is the spawning fraction (percentage of females spawning per day) and W_f is the female mean weight.

From 1987 to 1993 the sex ratio in numbers resulted to be not significantly different from 50%. Therefore, since 1994 the sex ratio in numbers is assumed to be 0.5 and the sex ratio in weight per sample is estimated as the ratio between the average female weight and the sum of the average female and male weights of the anchovies in each of the samples.

A linear regression model between total weight (*W*) and gonad free weight (W_{gf}) was fitted to data from non hydrated females:

(7) $$E[W] = a + b * W_{gf} .$$

This model was used to correct the weight increase of hydrated anchovies. The female mean weight (W_f) per sample was calculated as the average of the individual female weights.

For the batch fecundity (*F*) the hydrated egg method was followed (Hunter and Macewicz., 1985). The number of hydrated oocytes in gonads of a set of hydrated females was counted. This number was deduced from a sub-sampling of the hydrated ovary. Three pieces of approximately 50 mg were removed from the extremes and the centre of one of the ovary lobule of each hydrated anchovy. Those were weighted with precision of 0.1 mg and the number of hydrated oocytes counted. Finally, the number of hydrated oocytes in the sub-sample was raised to the gonad weight of the female according to the ratio between the weights of the gonad and the weight of the sub-samples

The model between the number of hydrated oocytes and the female gonad free weight was fitted as a Generalized Linear Model with Gamma distribution and identity link:

$$E[F] = a + b * W_{gf} \quad . \tag{8}$$

The average of the batch fecundity for the females of each sample as derived from the gonad free weight - eggs per batch relationship was then used as the sample estimate of batch fecundity.

Once sex ratio, female mean weight and batch fecundity were estimated per sample, overall mean and variance for each of these parameters were estimated following equations for cluster sampling (Picquelle & Stauffer, 1985):

$$\bar{y} = \frac{\sum_{i=1}^{n} M_i \bar{y}_i}{\sum_{i=1}^{n} M_i} \quad \text{and} \tag{9}$$

$$Var(\bar{y}) = \frac{n \sum_{i=1}^{n} M_i^2 (\bar{y}_i - \bar{y})^2}{\left(\frac{\sum_{i=1}^{n} M_i}{n} \right)^2 n(n-1)} \quad , \tag{10}$$

where *Yi* and *Mi* are the mean of the adult parameter *Y* and the cluster sample size in sample *i* respectively. The variance equation for the batch fecundity was corrected according to Picquelle and Stauffer (1985) in order to account for the additional variance due to model fitting.

The weights *Mi* were taken to reflect the actual size of the catch and to account for the lower reliability when the sample catch was small (Picquelle and Stauffer, 1985). For the estimation of *W* and *F* when the number of mature females per sample was less than 20 the weighting factor was equal to the number of mature females per sample divided by 20, otherwise it was set equal to 1. In the case of R when the total weight of the sample was less than 800 g then the weighting factor was equal to the total weight of the sample divided by 800g, otherwise it was set equal to 1.

The estimation process of the spawning frequency parameter is currently under revision (Uriarte *et al*, 2011). Until this process is completed the spawning frequency was taken as the average of the historical series.

SSB and numbers at age

The Spawning Stock Biomass (*SSB*) was estimated as the ratio between the total egg production (P_{tot}) and daily fecundity (*DF*) estimates and its variance was computed using the Delta method (Seber, *1982*).

Two regions, North (N) and South (S) delimited by the 45º14`N latitude, were defined depending on the distribution of the adult samples (size, weight and age) and the distribution of anchovy eggs (Figure 2). Mean and variance of anchovy mean weights and proportions at age in the adult population were computed as a weighted average of the mean weight and age composition per samples (equations 9 and 10) where the weights were proportional to the population (in numbers) in each region. In particular, the weighting factors were proportional to the egg abundance divided by the numbers of adult samples in the region and the mean weight of anchovy per sample.

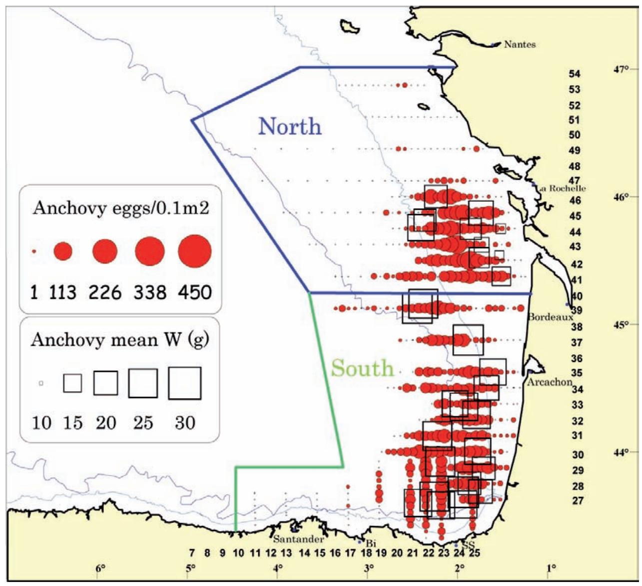


Figure 2. The two regions defined for the estimation of the numbers at age.

Results

Survey description

The limit of the spawning area was found at 3º12’W to the west in the Cantabrian Coast and 46º15’N to the north in the French platform (Figure 1). Spatial distributions of vertical hauls performed with the PairoVET net are shown in Figure 1. The total number of PairoVET samples obtained was 484. The number of CUFES samples obtained was 1,156. The total area surveyed was 61,940 km² and the spawning area was 37,633 km². From 484 PairoVET samples, 309 had anchovy eggs (64%) with an average of 12 eggs 0.1m^{-2} per station and a maximum of 126 eggs 0.1m^{-2} in a station. A total of 5,588 anchovy eggs were encountered and classified.

The anchovy eggs were concentrated principally in the area of the French continental shelf between Cap Breton and

Arcachon, mostly between the isoline of 100 m depth and crossing the shelf break, and in the area of influence of the Gironde estuary between 45º22'N and 46ºN. (Figure 1)

Figure 3 shows the sea surface temperature and sea surface salinity maps overlapped with the abundance of anchovy eggs as observed during the BIOMAN2010 survey.

