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Direct assessment of small pelagic fish by the PELGAS15 acoustic survey

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1. MATERIAL AND METHOD

1.1. PELGAS survey on board Thalassa

Acoustic surveys are carried out every year in the Bay of Biscay in spring onboard 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 are anchovy and sardine but they are considered in a multi-specific context and within an ecosystemic approach as they are located in the centre of pelagic ecosystem.

These surveys are connected with IFREMER programs 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 and Portugal in order to have most of the potential area covered from Gibraltar to Brest with the same protocol regarding sampling strategy. Data are available for the ICES working groups WGHANSA, WGWIDE and WGACEGG.

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

1) Continuous acquisition of acoustic data from six different frequencies and pumping sea-water under the surface in order to evaluate the number of fish eggs using a CUFES system (Continuous Under-water Fish Eggs Sampler). Concurrently, a visual counting and identification of cetaceans and birds (from board) carried out in order to characterise the higher level predators of the pelagic ecosystem.
2) Discrete sampling at stations (by pelagic trawls, plankton nets, CTD).

Satellite imagery (temperature and sea colour) and modelling have been also used before and during the survey to recognise the main physical and biological structures and to improve the sampling strategy.

The strategy this year was the identical to previous surveys (2000 to 2014). The survey protocols are described *in Doray M, Badts V, Masse J, Duhamel E, Huret M, Doremus G, Petitgas P (2014).* ***Manual of fisheries survey protocols. PELGAS surveys (PELagiques GAScogne)***. *http://dx.doi.org/10.13155/30259:*

- acoustic data were collected along systematic parallel transects perpendicular to the French coast (figure 1.1.1). The length of the ESDU (Elementary Sampling Distance Unit) was 1 mile and the transects were uniformly spaced by 12 nautical miles and cover the continental shelf from 20 m depth to the shelf break (or sometimes more offshore – see figure below).
- acoustic data were only collected during the day because of pelagic fishes behaviour in this area. These species are usually dispersed very close to the surface during the night and so "disappear" in the blind layer of the echo-sounders between the surface and 8 m depth.

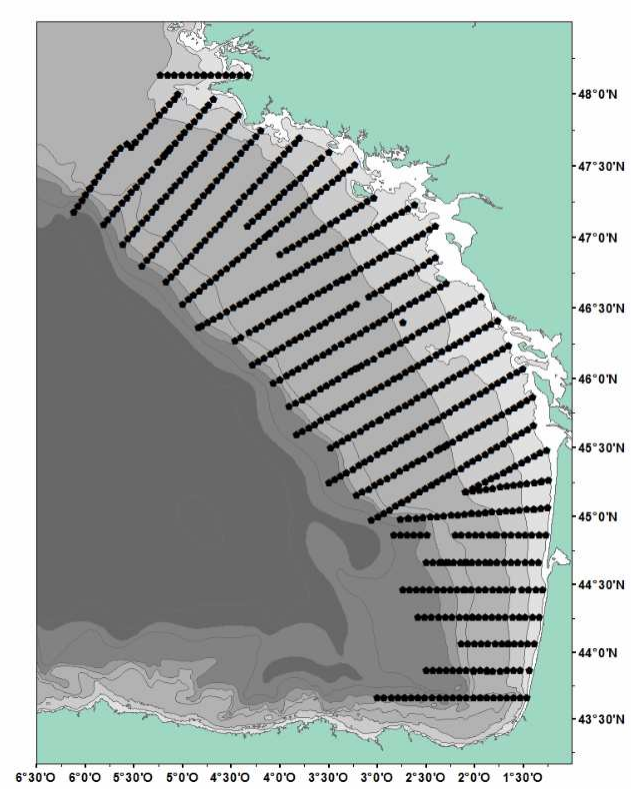


Fig. 1.1.1 - Transects prospected during PELGAS15 by Thalassa.

Three different echo-sounders were used during the survey :

In 2014, as in previous surveys (since 2009), three modes of acoustic observations were used :

- 6 split beam vertical echo-sounders (EK60), 6 frequencies, 18, 38, 70, 120, 200 and 333 kHz
- 1 horizontal echo-sounder on the starboard side for surface echo-traces
- 1 SIMRAD ME70 multi-beam echo-sounder (21 2 to 7°beams, from 70 to 120 kHz) used essentially for visualisation to observe the behaviour and shapes of fish schools during the whole survey. Nevertheless, only echoes stored on the vertical echo-sounder were used for abundance index calculation.

Energies and samples provided by all sounders were simultaneously visualised and stored using the MOVIES+ and MOVIES3D software and stored at the same standard HAC format.

The calibration method was the same that the one described for the previous years (see WD 2001) and was performed at anchorage near Brest, in the West of Brittany, in optimal meteorological conditions at the beginning of the survey.

Acoustic data were collected by R/V Thalassa along a total amount of 5400 nautical miles from which 1990 nautical miles on one way transect were used for assessment. A total of 37679 fishes were measured (including 13 353 anchovies and 9022 sardines) and 3057 otoliths were collected for age determination (1607 of anchovy and 1450 of sardine).

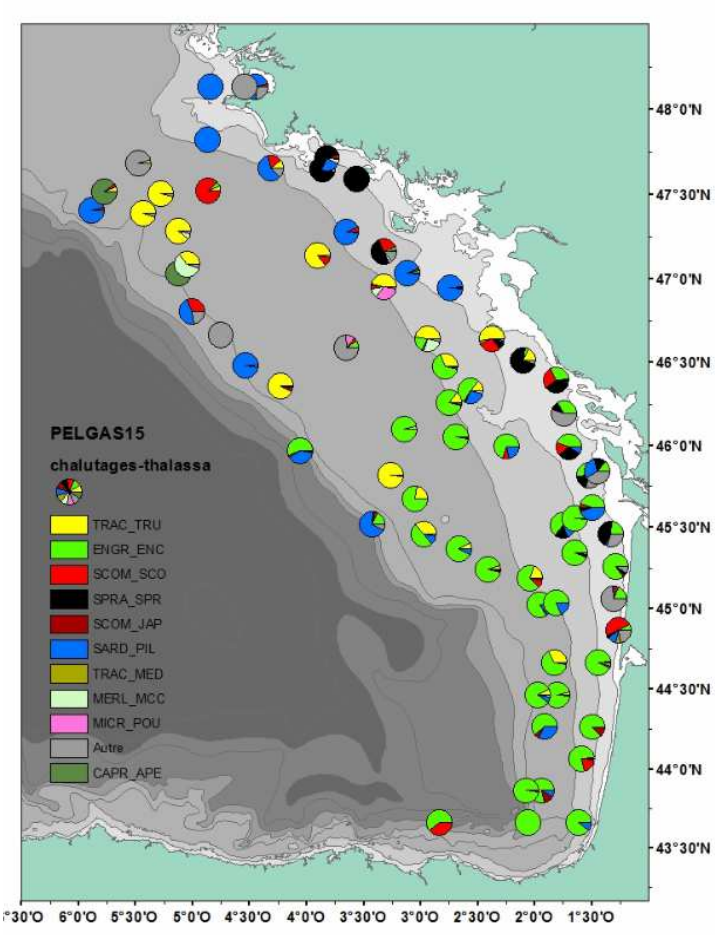


Fig. 1.1.2: Species distribution according to Thalassa identification hauls.

1.2. The consort survey

A consort survey is routinely organised since 2007 with French commercial vessels during 18 days. This approach, in the continuity of last year survey, and their trawl hauls were used for echoes identification and biological parameters at the same level than Thalassa ones.

Four commercial vessels (two pairs of pelagic trawlers) participated to PELGAS15 survey:

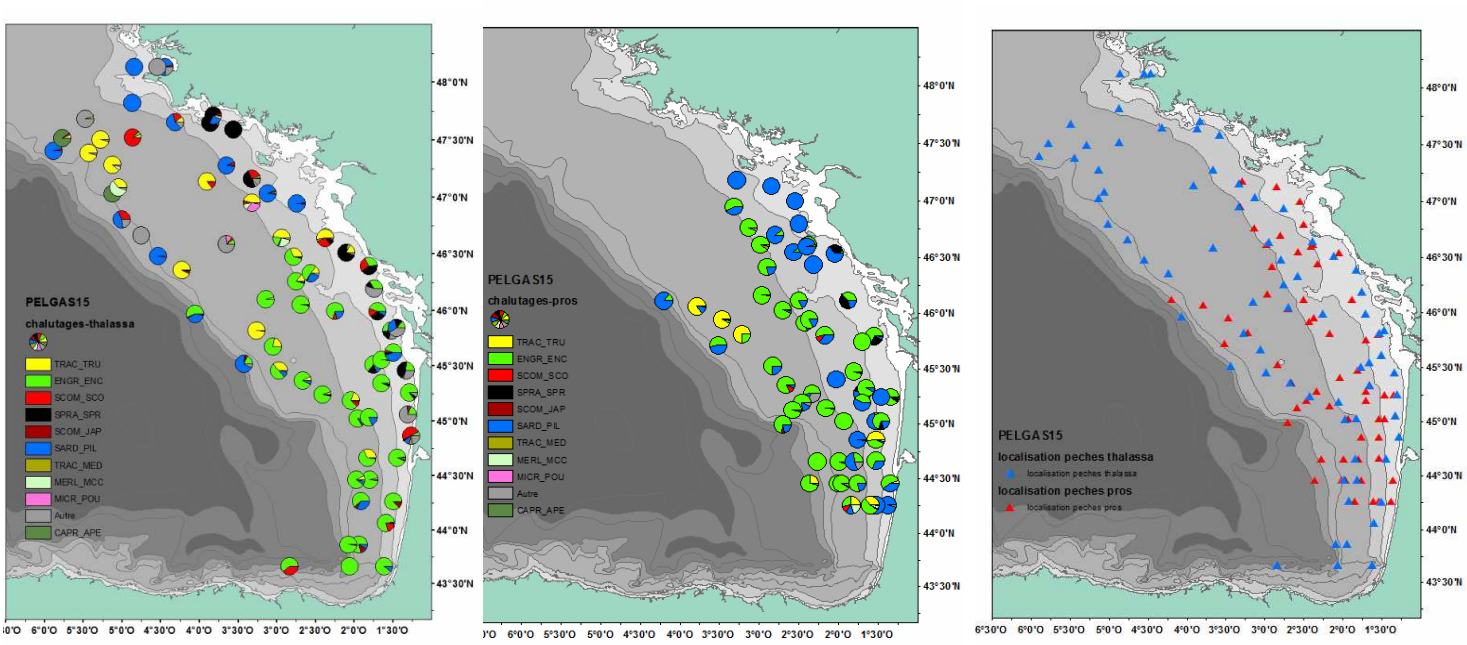
Vessel	gear	Period	Days at sea
Maïlys-Charlie / Pen Kiriac 3	Pelagic pair trawl	03/05 to 12/05/2015	9
Jeremi-Simon / Prométhée	Pelagic pair trawl	12/05 to 20/05/2015	9

The regular transects network agreed for several years for Thalassa is 12 miles separated parallel transects. Commercial vessels worked between standard transects and 2 NM northern. Sometimes, they carried out fishing operations on request (complementary to Thalassa, particularly for surface hauls or in very coastal areas) Their pelagic trawl was until 25 m vertical opening and the mesh of their codend was similar to Thalassa (12 mm).

A scientific observer was onboard to control every operation, and to collect biological data. The fishing operations were systematically agreed after a radio contact with Thalassa in order to confirm their usefulness. In some occasions, the use was to check the spatial extension of species already observed and identified by Thalassa (and therefore the spatial distribution), in others the objective was to enlarge the vertical distribution description by stratified catches. Globally, a great attention was given on a good distribution of samples to avoid over-sampling on some situations. Regularly a biological sample was provided by commercial vessels to Thalassa to improve otoliths collection and sexual maturity (160 otoliths of anchovy, 138 of sardine). A total of 16 674 fishes were measured onboard commercial vessels, including 8 150 anchovies and 4 506 sardines.

The catches and biological data have been directly used with the same consideration than Thalassa ones for identification and biological characterisation.

