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Direct assessment of small pelagic fish by the PELGAS16 acoustic survey

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1. MATERIAL AND METHOD

1.1. PELGAS survey on board Thalassa

An acoustic survey (PELGAS) is carried out every year in the Bay of Biscay in spring onboard the French research vessel Thalassa. The objective of PELGAS survey 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.

This survey is 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. This survey 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:

- Continuous acquisition of acoustic data from six different frequencies, 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) and 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.
- 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 2015). 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.

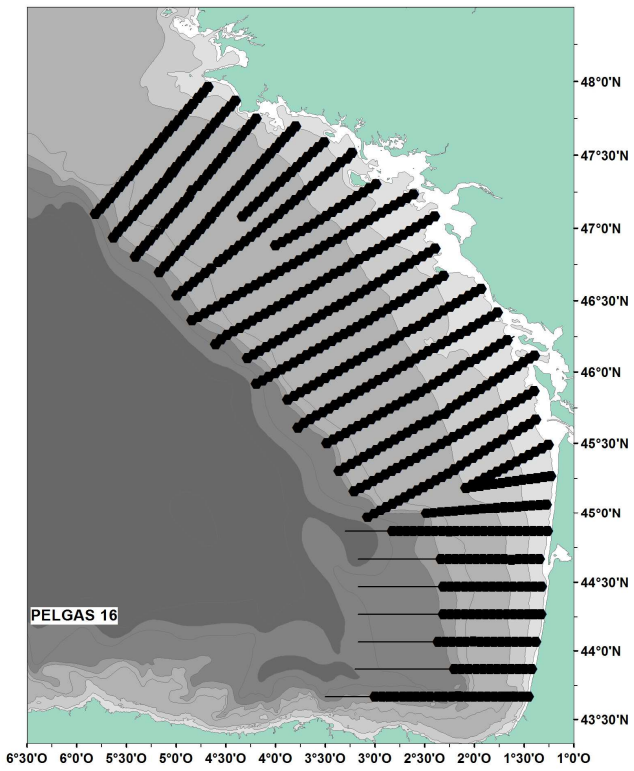


Fig. 1.1.1 - Transects prospected during PELGAS16 by Thalassa.

In 2016, 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 and observing 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 5220 nautical miles from which 1876 nautical miles on one way transect were used for assessment. A total of 28 859 fishes were measured (including 7 433 anchovies and 4 702 sardines) and 2857 otoliths were collected for age determination (1621 of anchovy and 1236 of sardine).

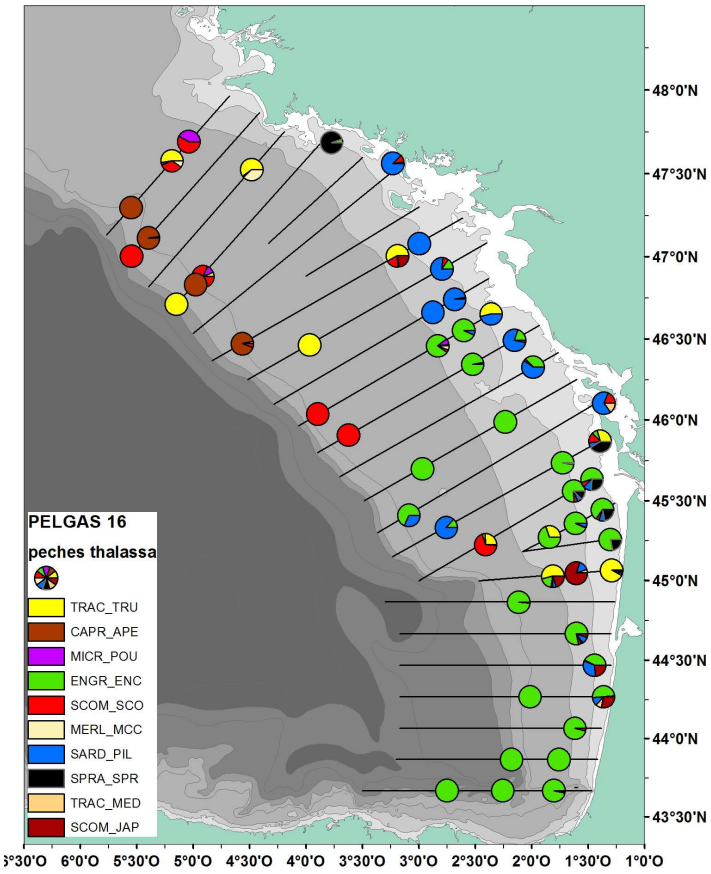


Fig. 1.1.2: Species distribution according to Thalassa identification hauls.