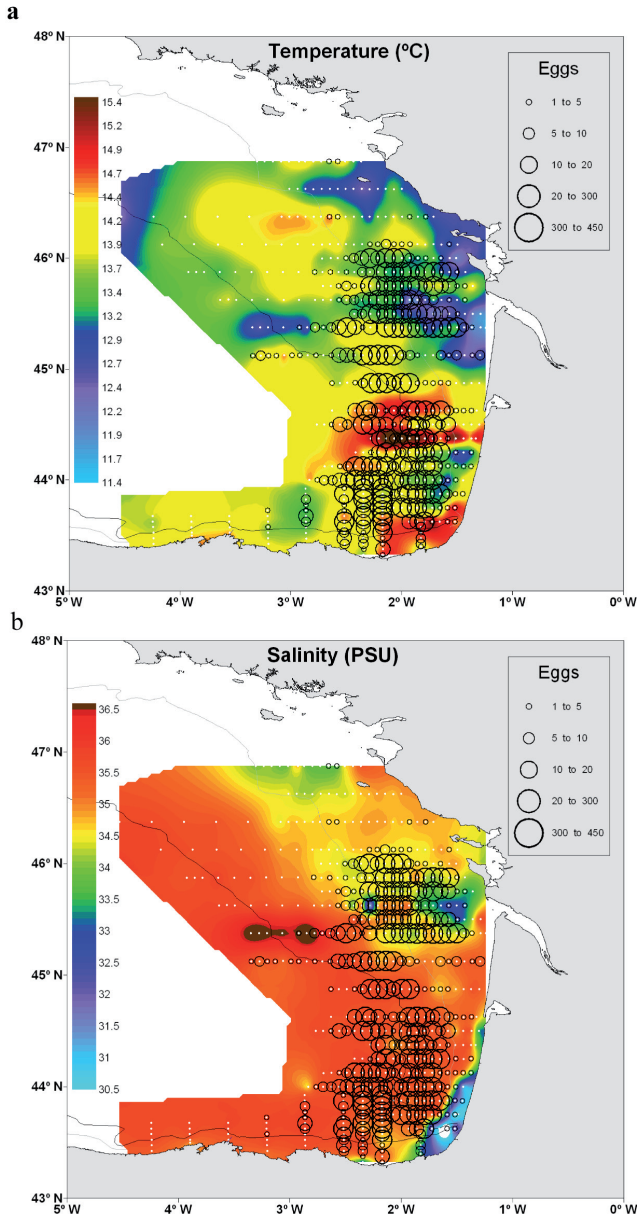


Figure 3. Sea surface temperature (a) and sea surface salinity (b) within the anchovy egg abundance observed during the survey BIOMAN2010

This year the mean SST of the survey 13.8ºC, in a range between 11.6 and 16.1 ºC, was one of the lowest of the historical series along with 2004 (13.7ºC). Mean sea surface salinity was 35 with a range between 28.8 and 37.26. The lowest salinity was found in the area of influence of the Adour River and Gironde estuary. Adour River (provided by the French National Database for Hydrometry and Hydrology, HYDRO) presented a flow rate exceeding 300m^{3}s^{-1} between 6th and 9th May 2010 (Figure 4.). This fact can be clearly seen on the sea surface salinity map obtained during the survey (Figure 3b). Between 8th and 10th May, salinity lower than 31 was observed on the French coast around the Adour River and along the coast farther north. In this map, it can be observed the same behaviour for the Garonne River. In this case, the salinity was measured between 13th and 16th. It can be seen between 2.3ºW and 1.5ºW surface water masses with salinity and temperature features lower to the surroundings that seem to come from the Garonne River. These water masses would be derived offshore with the surface currents and beyond the platform, as indicated by the predictions of 4 day-long trajectories of particles released at the sea surface in the Bay of Biscay on 11th May (Figure 5). These trajectories were obtained with the hydrodynamic model ROMS (Shchepetkin and McWilliams, 2005) coupled to a Lagrangian Particle-Tracking Model (Ferrer *et al.*, 2009).

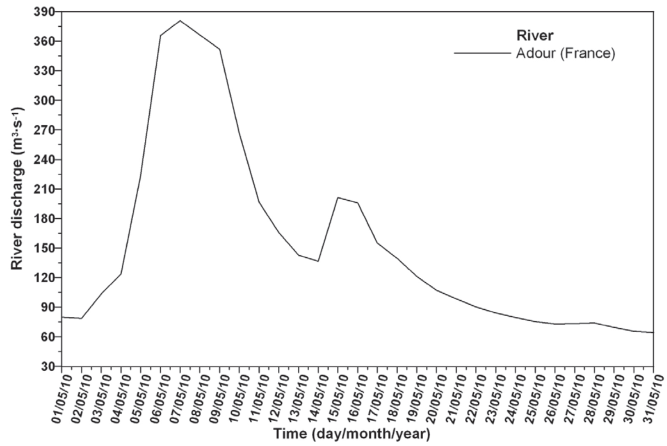


Figure 4. Adour river discharge in May 2010.

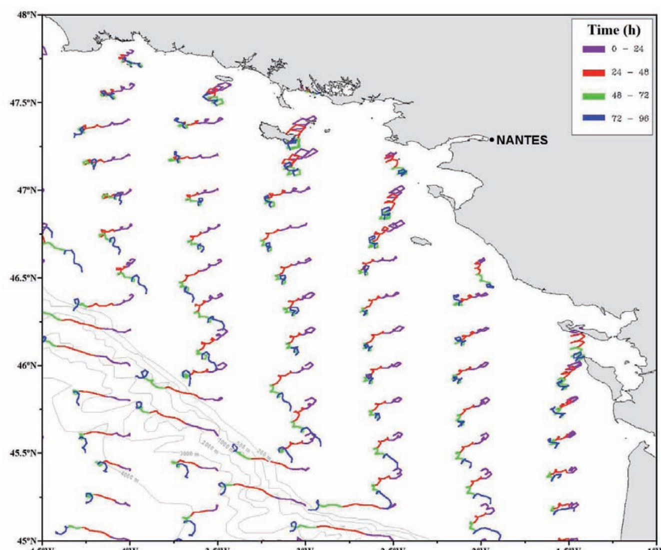


Figure 5. Predictions of 4 day-long trajectories of particles released at the sea surface in the Bay of Biscay on 11th May, carried out with the hydrodynamic model ROMS coupled to a Lagrangian Particle-Tracking Model

The adult samples covered adequately the positive spawning area as shown in Figure 6. Overall 34 pelagic trawls were performed from which 30 provided anchovy samples and were selected for the analysis. 6 additional samples from the purse seines were also selected. Most hauls consisted of anchovy, horse mackerel, sardine and mackerel.