A total of 136 hauls were carried out during the assessment coverage including 73 hauls by Thalassa and 63 hauls by commercial vessels.



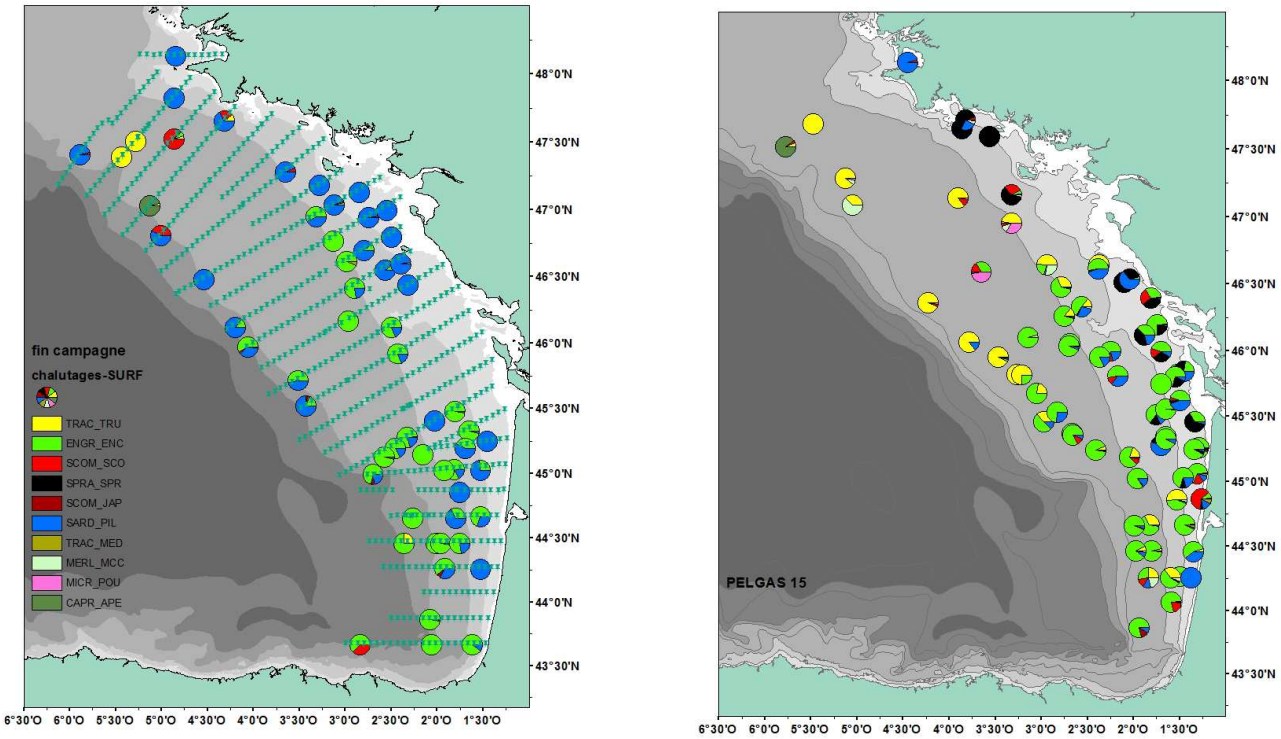
a) Thalassa (nb :73) *b) Commercial vessels (nb : 63)* *c) all fishing hauls (nb :136) thalassa in Blue and commercial in red*

Figure 1.2.2 : fishing operations carried out by Thalassa and commercial vessels during consort survey PELGAS15

The collaboration between Thalassa and commercial vessels was excellent. It was once more a very good opportunity to explain to fishermen our methodology and furthermore, to verify that both scientists and fishermen observe the same types of echo-traces and have similar interpretations. Some fishing operations were done in parallel by Thalassa and commercial vessel in order to check if the catches were well comparable (in proportion of species and, most of the time, in quantity as well - taking the vertical and horizintal opening). As last year, the fishing operations by commercial vessels were carried out only during day time (as for Thalassa) each time it was necessary and preferentially at the surface or in mid-water, since the pair trawlers are more efficient at surface than single back trawlers.

	thalassa	commercial	total
surface hauls	21	38	59
classic hauls	49	23	72
null	3	2	5
total	73	63	136

Table 1.2.3. : number of fishing operations carried out by Thalassa and commercial vessels during consort survey PELGAS15



a) Hauls carried out at surface or in mid-water levels (Thalassa & commercial vessels)

b) classic Hauls carried out near the bottom and 50m upper (Thalassa + commercial vessels)

Figure 1.2.4 : Vertical localisation of fishing operations carried out by Thalassa and commercial vessels during survey PELGAS15

2. ACOUSTICS DATA PROCESSING

2.1. Echo-traces classification

All the acoustic data along the transects were processed and scrutinised by the date of the meeting. Acoustic energies (Sa) have been cleaned by sorting only fish energies (excluding bottom echoes, parasites, plankton, etc.) and classified into 5 categories of echo-traces this year :

D1 – energies attributed to mackerel, chub mackerel, horse mackerel, blue whiting, hake, whiting, 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, sardine, and sprat corresponding to the usual echo-traces observed in this area since more than 15 years, constituted by schools well defined, mainly situated between the bottom and 50 meters above. These echoes are typical of clupeids in coastal areas and sometimes more offshore.

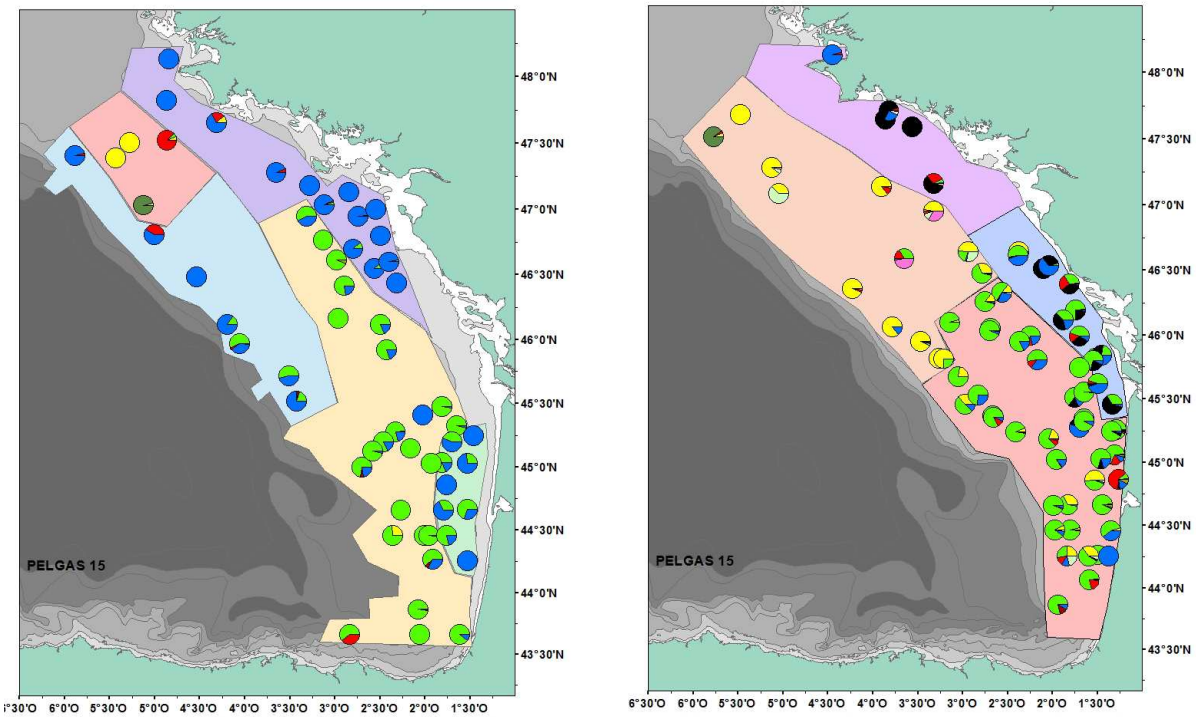
D3 – energies attributed to scattered detection corresponding to blue whiting, myctophids, boarfish, mackerel and horse mackerel.

D4 – energies attributed to sardine, mackerel and anchovy corresponding to echoes very close to the surface. this year boarfish and horse mackerel were also in this category

D8 – energies attributed exclusively to sardine (big and very dense schools).

2.2. Splitting of energies into species

As for previous years (except in 2003, see WD-2003), the global area has been split into several strata where coherent communities were observed (species associations) in order to minimise the variability due to the variable mixing of species. Figure 2.2. shows the strata considered to evaluate biomass of each species. For each strata, energies where converted into biomass by applying catch ratio, length distributions and weighted by abundance of fish in the haul surrounded area.



Coherent surface strata Coherent classic strata

Fig. 2.2. – Coherent strata (classic and surface), in terms of echoes and species distribution, taken into consideration for multi-species biomass estimate from acoustic and catches data during PELGAS15 survey.

2.3. Biomass estimates

The fishing strategy has been followed all along the survey in order to profit of the best efficiency of each vessel and maximise the number of samples (in term of identification and biological parameters as well). Therefore, the commercial vessels carried out mostly surface hauls when Thalassa fish preferably in the bottom layer. According to previous strata, using both Thalassa and consort fishing operations, biomass estimates have been calculated for each main pelagic species in the surveyed area.

Biomass indices are gathered in tables 2.3.1. and 2.3.2., and in figure 2.3.1. No estimate has been provided for mackerel according to the low level of TS and particular behaviour in the Bay of Biscay where it is scattered and mixed with plankton echoes.

Anchovy was present this year the best abundance index never observed before, with around 370 000 tonnes, with highest densities in the Gironde area, from the coast to the shelfbreak and in the whole water column, from bottom to the surface.

Sardine was still well present this year, mostly in coastal waters from the South until the North of the bay of Biscay, and she was also spotted mainly near the surface in the Northern part, on the platform and at the shelfbreak.

About other species, an other characteristic of this year is that horse mackerel shows a small increase of the biomass, but keep a low level at this period in the bay of Biscay.

Mackerel appears very dispersed all over the area and seems to be rather absent of te bay of Biscay.

	classic	surface	total
Anchovy	295 110	77 806	**372 916**
blue whiting	8 657	27	**8 684**
sardine	145 310	271 214	**416 524**
mackerel	73 466	169 468	**242 935**
sprat	91 248	0	**91 248**
horse mackerel	55 075	22 067	**77 142**

Table 2.3.1. Acoustic biomass index for the main species by strata during PELGAS15

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
anchovy	**113 120**	**105 801**	**110 566**	**30 632**	**45 965**	**14 643**	**30 877**	**40 876**	**37 574**	**34 855**	**86 354**	**142 601**	**186 865**	**93 854**	**125 427**	**372 916**
CV anchovy	*0.064*	*0.141*	*0.113*	*0.132*	*0.167*	*0.171*	*0.136*	*0.100*	*0.162*	*0.112*	*0.147*	*0.0774*	*0.04665*	*0.1282*	*0.062928*	0.0735509
Sardine	**376 442**	**383 515**	**563 880**	**111 234**	**496 371**	**435 287**	**234 128**	**126 237**	**460 727**	**479 684**	**457 081**	**338 468**	**205 627**	**407 740**	**339 607**	**416 524**
CV sardine	*0.083*	*0.117*	*0.088*	*0.241*	*0.121*	*0.135*	*0.117*	*0.159*	*0.139*	*0.098*	*0.091*	*0.0699*	*0.07668*	*0.0738*	*0.065212*	0.1023153
Sprat	**30 034**	**137 908**	**77 812**	**23 994**	**15 807**	**72 684**	**30 009**	**17 312**	**50 092**	**112 497**	**67 046**	**34 726**	**6 417**	**44 651**	**33 894**	**91 248**
CV sprat	*0.098*	*0.155*	*0.120*	*0.198*	*0.178*	*0.228*	*0.162*	*0.132*	*0.268*	*0.108*	*0.108*			*0.1992*	*0.241009*	0.1953397
Horse mackere	**230 530**	**149 053**	**191 258**	**198 528**	**186 046**	**181 448**	**156 300**	**45 098**	**100 406**	**56 593**	**11 662**	**61 237**	**7 435**	**33 471**	**53 154**	**77 142**
CV HM	*0.079*	*0.204*	*0.156*	*0.137*	*0.287*	*0.160*	*0.316*	*0.065*	*0.455*	*0.09*	*0.188*			*0.3007*	*0.227089*	0.1549802
Blue Whiting	-	-	**35 518**	**1 953**	**12 267**	**26 099**	**1 766**	**3 545**	**576**	**4 333**	**48 141**	**11 823**	**68 533**	**25 715**	**25 015**	**8 684**
CV BW	-	-	*0.386*	*0.131*	*0.202*	*0.593*	*0.210*	*0.147*	*0.253*	*0.219*	*0.074*			*0.1542*	*0.337606*	*0.2234791*