1.2. The consort survey

A consort survey is routinely organised since 2007 with French commercial vessels during 19 days. This approach is in identical to last year's surveys, using the commercial vessel's hauls were for echoes identification and biological parameters to complement hauls made by the R/V Thalassa.

Four commercial vessels (two pairs of pelagic trawlers) participated to PELGAS16 survey:

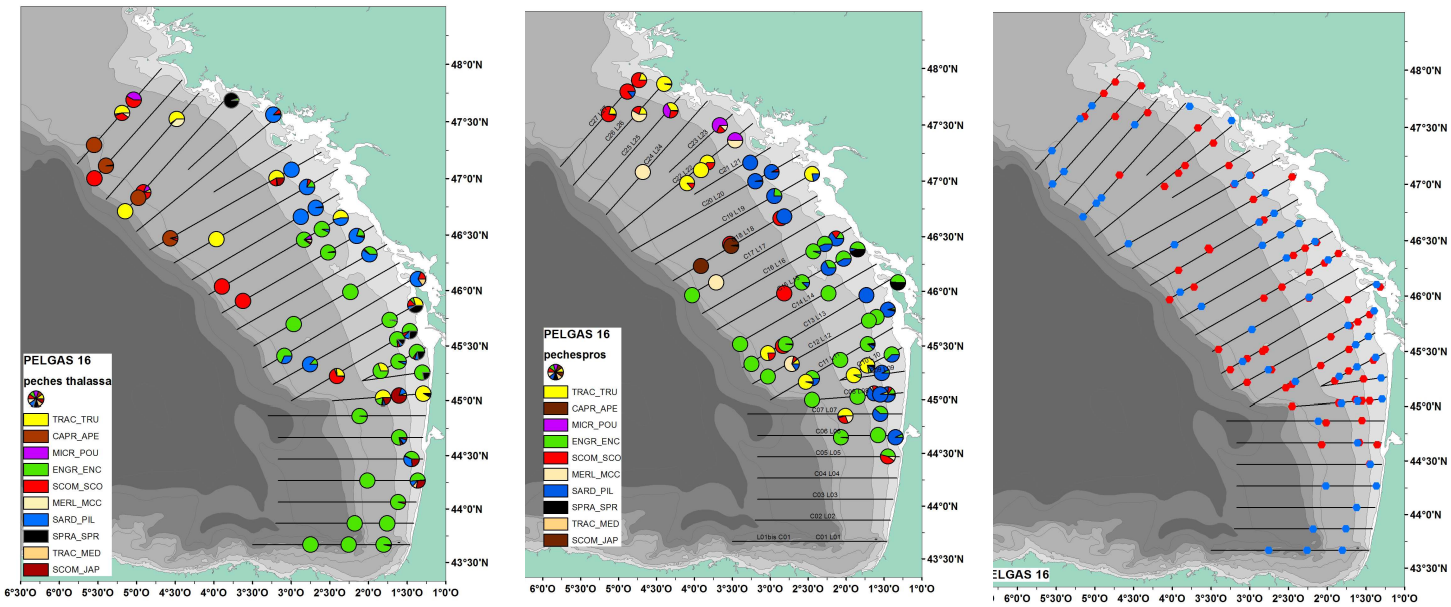
Vessel	Gear	Period	Days at sea
Carla-Eglantine / El Amanecer	Pelagic pair trawl	04/05 to 12/05/2015	9
Papi Paul / Joker	Pelagic pair trawl	12/05 to 21/05/2015	10

The regular transects network agreed for several years for Thalassa is 12 miles separated in 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 up to 25 m vertical opening and the mesh of their codend was similar to the on uses by the R/V Thalassa (12 mm).

A scientific observer was on board the commercial vessel to control every fishing 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, these fishing operation were used 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 the commercial vessels to Thalassa to improve otoliths collection and sexual maturity (240 otoliths of anchovy, 200 of sardine). A total of 7743 fishes were measured onboard commercial vessels, including 3118 anchovies and 1772 sardines.

Catches and biological data were used to complement the sampling made on boar the R/V Thalassa.