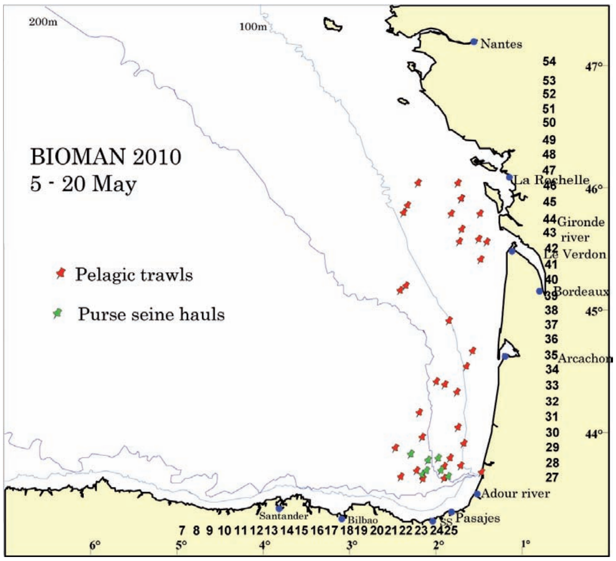


Figure 6. Spatial distribution of fishing hauls from R/V Emma Bardán (pelagic trawler) and the fleet (purse seine) in 2010.

Total daily egg production

The exponential decay mortality model fitted to the egg daily cohort frequency and their mean age is shown in Figure 7. The daily egg production (P_0) was 61.7 egg m^{-2} day^{-1} with a CV of 0.12. The daily mortality rate Z was 0.34 with a CV of 0.16. Then, the total daily egg production as the product of spawning area and daily egg production was 2.32 E+12 with a CV of 0.12 (Table 3).

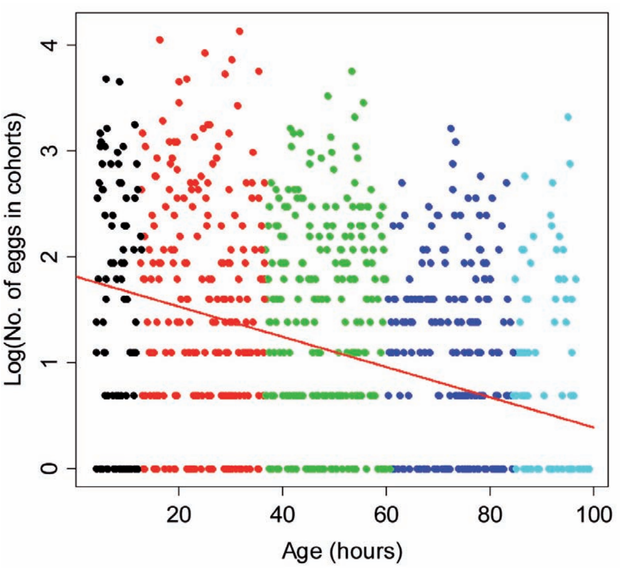


Figure 7. Logarithm of the number of eggs in cohorts (each cohort is represented by a colour) by age and the exponential mortality model adjusted using a Generalised Linear Model (GLM).

Daily fecundity

The spatial distribution of the samples and their species composition is shown in Figure 8. Anchovy is mainly found with sprat in the Gironde river plume, with horse mackerel and sardine in the Arcachon area and in the Adour river plume and with mackerel in the oceanic area.

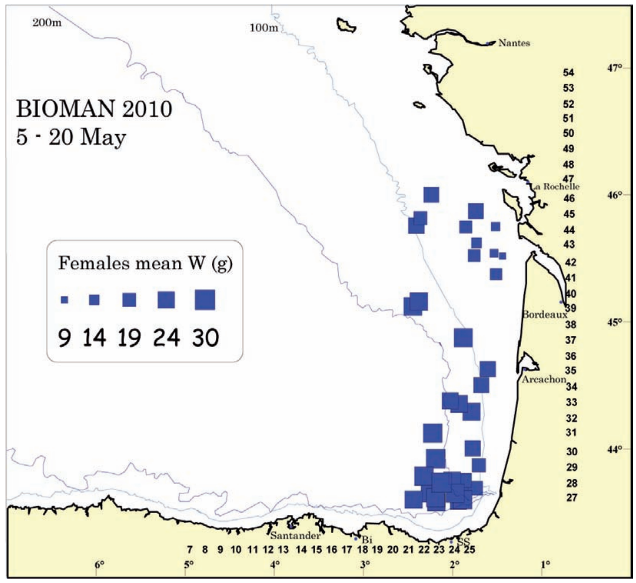


Figure 8. Species composition of fishing hauls from R/V Emma Bardán during BIOMAN2010

Spatial distribution of mean size and female mean weights are shown in Figures 9 and 10. Smaller individuals and females with less weight were found all along the 100 m depth isoline and in the influence of the Gironde estuary while larger and heavier anchovies were found offshore.