Table 2.3.2. Acoustic biomass index for the five main pelagic species since the beginning of PELGAS surveys (2000)

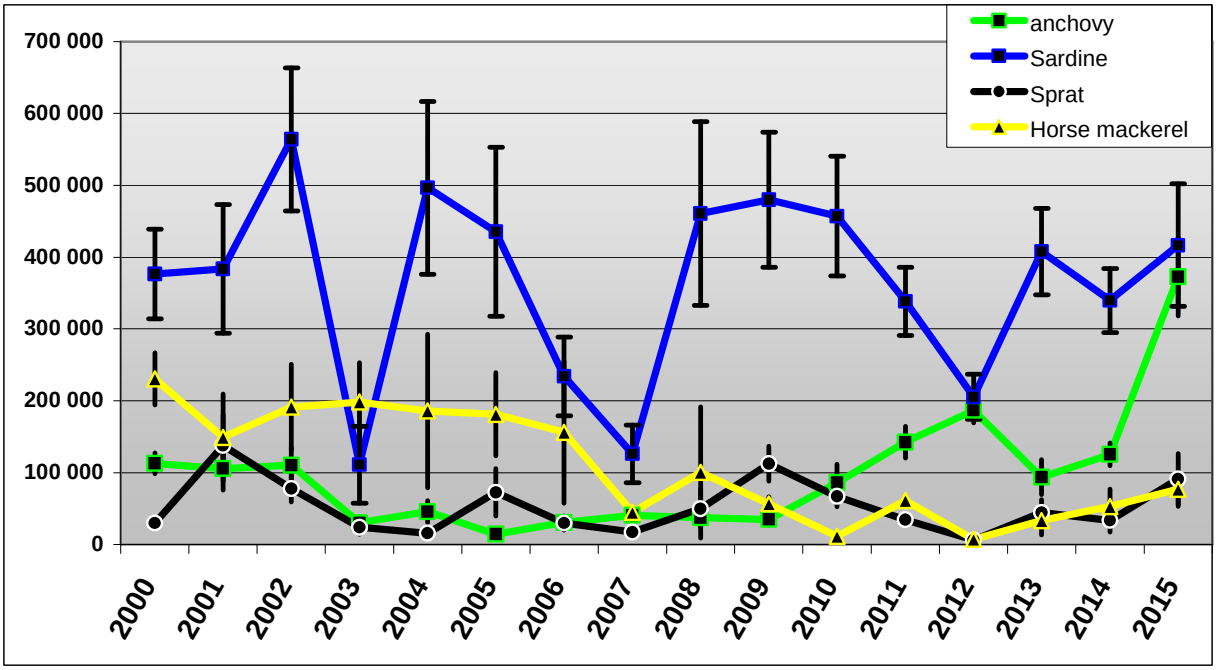


figure 2.3.1. – biomass estimate using Thalassa acoustic data along transects and all the consort identification fishing operations (Thalassa + commercial vessels) and coefficients of variation associated.

3. ANCHOVY DATA

3.1. anchovy biomass

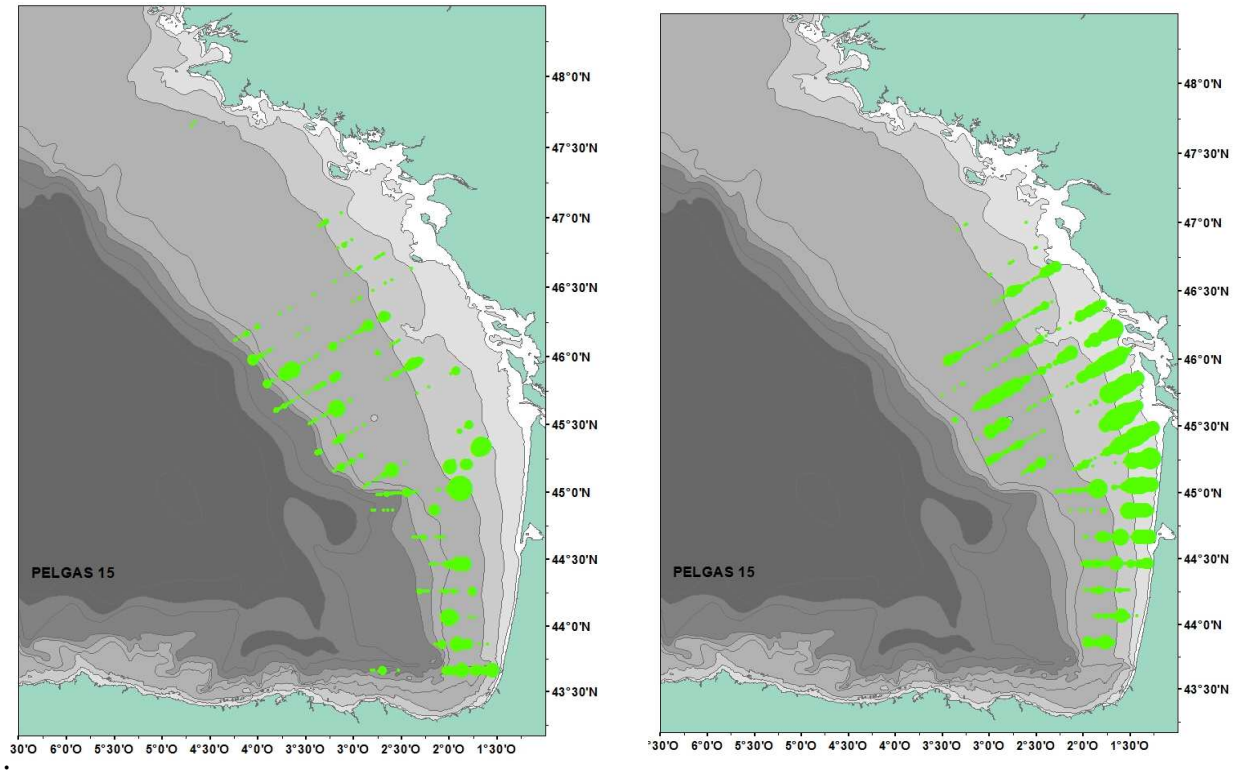
The biomass estimate of anchovy observed during PELGAS13 is **372 916** tons. (table 2.3.2.), which is the highest level never observed on the PELGAS series, and constituting an exceptional increase of this biomass in the bay o Biscay.

The main observation in 2015 is that sardine, anchovy and sprat (all clupeids grouped) were well present as densities never observed before. These echoes were systematically identified on each transect and revealed almost pure anchovy (very small) in the Gironde area (exclusively one year old in front of the river plume, and immature).

In the Gironde area, the configuration was unusual (in size and in Sa), with an acoustic energy attributed to anchovy far above the average and anchovies never observed so small at this period of the year. Nevertheless, anchovy was predominant in this area.

The one year old anchovies were mostly present around the Gironde plume (in terms of energy and, as well, biomass) but they were still well present on the platform, from the south of the bay until the latitude of 46°30

On the South coast of Brittany, no real sightings of anchovy occurred this year



Surface distribution

Near-seabed distribution, between the bottom and 40m above

Figure 3.1. – Anchovy distribution according to PELGAS15 survey.

3.2. Anchovy length structure and maturity

Length distribution in the trawl hauls were estimated from random samples. The population length distributions (figures 3.2.1 and 3.2.2) has been estimated by a weighted average of the length distribution in the hauls. Weights used are acoustic coefficients (Dev*Xe Moule in thousands of individuals per n.m.^{2}) which correspond to the abundance in the area sampled by each trawl haul.

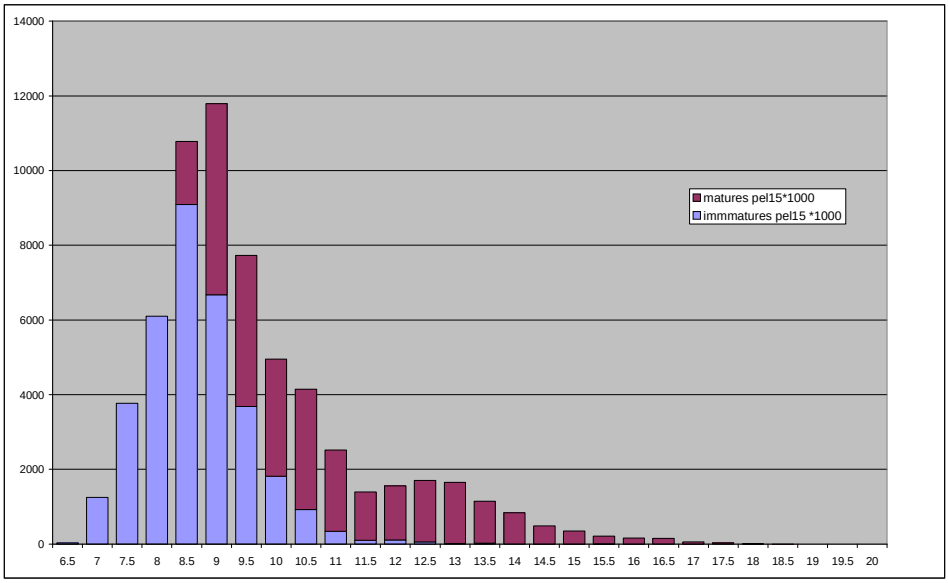


Figure 3.2.1: length distribution of global anchovy as observed during PELGAS15 survey and maturity associated

Globally, we observe that this year most part of the anchovies were small (mode < 11 cm) and constitutes the smallest anchovies never observed before. It is essential to notice than this year, mainly due to their very small lengths, lots of anchovies were immature, contrary to all other years when almost all individuals were in spawning period. Most of these immature fishes just started their maturation. So, they are 1 year old, they are considered as adults, but not spawning at the survey time.