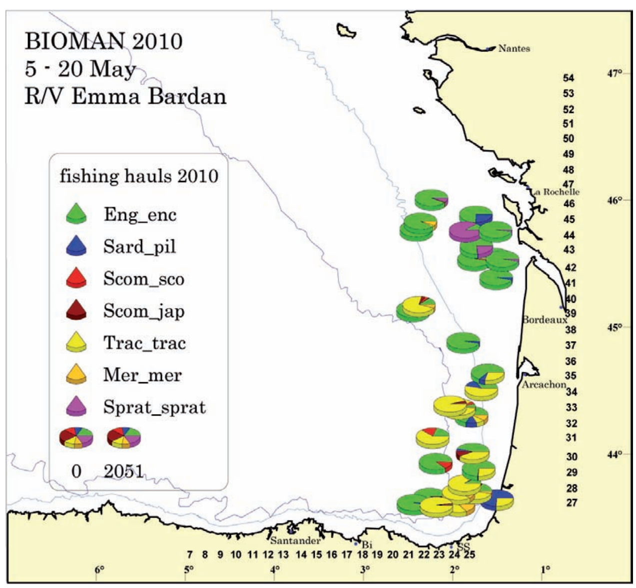


Figure 9. Mean size of anchovies per haul

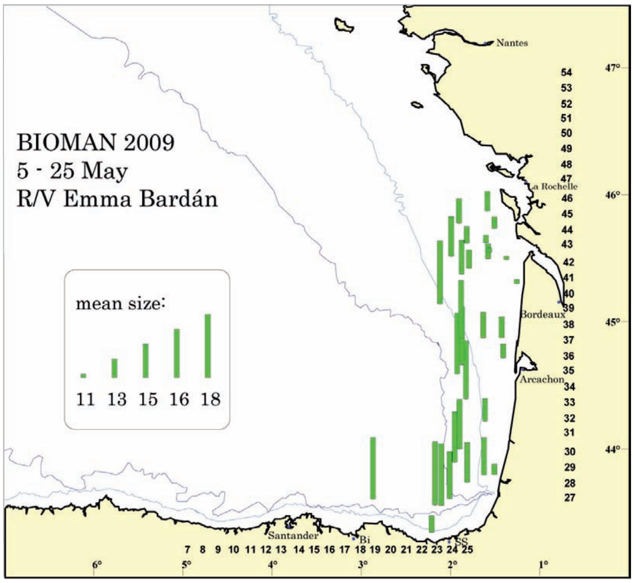


Figure 10. Spatial distribution of female mean weights in 2010.

The linear regression model between gonad-free-weight and total weight fitted to non-hydrated females is given in Table 1. The model fitted the data adequately (Figure 11, R^2=99.7%, n= 609). The female mean weight was obtained as the weighted mean of the average female weights per sample (Lasker, 1985).

Table 1. Coefficients resulted from the linear regression model between gonad-free-weight and total weight fitted to non-hydrated females with their standard error and the P-Value

Parameter	Estimate	Standard error	P-Value
Intercept	-0.5221	0.0574	0
Slope	1.1064	0.0027	0

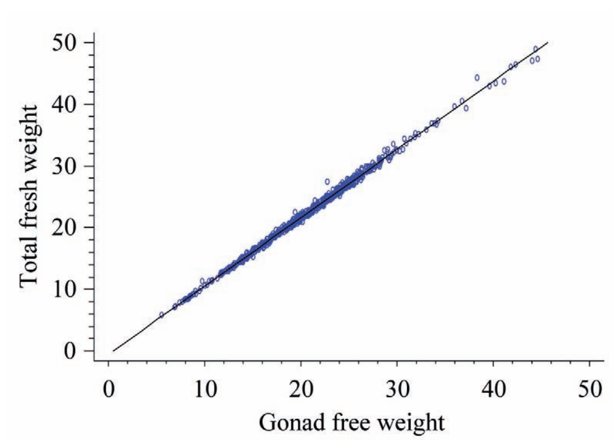


Figure 11. Plot of linear regression model used to correct the increase of weight of the females due to hydration.

For the batch fecundity 110 hydrated females from 17 samples, ranging from 8.7 to 50.6 g gonad free weight were examined. The coefficients of the generalised linear model with Gamma distribution and identity link are given in Table 2 and the fitted model is shown in Figure 12. It was tested whether the model coefficients changed between the strata North/South used in the estimation of the age structure of the population (Figure 2). No statistically significant differences among the regions at the 95% confidence level were found, so the model fitted to the single region was then used to estimate batch fecundity from the gonad free weight for all the females of all samples. Hence, the overall batch fecundity estimate was obtained as a weighted sample mean of the batch fecundity per sample (Lasker, 1985).

Table 2. Coefficients of the generalised linear model with Gamma distribution and identity link between the number of hydrated oocytes and the female gonad free weight (wgf)

Parameter	estimate	Standard error	Pr(>|t|)
Intercept	-5636	348	<2e-16
wgf	709	29	<2e-16

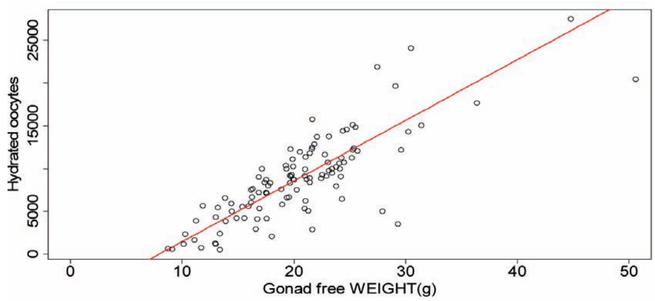


Figure 12. Fitted GLM (Generalised Linear Model) between hydrated oocytes and gonad-free weight.

Estimates of the mean female weight, batch fecundity, sex ratio and spawning frequency with their CVs are given in Table 3.

Table 3. All the parameters to estimate de Spawning Stock Biomass(SSB) using the Daily Egg Production Method (DEPM) for 2010: Ptot (total egg production), R (sex ratio), S(Spawning frequency), F (batch fecundity), Wf (female mean weight), DF (daily fecundity) and Wt (total mean weight(female and male) with correspondent Standard errors (S.e.) and coefficients of variation (CV).

Parameter	estimate	S.e.	CV
Ptot	2,32E+12	2,90E+11	0,1249
R'	0,53	0,0023	0,0044
S	0,25	0,0087	0,0353
F	9.394	635	0,0676
Wf	22,90	0,89	0,0387
DF	54,02	4,02	0,0744
BIOMASS	42.979	6.249	0,1454
Wt	19,79	1,24	0,0627

SB and Numbers at age

The *SSB* estimate from the DEPM was 42,979 t with a CV of 0.15 (Table 3).

For the purposes of producing population at age estimates, the age readings based on 1,870 otoliths from 31 samples were available. Estimates of anchovy mean weights and proportions at age in the population were the average of proportions at age in the samples, weighted by the population each sample represents. Given that mean weights of anchovies change between different regions (Figure 2) proportionality between the amount of samples and approximate biomass indices by regions was checked. The approximate index of biomass by regions was set equal to egg abundance by areas (assuming equal daily fecundity at each area) (Table 2). According to that table, the 36 samples selected can not be considered to be balanced between those regions and differential weighting factors were applied to each sample coming from one or the other region for the purposes of the number at age estimates.