A map was also realised to see how immatures were met this year (see figure 3.2.2.):

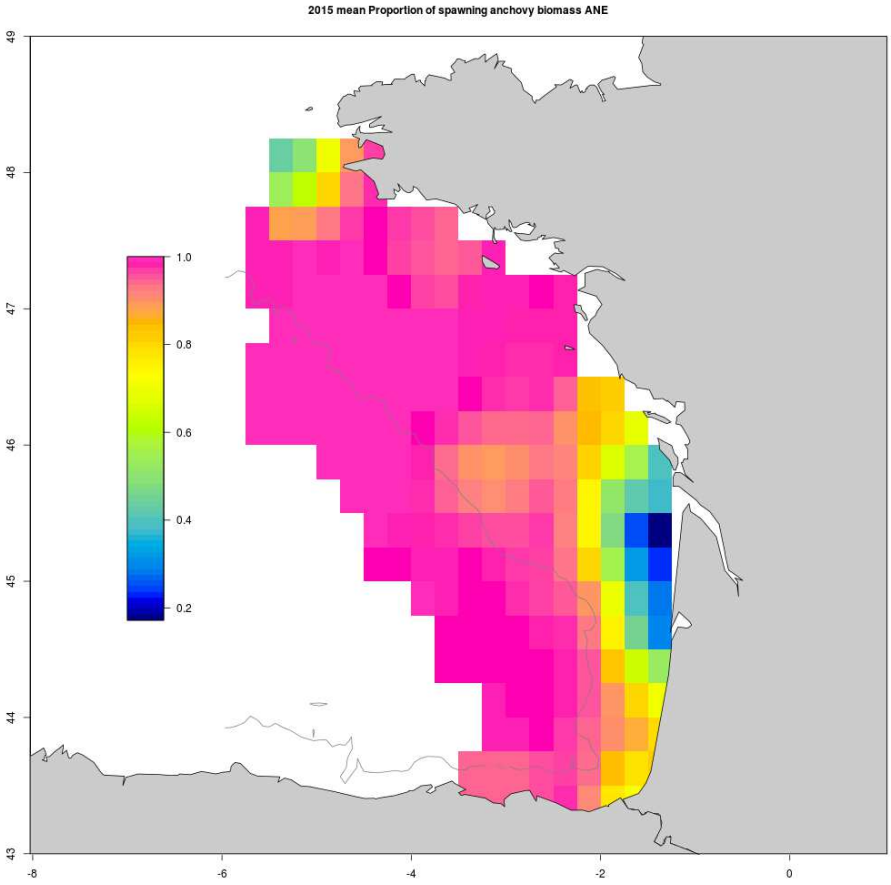


figure 3.2.2 : grid map of anchovy maturity during PELGAS15 survey

. 3.3. Demographic structure

An age length key was built for anchovy from the trawl catches (Thalassa hauls) and samples from commercial vessels. We took the otoliths from a set number of fishes per length class (4 to 6 / half-cm), for a total amount of around 50 fish per haul. As there was more fishing operations where anchovy was present compared to previous surveys, the number of otoliths we took during the survey increased compared to last years (1607 otoliths of anchovy taken and read on board), The population length distributions were estimated by a weighted use of length distributions in the hauls, weighted as described in section 3.2.

NB age	age				
length (mm)	1	2	3	4	5
65	100.0%				
70	100.0%				
75	100.0%				
80	100.0%				
85	100.0%				
90	100.0%				
95	100.0%				
100	100.0%				
105	100.0%				
110	100.0%				
115	100.0%				
120	96.4%	3.6%			
125	91.0%	7.4%	1.6%		
130	85.4%	13.0%	1.6%		
135	67.0%	30.1%	1.9%	1.0%	
140	69.9%	29.0%	1.1%		
145	44.3%	47.7%	5.7%	2.3%	
150	27.9%	70.6%	1.5%		
155	18.8%	75.0%	6.3%		
160	3.4%	89.7%	6.9%		
165	3.8%	88.5%	7.7%		
170	2.9%	88.6%	8.6%		
175		83.3%	10.0%	3.3%	3.3%
180		81.8%	18.2%		
185		77.8%	11.1%	11.1%	
190		33.3%	66.7%		
195			100.0%		
200		100.0%			

Table 3.3.1. PELGAS15 anchovy Age/Length key.

Applying the age distribution to the abundance in biomass and numbers, the distribution in age of the biomass has been calculated. The total biomass used here has been updated with the value obtained from the previous method based on strata.

Age distribution is shown in figures 3.3.2. The age distributions compared from 2000 to 2014 are shown in figure 3.3.3.

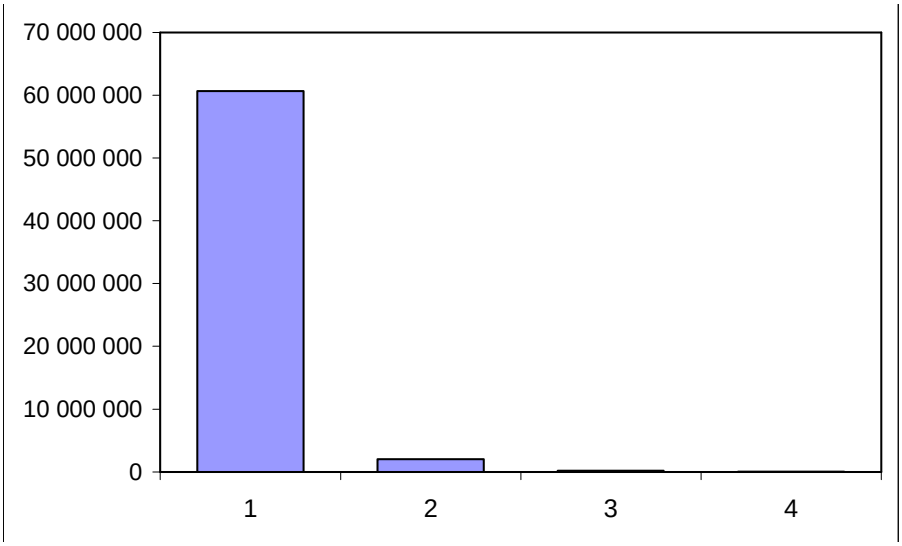


Figure 3.3.2– global age composition (numbers) of anchovy as observed during PELGAS15.

Looking at the numbers at age since 2000 (fig 3.3.3.), the number of 1 year old anchovies this year constitutes the very best recruitment of anchovy on the bay of Biscay never seen before.

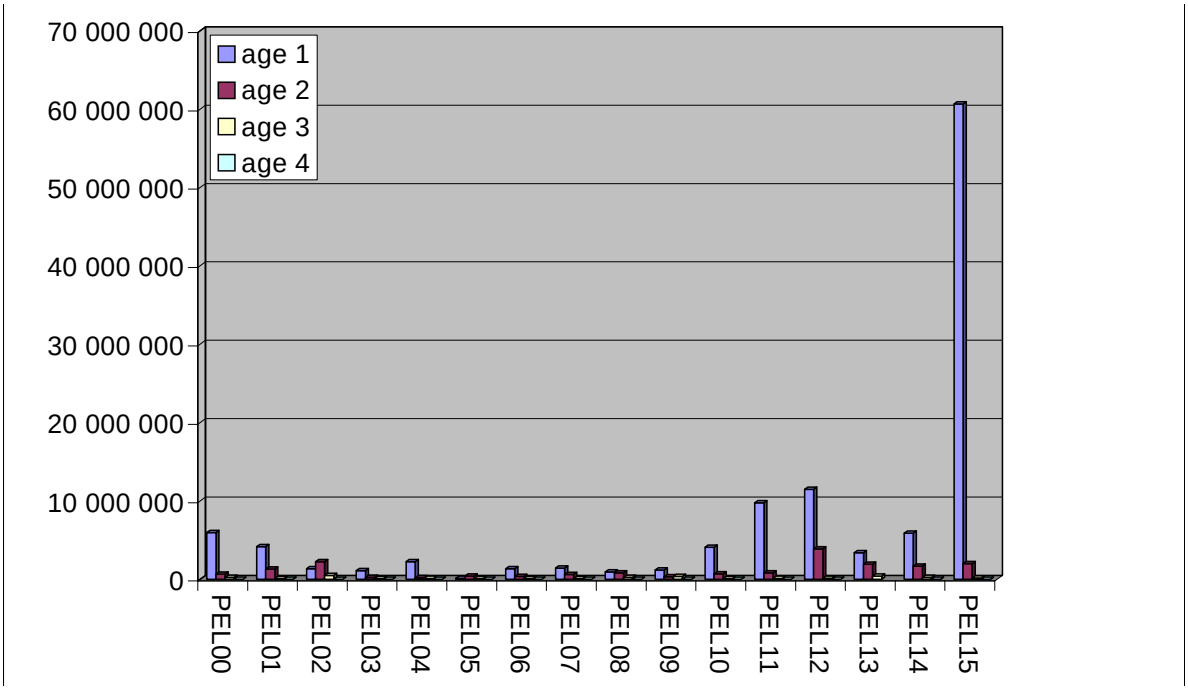


Figure 3.3.3 Anchovy numbers at age as observed during PELGAS surveys since 2000

This huge number of age 1 this year is due to a huge recruitment of age 1 in biomass (the best of the whole serie) and the fact that this one year old anchovy is the smallest never observed before (see paragraph 3.2.). We will see later the mean length and mean weight at age.

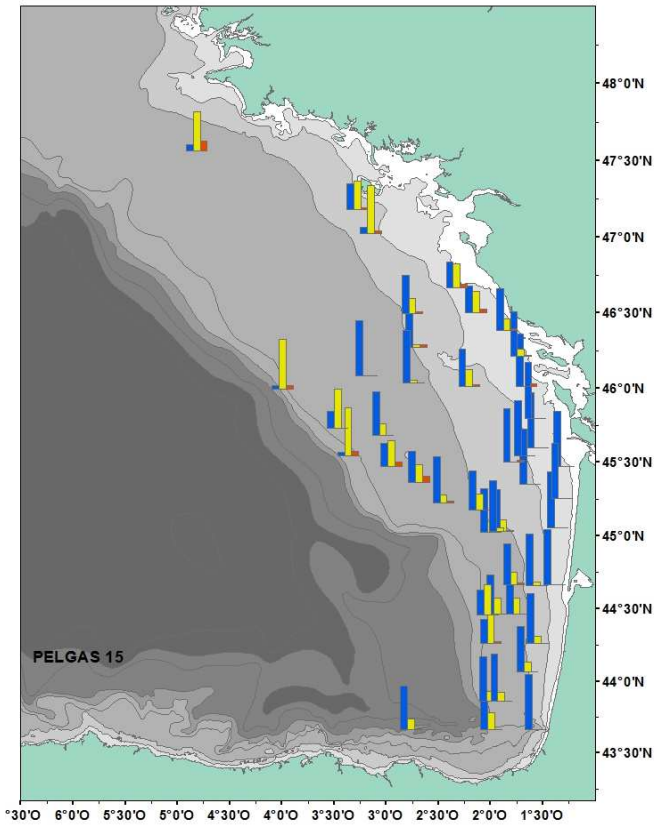


Figure 3.3.4 Anchovy proportion at age in each haul as observed during PELGAS15 survey (blue = age 1, yellow = age 2).

During previous surveys, anchovy was well geographically stratified depending on the age (*see WD 2010, Direct assessment of small pelagic fish by the PELGAS10 acoustic survey, Masse J and Duhamel E.*). It is less true this year, as in 2014, as age1 were as usual predominant (almost pure) in the Gironde area, but also dispersed on the platform, mixed (or not) with age 2. It is particularly noticeable this year than age one is still present, even in minority, along the shelf break.

anchovy	pel 15 - % - N
age 1	96.5%
age 2	3.2%
age 3	0.3%
age 4	0.0%
age 5	0.0%

anchovy	pel 15 - % - W
age 1	84.0%
age 2	14.1%
age 3	1.6%
age 4	0.2%
age 5	0.0%

Figure 3.3.5 percentage by age of the Anchovy population observed during PELGAS15 in numbers (left) and biomass (right).