Mean weight, age composition and weighting factors by sample are presented in Table 4. The proportion by age and population at age estimates are given in Table 5. 84% of the population correspond to age 1. Figure 13 shows the distribution of anchovy age composition in space.

Table 4. Balance of the adult sampling to egg abundance by 2 regions (north-N and south-S) in the Bay of Biscay (Figure 2). The row of the table above the mean weights corresponds to the weighting factor of each of the samples by regions to obtain the preliminary estimates of the population structure. Mean weight by regions arise from the adult samples selected for the analysis. SSB (Spawning Stock Biomass)

Estrata	N	S	Addition
Total egg abundance	2,0E+12	3,1E+12	5,12,E+12
% egg abundance	40%	60%	100%
Nº of adult samples	11	25	36
%Egg/sample	0,04	0,02	
Proportion of SSB relative to South str.	1,49	1,00	
W. factor proportional to the population	1.49/wi	1/wi	
Mean weight of anchovies by region	15,64	24,11	
Standard Deviation	4,41	2,58	
CV	28%	11%	

Table 5. SSB (Spawning Stock Biomass) 2010 estimates and correspondent standard error (S.e.) and coefficient of variation (CV) of the percentage, numbers, weight and Spawning Stock Biomass (SSB) at age estimates. W (weight)

Parameter	estimate	S.e.	CV
BIOMASS (Tons)	42.979	6.249	0,1454
Total mean W (g)	19,79	1,24	0,0627
Population (millions)	2.181	351	0,1607
Percentage age 1	0,84	0,02	0,0202
Percentage age 2	0,15	0,02	0,1036
Percentage age 3	0,01	0,00	0,2545
Numbers at age 1	1.833	302	0,1647
Numbers at age 2	330	59	0,1797
Numbers at age 3	19	5	0,2835
Weight at age 1	17,7		
Weight at age 2	24,7		
Weight at age 3	40,5		
SSB at age 1	32.441		
SSB at age 2	8.142		
SSB at age 3	759		

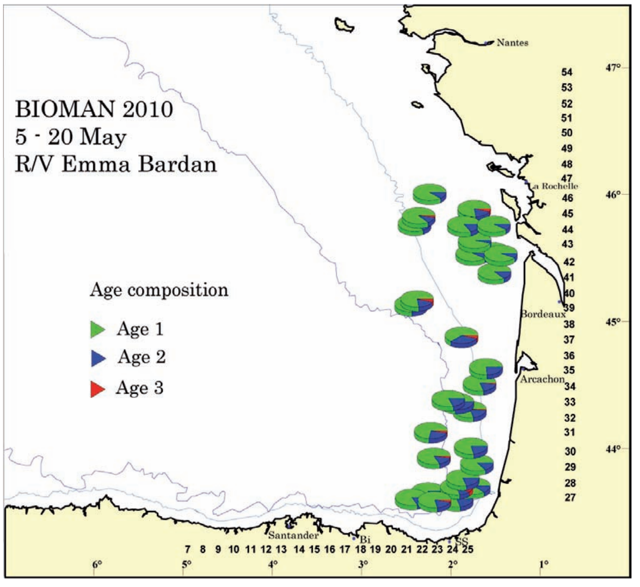


Figure 13. Distribution of the anchovy ages 2010 in space.

Historical perspective

In order to provide a broader point of view for the interpretation of current survey results, this year's results were compared to the ones obtained in the historical series. The whole series of biomass estimates from the DEPM, including the current estimate for 2010, are presented in Figure 14. The biomass estimate in 2010 is the largest since 2002, being about 73% larger than the 2009 estimate.

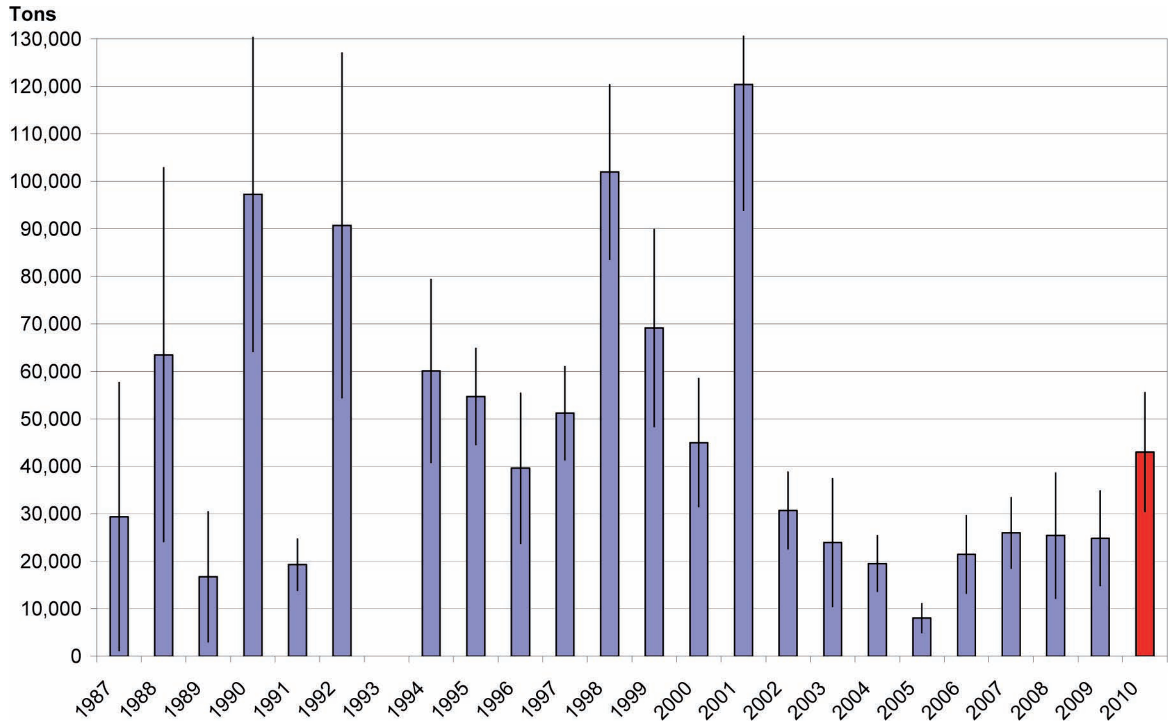


Figure 14. Series of Biomass estimates (tonnes) obtained from the daily egg production method (DEPM) since 1987. Most of them are full DEPM estimates, except in 1996, 1999 and 2000, which were deduced indirectly. Error bars represented 2standar errors. The red bar represent 2010 year estimate.

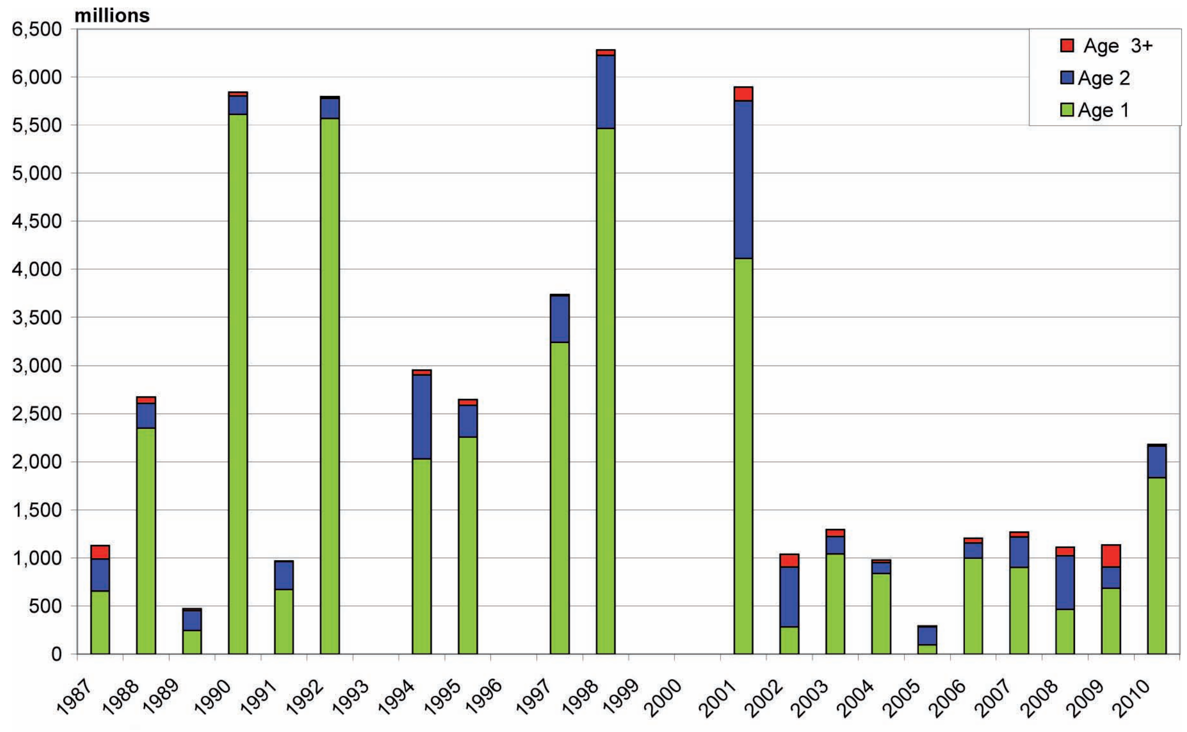
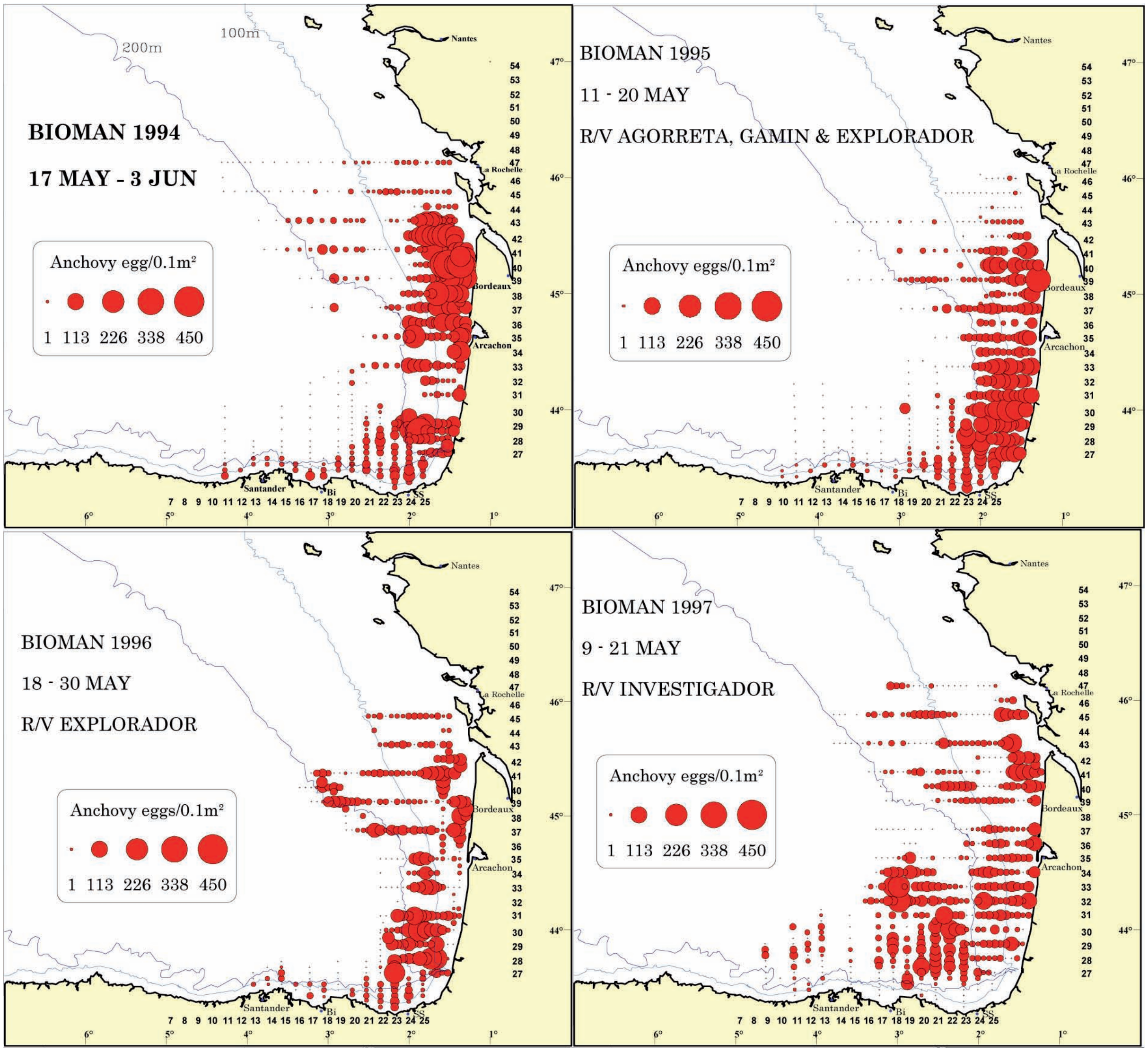