3.4. Weight/Length key

Based on 1607 weights of individual fishes, the following weight/length key was established (figure 4.5.) :

$W = 2E\text{-}06L^{3.2749}$ with R2 = 0.9712 *(with W in grams and L in mm)*

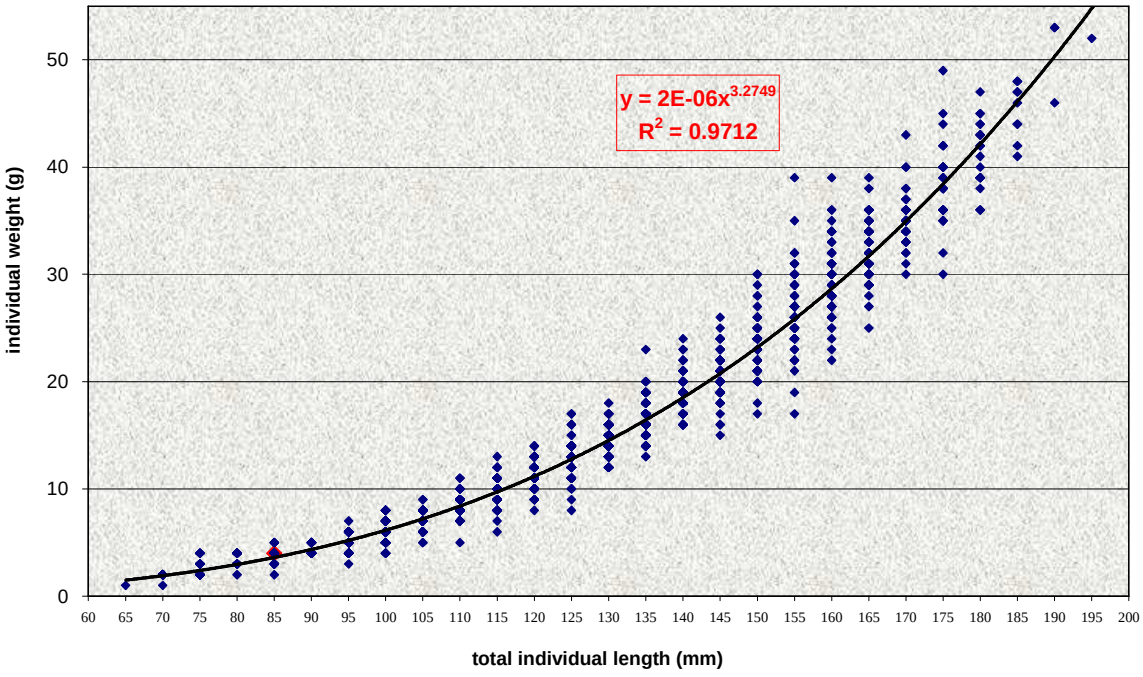


Fig. 3.4. – Weight/length key of anchovy established during PELGAS15

3.5. Mean Weight at age

mean weigth at age (g)	AGE				
survey	1	2	3	4	5
PEL00	14.78	25.98	30.62	36.06	
PEL01	16.09	25.91	21.28	36.39	
PEL02	20.41	27.17	28.49	36.85	
PEL03	16.73	25.63	32.79	28.79	
PEL04	15.12	32.83	36.98	52.32	
PEL05	18.80	26.29	32.75	30.74	
PEL06	13.39	25.47	31.87	46.12	
PEL07	17.80	24.28	20.66		
PEL08	11.57	26.94	27.34	27.37	
PEL09	15.26	31.04	40.24	41.59	
PEL10	15.74	25.94	34.78	48.11	50.52
PEL11	11.33	27.13	26.02	60.54	
PEL12	7.72	19.70	20.85	35.36	
PEL13	12.61	21.34	26.46		
PEL14	14.52	18.92	21.82	28.53	
PEL15	5.13	20.43	19.94	19.63	38.43

Fig. 3.5. – mean weight at age (g) of anchovy for each PELGAS survey

As previous years, we observe that globally the trend of the mean weight at age is a decrease. This trend is the same for sardine in the bay of Biscay. Further investigates should be done and, if we have some hypothesis (maybe an effect of density-dependance), we do not have real explanation for the time being.

3.6. Eggs

During this survey, in addition of acoustic transects and pelagic trawl hauls, 661 CUFES samples were collected and counted, 64 vertical plankton hauls and 104 vertical profiles with CTD were carried out. Eggs were sorted and counted during the survey.

2015, as from 2011, was marked by a large quantity of collected and counted anchovy eggs.

Their spatial pattern of distribution was quite usual, with major part of the abundance South of 46°N. However, eggs are also abundant on 2 more transects than usual North of the Gironde estuary, with a connection all over the shelf between the classical inshore and slope distributions. This may be related to the large extension of the Gironde plume to the North-West, as well as the large adult abundance spreading larger than usual. South of the Gironde eggs are mostly located in the mid-shelf, with extension off-shelf on some of the transects. Small amount of eggs are again found in front of the Loire mouth and along the southern coast of Brittany.

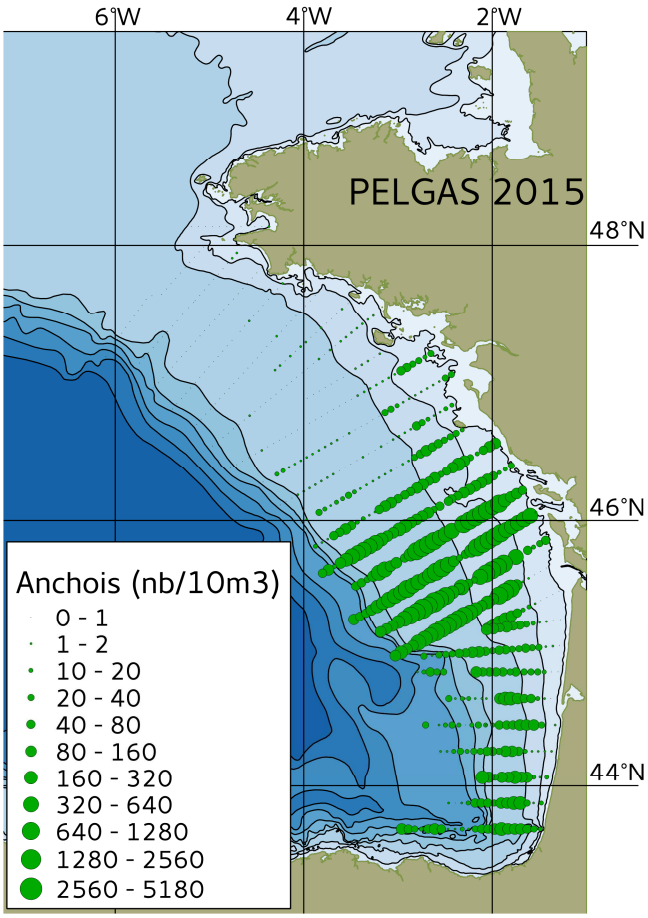


Figure 3.6.1 – Distribution of anchovy eggs observed with CUFES during PELGAS15.

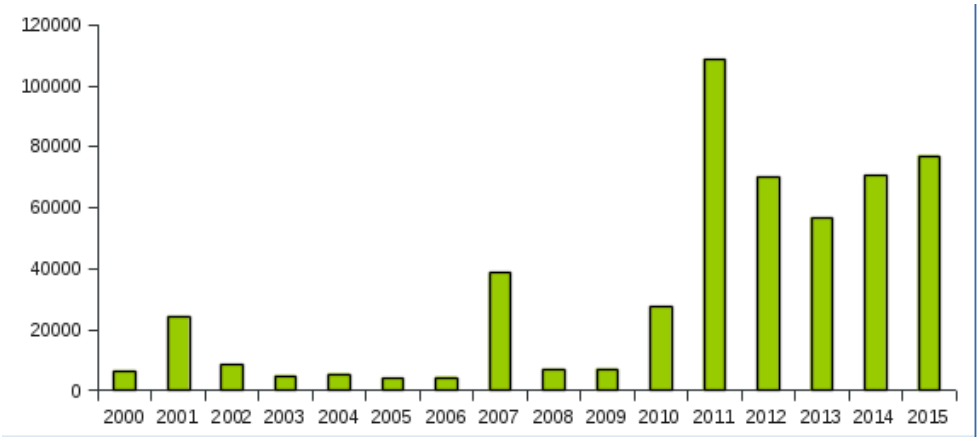


Figure 3.6.2 – Number of eggs observed during PELGAS surveys from 2000 to 2015

3.7. Coherence between CUFES and Acoustic survey indices

Taking advantage of the fact that we have an egg survey (CUFES) providing Ptot and an acoustic survey providing B, we may simply estimate the daily fecundity (DF: # eggs g-1 d-1) by the ratio Ptot/B. Note that here, DF is the egg production by gram of stock (i.e., both females and

males). Because the two indices Ptot and B are linked through DF, the coherence between the egg (CUFES) and the acoustic survey indices of PELGAS can be investigated.

The daily egg production was estimated as described in *Petitgas et al. (2009)* with the developments made by Gatti (2012) and discussed at the benchmark workshop WKPELA 2013.

Briefly, the eggs at each CUFES sample are staged in 3 stages, the duration which are temperature dependent. The CUFES egg concentration is converted into egg abundance (vertically integrated) by using a 1-dimensional distribution model which takes input account as parameters the egg buoyancy and dimension, the hydrological vertical profile, the tidal current and wind regime (Petitgas et al., 2006; Petitgas et al., 2009; Gatti, 2012). The complete series is shown on figure 3.7.1.

In 2015 the estimates are : B=372 916 tonnes ; Ptot= 1.14E+13egg d^{-1}

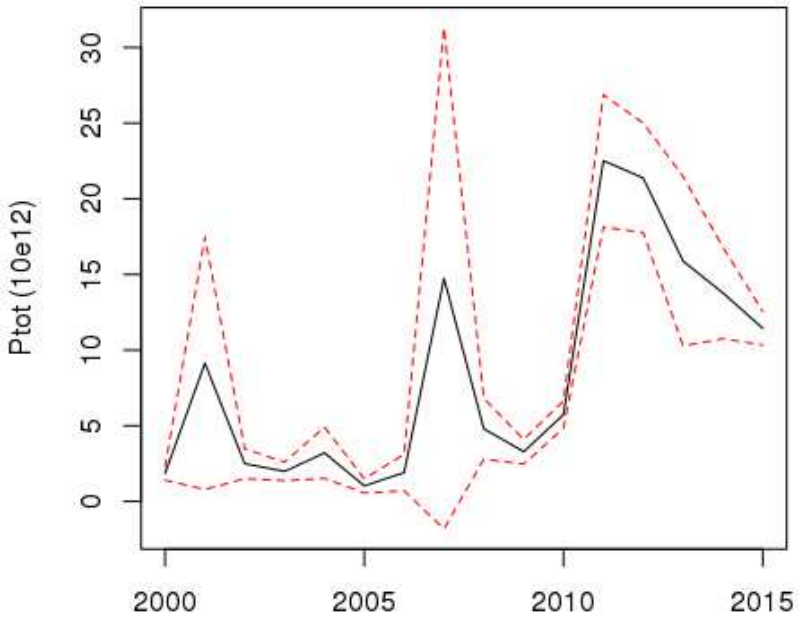


Figure 3.7.1 – Ptot serie from the CUFES index

The daily egg production Ptot depends on the spawning biomass (B) and the daily fecundity (DF). DF depends ultimately on environmental and trophic conditions, which determine individual fish fecundity (e.g., Motos et al., 1996). Daily egg production (Ptot) and spawning biomass (B) were linearly related (Fig 1). The slope of the linear regression is a (direct) estimate of the average DF over the series. Its value is : 92.26 eggs g-1. Residuals are particularly important for 2000, 2002 and 2007.

For first years of the serie (2000 to 2002) the mesh of the collector was 500 µm and is now 315 µm. But more investigation should be processed to asses the impact of the change of the mesh size on the aspect of the eggs collected, and on the number of them in each sample as well.

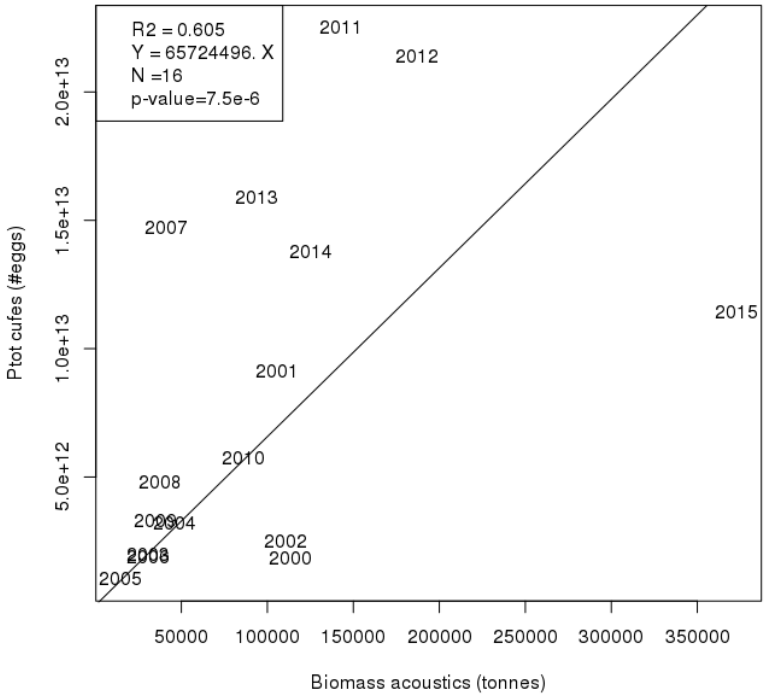


Figure 3.7.2 – Coherence between CUFES and Acoustic PELGAS survey indices

It must be noticed that with such a high acoustic biomass this year, the last point drives the linear regression. It must be simply explained by the fact that a high proportion of anchovies this year were not spawning at the time of the survey (see chapter 3.2). In near future, we'll correct this biomass with the real spawning one to adapt the regression between eggs and spawning biomass.

An other important thing is that this year is the first year when the eggs count is realised by the zoocam system, tested, improved and validated during previous surveys in quality and in quantity of eggs as well.

At this time, the only thing we are currently finishing to improve is the staging of the eggs.

4. SARDINE DATA

4.1. Adults

The biomass estimate of sardine observed during PELGAS15 is **416 524** tons (table 2.3.), which is at the average level of the PELGAS series, and constituting a small increase of the biomass compared to last year. It must be enhance that this survey doesn't cover the total area of potential presence of sardine, and it is possible that some years, this specie could be present up to the North, in the Celtic sea, SW of Cornouailles or Western Channel where some fishery occurs, more or less regularly. It is also possible that sometimes, a small fraction of the population could be present in very coastal waters, when the R/V Thalassa is unable to operate in those waters. The estimate is representative of the sardine present in the survey area at the time

of the survey and can be therefore considered as an estimate of the Bay of Biscay (VIIIab) sardine population.

Sardine was distributed all along the French coast of the bay of Biscay, from the South to the North. Then, sardine appeared almost pure along the Landes's coast, where a small upwelling occurred. Sardine was also present mixed with anchovy from the Gironde to the South coast of Brittany. Sardine appeared almost exclusively close to the surface in the Northern part of the bay of Biscay, along the shelf break, sometimes mixed with mackerel or anchovy. Sardine appears also along the southern coast of Brittany, sometimes mixed with sprat

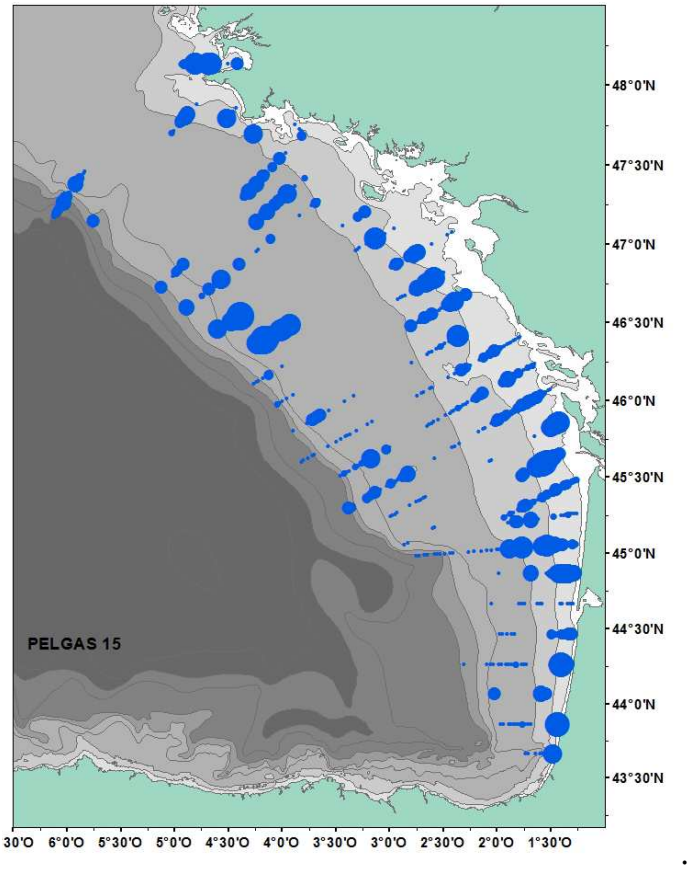


Figure 4.1.1 – distribution of sardine observed by acoustics during PELGAS15

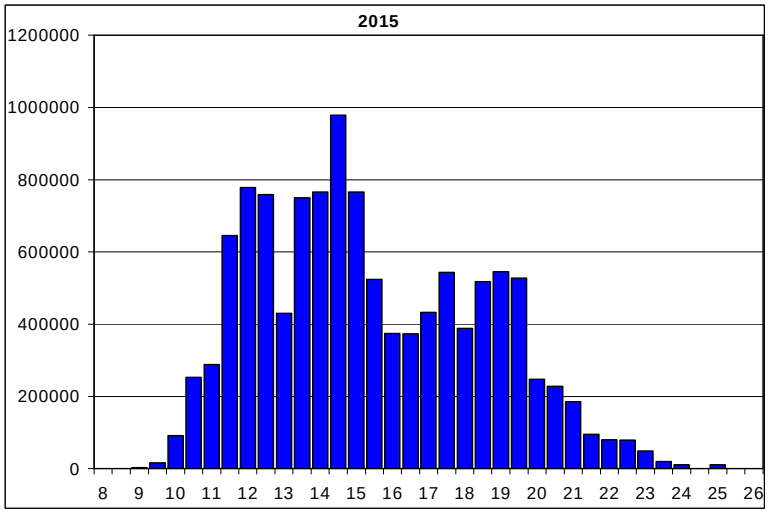


Figure 4.1.2. – length distribution of sardine as observed during PELGAS15

Length distributions in the trawl hauls were estimated from random samples. The population length distributions have been estimated by a weighted average of the length distribution in the hauls. Weights used are the acoustic biomass estimated in the post-stratification regions comprising each trawl haul. The global length distribution of sardine is shown on figure 4.1.2.

As usual (but less than recent years), sardine shows a bimodal length distribution, the first one (about 14 cm, corresponding to the age 1, and present this year along the coast) and the second about 19 cm, which is mainly constituted by the 2 and 3 years old (still present a bit more offshore than the 1 year class, mainly between depths 60 and 80 m, and also along the shelf break). The older individuals (age 4 and more) seems to be rather absent of the bay of Biscay this year.

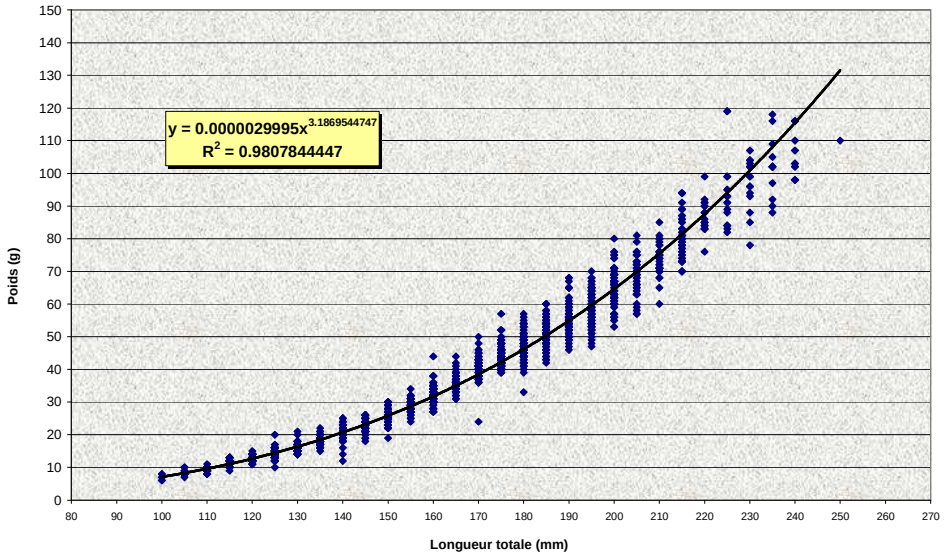


Figure 4.1.3 – Weight/length key of sardine established during PELGAS15

NB age	age									
length (mm)	1	2	3	4	5	6	7	8	9	Total
85	1	0	0	0	0	0	0	0	0	1
90	1	0	0	0	0	0	0	0	0	1
95	1	0	0	0	0	0	0	0	0	1
100	1	0	0	0	0	0	0	0	0	1
105	1	0	0	0	0	0	0	0	0	1
110	1	0	0	0	0	0	0	0	0	1
115	1	0	0	0	0	0	0	0	0	1
120	1	0	0	0	0	0	0	0	0	1
125	1	0	0	0	0	0	0	0	0	1
130	1	0	0	0	0	0	0	0	0	1
135	1	0	0	0	0	0	0	0	0	1
140	1	0	0	0	0	0	0	0	0	1
145	1	0	0	0	0	0	0	0	0	1
150	1	0	0	0	0	0	0	0	0	1
155	1	0	0	0	0	0	0	0	0	1
160	0.9375	0.046875	0.015625	0	0	0	0	0	0	1
165	0.65714286	0.34285714	0	0	0	0	0	0	0	1
170	0.2345679	0.74074074	0.02469136	0	0	0	0	0	0	1
175	0.08247423	0.79381443	0.12371134	0	0	0	0	0	0	1
180	0.06	0.63	0.3	0.01	0	0	0	0	0	1
185	0	0.42045455	0.56818182	0.01136364	0	0	0	0	0	1
190	0	0.27631579	0.63157895	0.07894737	0.01315789	0	0	0	0	1
195	0	0.13235294	0.66176471	0.19117647	0	0.01470588	0	0	0	1
200	0	0.15217391	0.56521739	0.2173913	0.04347826	0	0.02173913	0	0	1
205	0	0.02564103	0.58974359	0.23076923	0.1025641	0.05128205	0	0	0	1
210	0	0.02941176	0.44117647	0.26470588	0.20588235	0.02941176	0.02941176	0	0	1
215	0	0	0.13043478	0.30434783	0.2173913	0.17391304	0.13043478	0	0.04347826	1
220	0	0	0.2	0.26666667	0.06666667	0.26666667	0.13333333	0.06666667	0	1
225	0	0	0	0.06666667	0.13333333	0.46666667	0.2	0.13333333	0	1
230	0	0	0	0.15384615	0.23076923	0.30769231	0.30769231	0	0	1
235	0	0	0	0	0.44444444	0	0.33333333	0.22222222	0	1
240	0	0	0	0.14285714	0	0.57142857	0.14285714	0	0.14285714	1
245										
250	0	0	0	0	0	0	1	0	0	1

Table 4.1.4 : sardine age/length key from PELGAS15 samples (based on 1460 otoliths)

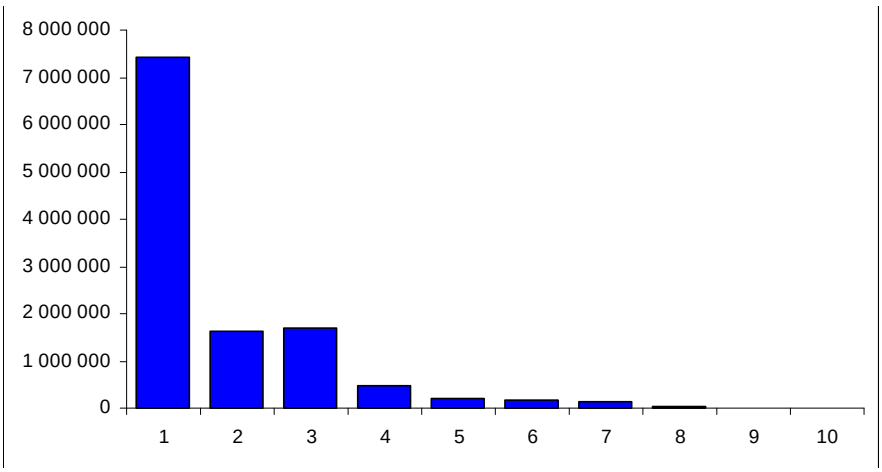


Figure 4.1.5.- Global age composition (nb) of sardine as observed during PELGAS 15

sardine	pel 15 - % - N
age 1	63.2%
age 2	13.7%
age 3	14.5%
age 4	4.1%
age 5	1.6%
age 6	1.4%
age 7	1.2%
age 8	0.2%
age 9	0.1%

sardine	pel 15 - % - W
age 1	33.5%
age 2	18.4%
age 3	25.9%
age 4	9.4%
age 5	4.3%
age 6	3.9%
age 7	3.9%
age 8	0.6%
age 9	0.3%

Figure 4.1.6 percentage by age of the sardine population observed during PELGAS15 in numbers (left) and biomass (right).