Figure 15. Historical series from 1987 to 2010 of numbers at age.

The historical series of numbers at age is shown in Figure 15. This year 2010 age 1, in numbers, was 84% of the population. Usually the age 1 class forms the largest fraction of the population. Exceptions occurred in 2002, 2005 and 2008 due to recruitment failures.

The raise in biomass and the high percentage of biomass at age 1, are indicative of a recovery in the recruitment after 5 years of failures. This suggested a neat recovery of the population by comparison with previous year's estimates. ICES after the incorporation of the present results from the DEPM survey and the French acoustic survey assessed the stock above B_{pa} levels at a biomass around 50,000 t. Certainly, the closure of the fishery had a positive effect in sustaining the recent levels of biomass as to reach the current recovery of the population.

Distribution maps in space of anchovy egg abundances from 1994 onwards are shown in Figure 16. The Gironde and Adour river plumes are repeated spawning sites along the years. However in years of high abundances the egg distribution is wider, up to 47º30'ºN and 5ºW. After various years of low egg densities and reduced spawning areas, in 2010 the egg distribution map is more similar to years of mid abundance as 1994 or 1996.



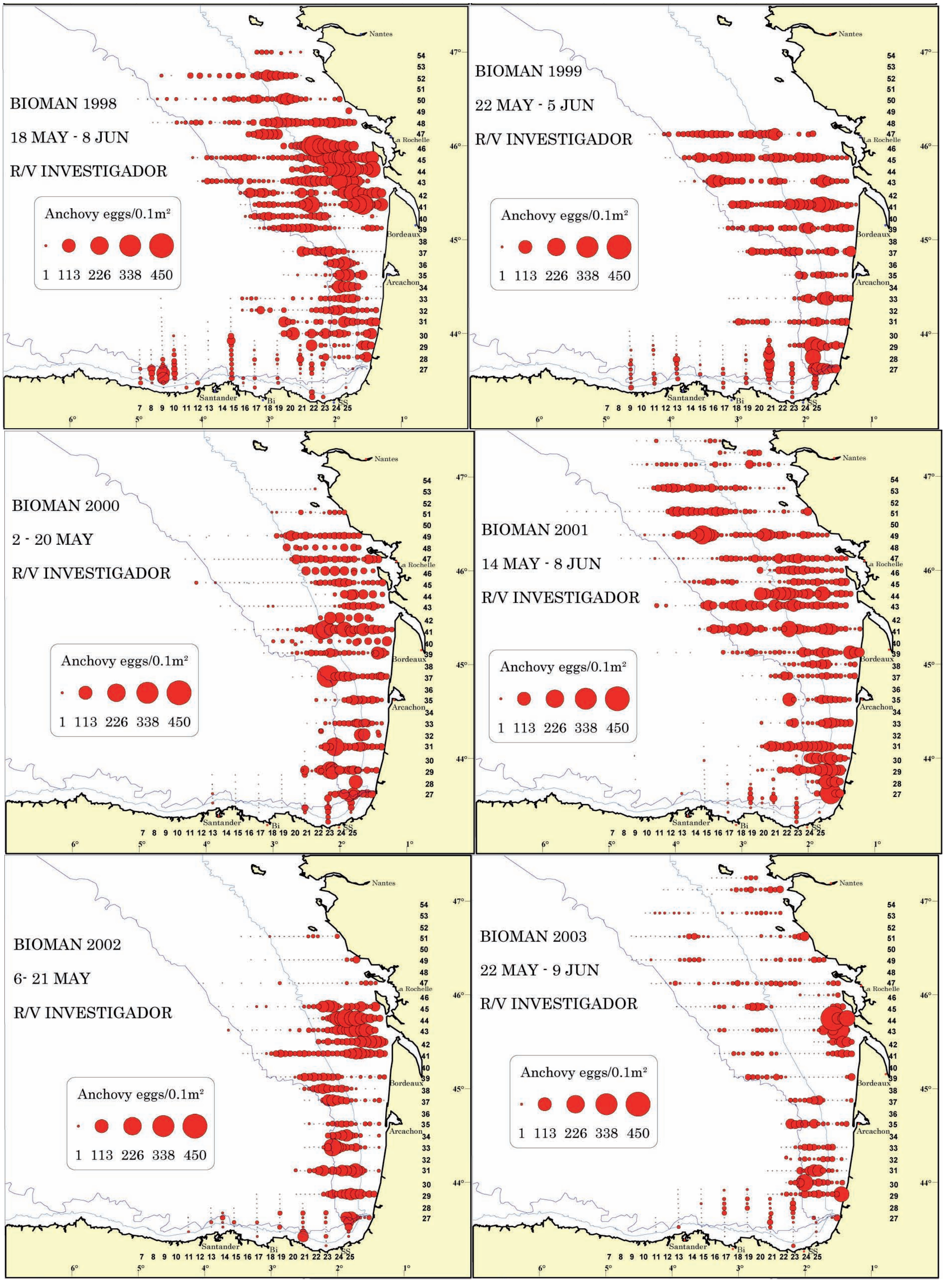


Figure 16. Spatial distribution of anchovy eggs from 1994 to 2010.

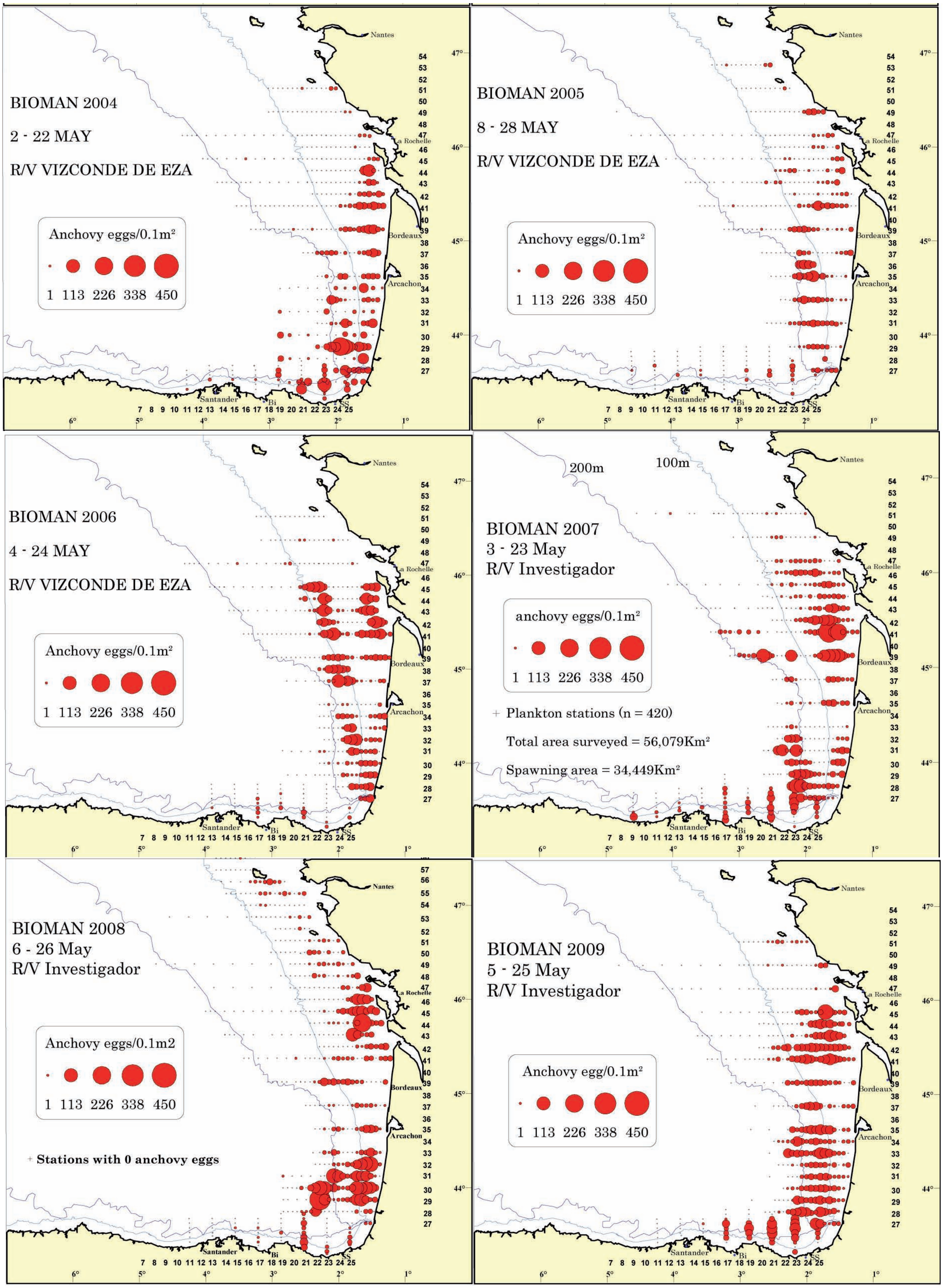


Figure 16. Spatial distribution of anchovy eggs from 1994 to 2010.

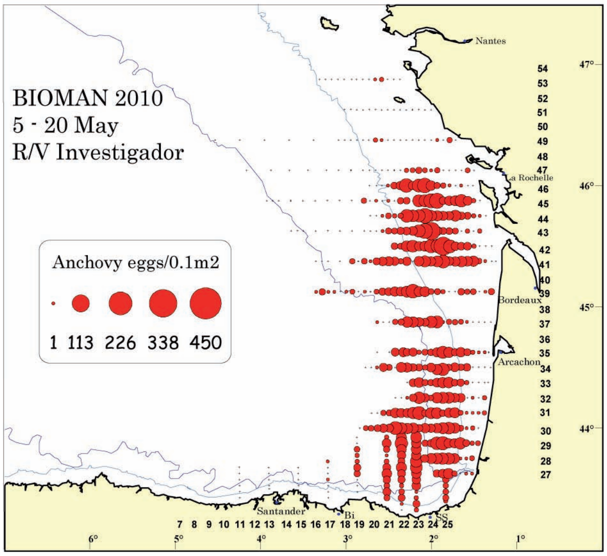


Figure 16. Spatial distribution of anchovy eggs from 1994 to 2010.

Conclusions

The survey BIOMAN2010 has covered the spawning area satisfactory and the total egg production has been estimated in the distribution area of the population.

The anchovy egg distribution in 2010 occupies a higher extension in the area of cap Breton or plateau de Landes and more spread than last year surpassing the 200 m depth. Total daily egg production is higher than the last 7 years.

A total of 30 positive anchovy samples were obtained with a pelagic trawler and 6 from the fleet, simultaneously to the egg sampling. All those were processed for batch fecundity, weight of females, total weight and sex ratio. Until a revision of the time series is completed, spawning frequency is estimated as the historical mean.

With all the adult parameters calculated from the samples (except for the spawning frequency) a daily fecundity of 54 eggs g^{-1} day^{-1} was obtained with a CV of 0.0744 The SSB estimate resulted in 42,979 t with CV of 0.1454. For the numbers at age the 84% of the population was 1 year old. This shows a good recruitment this year.

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