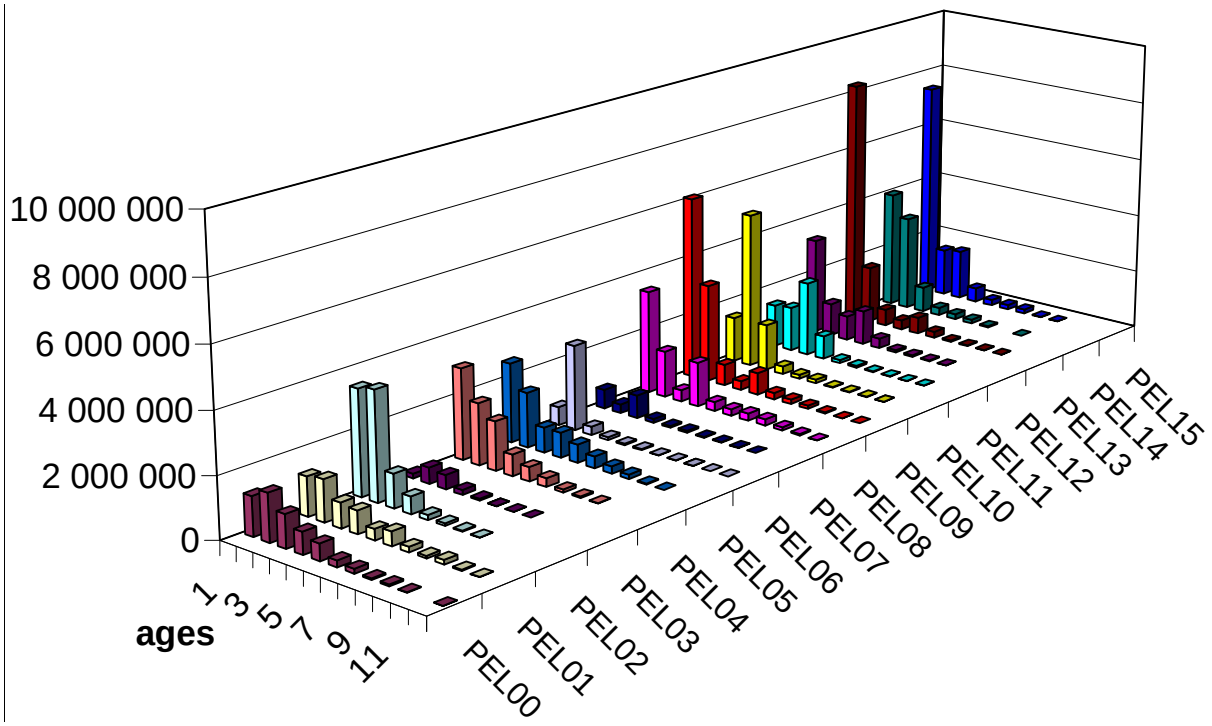


Figure 4.1.7- Age composition of sardine as estimated by acoustics since 2000

PELGAS serie of sardine abundances at age (2000-2015) is shown in Figure 4.1.7. Cohorts can be visually tracked on the graph. The respectively very low and very high 2005 and 2008 cohorts denote atypical years in terms of environmental conditions, and therefore fish (and particularly sardine) distributions.

	age							
survey	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
PEL00	35.05	54.74	69.15	76.46	84.82	89.93	98.83	110.18
PEL01	41.28	58.85	76.83	83.84	93.68	96.92	103.41	105.35
PEL02	40.48	60.2	74.94	81.7	92.31	99.42	106.68	118.05
PEL03	53.35	68.04	73.15	78.11	86.04	93.33	88.74	96.09
PEL04	35.94	64.73	76.54	84.39	95.87	98.83	104.34	109.19
PEL05	34.44	63.45	73.29	79.62	84.88	88.96	90.04	105.42
PEL06	39.17	58.37	70.78	81.18	86.37	82.48	91.25	97.22
PEL07	37.55	65.96	71.77	79.05	84.02	94.45	100.37	96.93
PEL08	33.44	60.33	71.1	75.18	83.82	92.84	90.45	95.67
PEL09	29.51	57.13	73.62	81.28	83.26	88.35	95.67	91.44
PEL10	30.33	50.55	64.04	73.05	78.43	87.58	93.16	105.88
PEL11	27.37	50.13	58.69	69.84	78.35	83.00	84.28	108.17
PEL12	22.88	44.66	57.40	65.45	78.42	87.83	95.26	92.27
PEL13	21.16	44.33	55.82	68.30	77.42	84.27	89.28	99.10
PEL14	23.02	44.53	55.93	62.07	69.35	76.11	78.46	
PEL15	18.75	44.73	56.98	67.22	78.86	87.07	94.81	95.23

Figure 4.1.8- mean Weight at age (g) of sardine for each PELGAS survey

The PELGAS sardine mean weights at age series (Table 4.1.8) shows a clear decreasing trend, whose biological determinant is still poorly understood.

4.2. Eggs

The spatial pattern of sardine eggs overlaps quite well with the one of anchovy for the southern part of the bay of Biscay until the 2 transects North of the Gironde. Then, sardine eggs are dominant in the northern part of the bay, with an extension along the coast and over the slope until the last transects at the Britany tip, but in quite low abundances.

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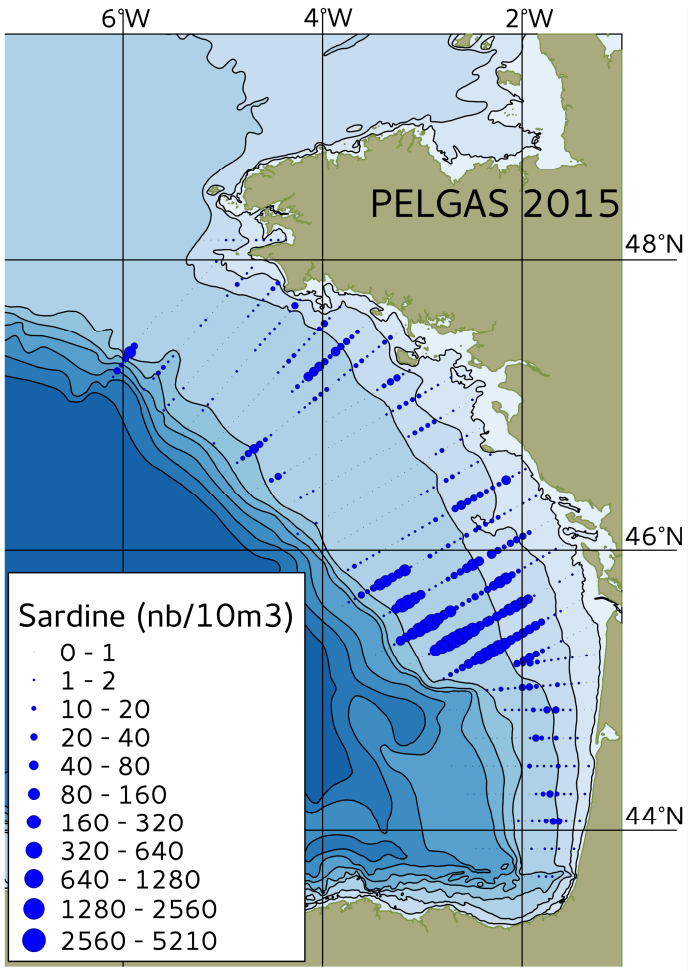

Figure 4.2.1. Distribution of sardine eggs observed with CUFES during PELGAS15.

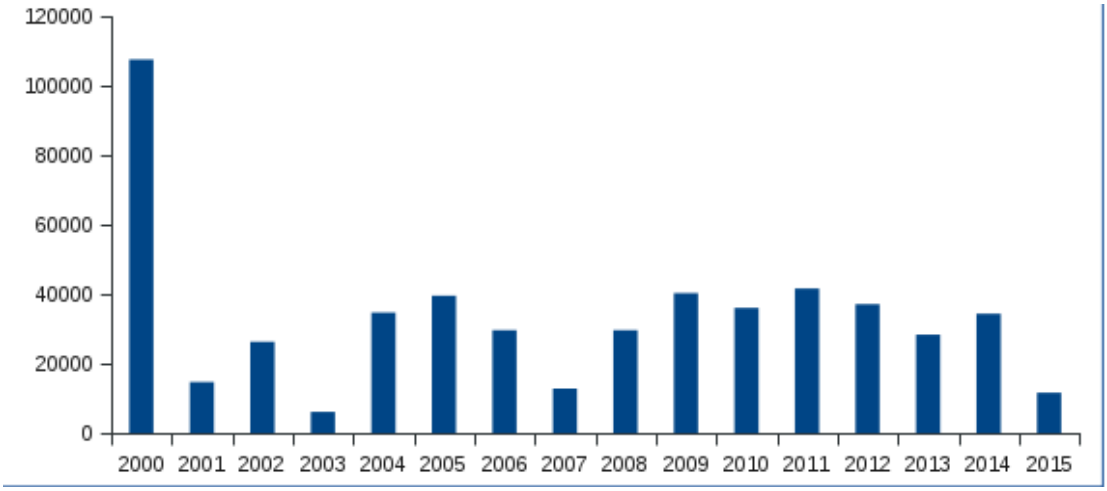

Figure 4.2.2. Number of eggs observed during PELGAS surveys from 2000 to 2015

2015 was marked by a relatively low abundance of sardine eggs as compared to the PELGAS time-series, according to the high abundance of age 1 individuals (see paragraph 4.1.), of whom 55% were not spawning (immature, maturing) at the period of the survey.

5. TOP PREDATORS

For the thirteenth consecutive year, monitoring program to record marine top predator sightings (marine birds and cetaceans) has been carried out , during the whole coverage of the transects network (from the 2nd of May to the 1st of June 2015).

A total of 255 hours of sighting effort were performed for 30 days (Figure 5.1.), with an average of 8.5 hours of sighting effort per day. Weather conditions were generally good with a majority of the effort deployed in Beaufort conditions 2 or 3.

During the survey, 2,240 sightings of animals or objects were recorded. Seabirds constitute the majority of sightings (70%). Other most frequent sightings concern either litter drifting at sea (12%), fishing ships (6%) and buoys (5%). Cetaceans only account for less than 2% of sightings.

5.1 – Birds

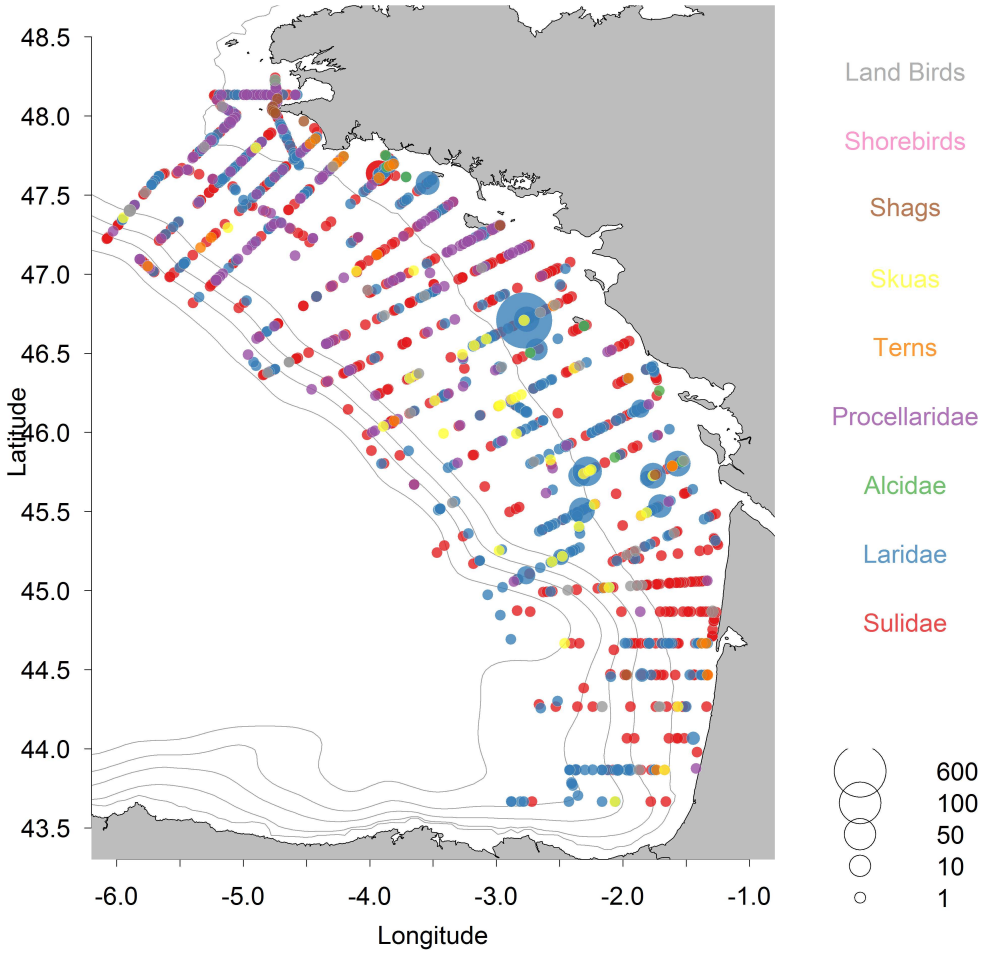

Figure 5.1. Distribution of birds observed during the PELGAS15 survey

Birds constitute the vast majority of sightings. Shorebirds and passerines accounted for less than 3% of bird sightings. 1,561 sightings of seabirds were found all over the Bay of Biscay (Figure 5.1), divided into 23 identified species and a raw estimate of 6,240 individuals.

Northern gannets accounted for 46% of all seabird sightings: its distribution is homogeneous across the Bay of Biscay.

The second most sighted species is the Northern Fulmar (Fulmar glacialis), mostly present in the northern part of the bay of Biscay. Few guillemots and no razobill were sighted in 2015. As in 2014, few terns were sighted. Large numbers of gulls were observed a few times, with one sighting of approx. 600 large gulls west of île d'Aix. Seabirds sightings have substantially decreased compared to 2014, which itself was below 2013 with respect to the number of sightings.

5.2 – Mammals

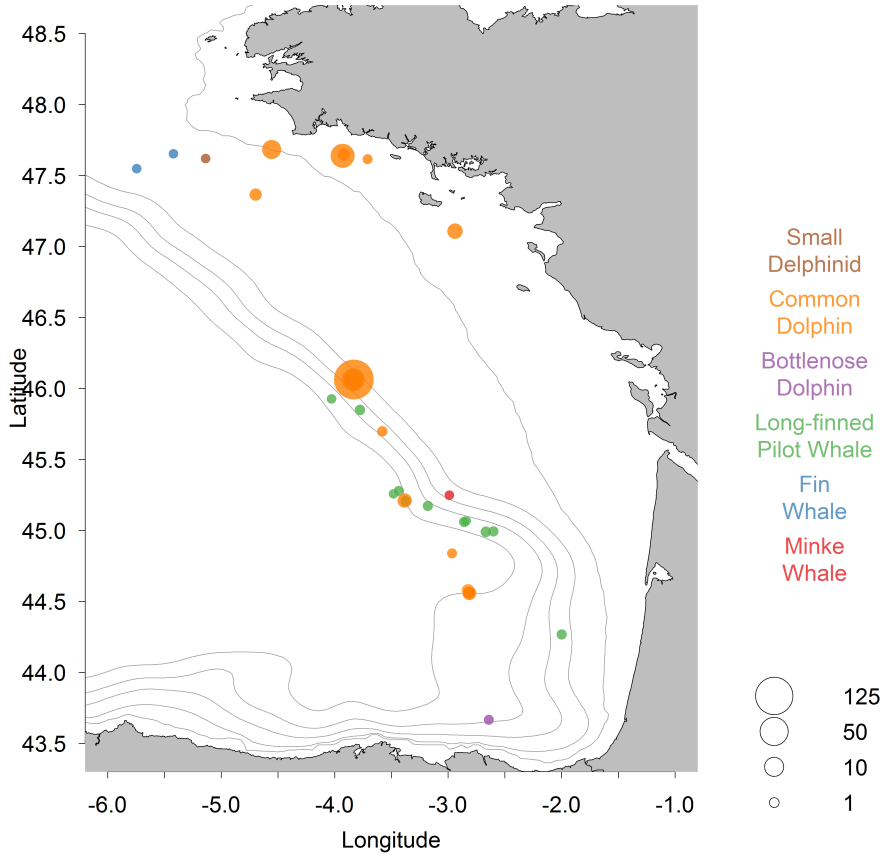

Figure 5.2. Distribution of mammals during the PELGAS15 survey.

A total of 36 sightings were recorded corresponding to a raw estimate of 500 individuals and 5 species of cetaceans clearly identified (Figure 2). The greatest diversity of marine mammals was observed in the Southern part of the Bay of Biscay. The overall distribution pattern is similar to that of previous PELGAS spring surveys.

Common dolphin is the most recorded species. Common dolphins were present on the inshore northern part of the continental shelf. No striped dolphins were sighted in 2015.

However, many long-finned pilot whales were sighted on the continental slope in the central part of the Bay of Biscay.

Bottlenose dolphins were sighted only once in the southern Bay of Biscay on the continental slope. A minke whale was sighting close to the Cap Ferret canyon and two fin whales were sighted in the northern part of the Bay of Biscay, which is rather unusual compared to previous years..

6. HYDROLOGICAL CONDITIONS

Before the survey, a nice and calm April month followed a wet winter. This was favorable to the establishment of the stratification, well marked from the beginning of the survey. Thermal stratification was associated to haline stratification over a large part of the shelf from the large run-off accumulation over winter and early-spring. Early spring blooms were quite intense, with a typical progression from the south to the north of the bay during april.

At the beginning of the survey, the stratification is then well established with a thermocline around 40m, but surface temperature are still relatively cold just above 14°C. Fresh conditions, even if without real wind events, keep these levels of temperature between 14 and 15°C throughout the survey conducted from the south to the north of the bay.

Surface phytoplanktonic production remains high along the coast under the influence of the plumes, with river runoffs also remaining strong. More offshore, chlorophyll maxima are well spotted at the thermocline, while at the end of the survey production can be quite homogeneous, certainly due to the wind event and associated mixing at the end of the first leg around 22th of May.

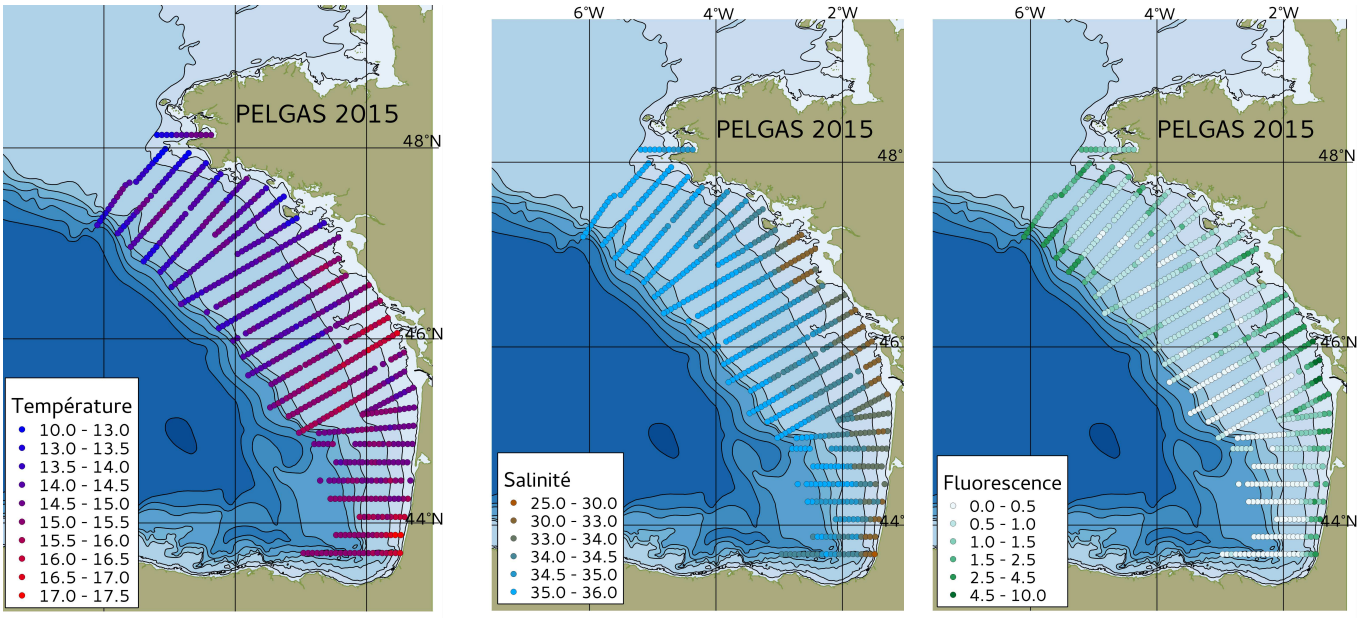

Figure 6.1. – Surface temperature, salinity and fluorescence observed during PELGAS15.

7. CONCLUSION

The Pelgas15 acoustic survey has been carried out with globally good weather conditions (regular low wind, medium temperatures) for the whole area, from the South of the bay of Biscay to the west of Brittany. The help of commercial vessels (two pairs of pelagic trawlers and a single one) during 18 days provided about 130 valid identification hauls instead of about 50 before 2007 when Thalassa was alone to identify echotraces. Their participation increased the precision of identification of echoes and some double hauls permitted to confirm that results provided by the two types of vessels (R/V and Fishing boats) were comparable and usable for biomass estimate purposes. These commercial vessels participated to the PELGAS survey in a very good spirit of collaboration, with the financial help of "France Filière Pêche" which is a groupment of French fishing organisations.

Temperature and salinity recorded during PELGAS13 were close to the average of the serie, with a surface temperature still relatively cold (just above 14°C) maintained by an absence of real wind event.

affected by relative good weather conditions before and during the survey, the water column was well stratified , with a surface temperature around the average of the serie (14°C). Surface phytoplanktonic production remained high along the coast under the influence of the river discharges.

The PELGAS15 survey observed the highest level of anchovy biomass never observed before (**372 916 tons**), pushed by a huge recruitment (the abundance of age 1 in 2015 is more or less 4 times the highest before) far from the highest level observed on the time series (186 865 tons in 2012). In the South, anchovy was mostly concentrated in the middle of the platform, and in the middle part of the bay of Biscay, anchovy appeared as very small fish with highest concentrations front of the Gironde, never observed before. In this area, anchovy was present from the coast until the shelf break continuously.

One of the main observation this year is that this very small anchovy concentrated in coastal area is mainly immature, and explain the spatial pattern of eggs.

The biomass estimate of sardine observed during PELGAS15 is **416 524 tons**, which constitutes a small increase of the last year level of biomass, and confirms that this specie is still at a high level of abundance in the bay of Biscay.

The high proportion of age 1 (63% in number, but 33 % in mass) seems to show that an other good recruitment occured. The global age structure of the population and his evolution trough years confirms the validity of age readings and the fact that we can follow sardine cohorts in the sardine population of the bay of Biscay. But it must be noticed that global weights and lengths at age are regularly decreasing in the bay of Biscay, maybe due to an effect of density-dependence. Old individuals (>4 years old) were rather absent of the area this year.

Concerning the other species, mackerel was rather absent this year compared to 2013 and 2014, while horse mackerel seems to be a bit more abundant for the third consecutive year, but still showing a low biomass.