A total of 136 hauls were carried out during the consort survey including 73 hauls by the R/V Thalassa and 63 hauls by commercial vessels.



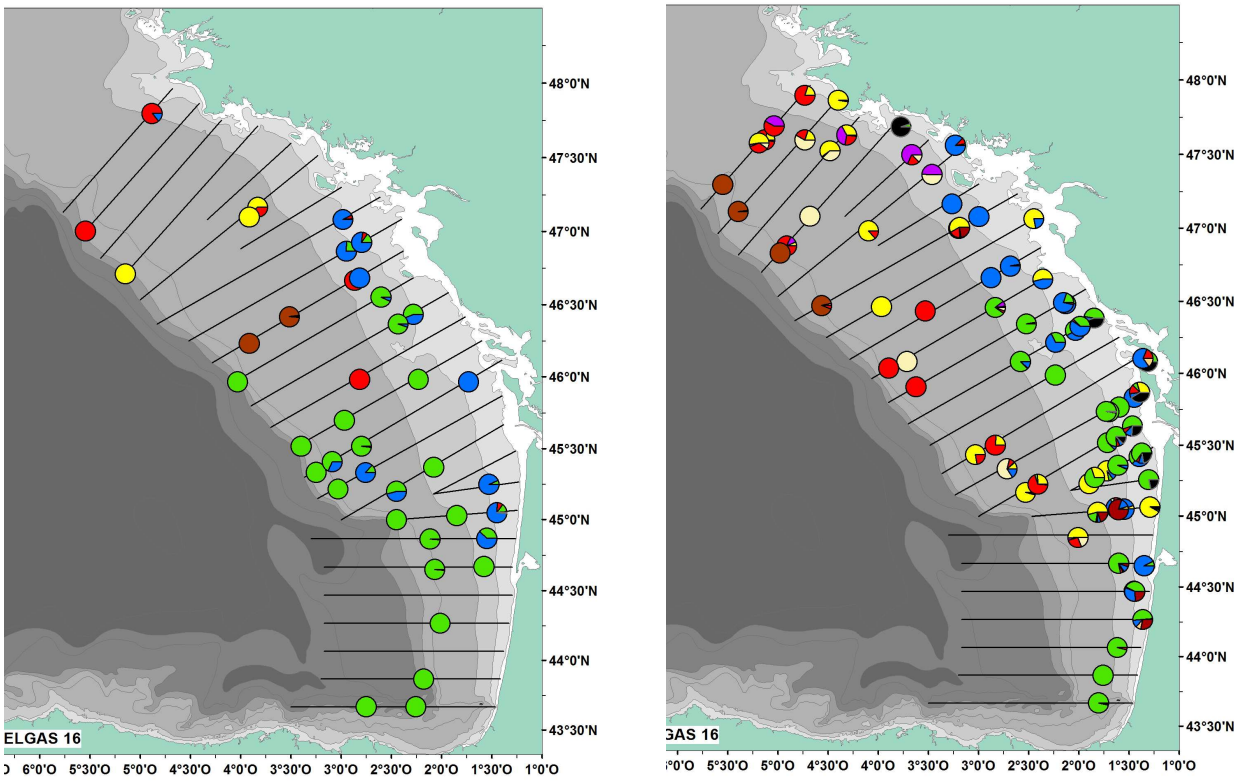
a) Thalassa (nb :54) *b) Commercial vessels (nb : 65)* *c) all fishing hauls (nb :119) thalassa in Blue and commercial in red*

Figure 1.2.2 : fishing operations carried out by Thalassa and commercial vessels during consort survey PELGAS16

The collaboration between Thalassa and commercial vessels was excellent. It was once more a very good opportunity to 1)explain our methodology to the fishermen and 2) check consistency between scientists and fishermen echo-trace's observation and interpretations. Some fishing operations were done in parallel by Thalassa and commercial vessel in order to check catches' similarity (in proportion of species and, most of the time, in quantity as well - taking the vertical and horizontal opening into account). As last year, commercial vessels' fishing operations were only carried out at 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.

Table 1.2.3. : Number of fishing operations carried out by Thalassa and commercial vessels during consort survey PELGAS16

	thalassa	commercial	total
surface hauls	12	27	39
classic hauls	42	35	77
null	0	3	3
total	54	65	119



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 and species composition during survey PELGAS16

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, and 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 and sometimes more offshore areas.

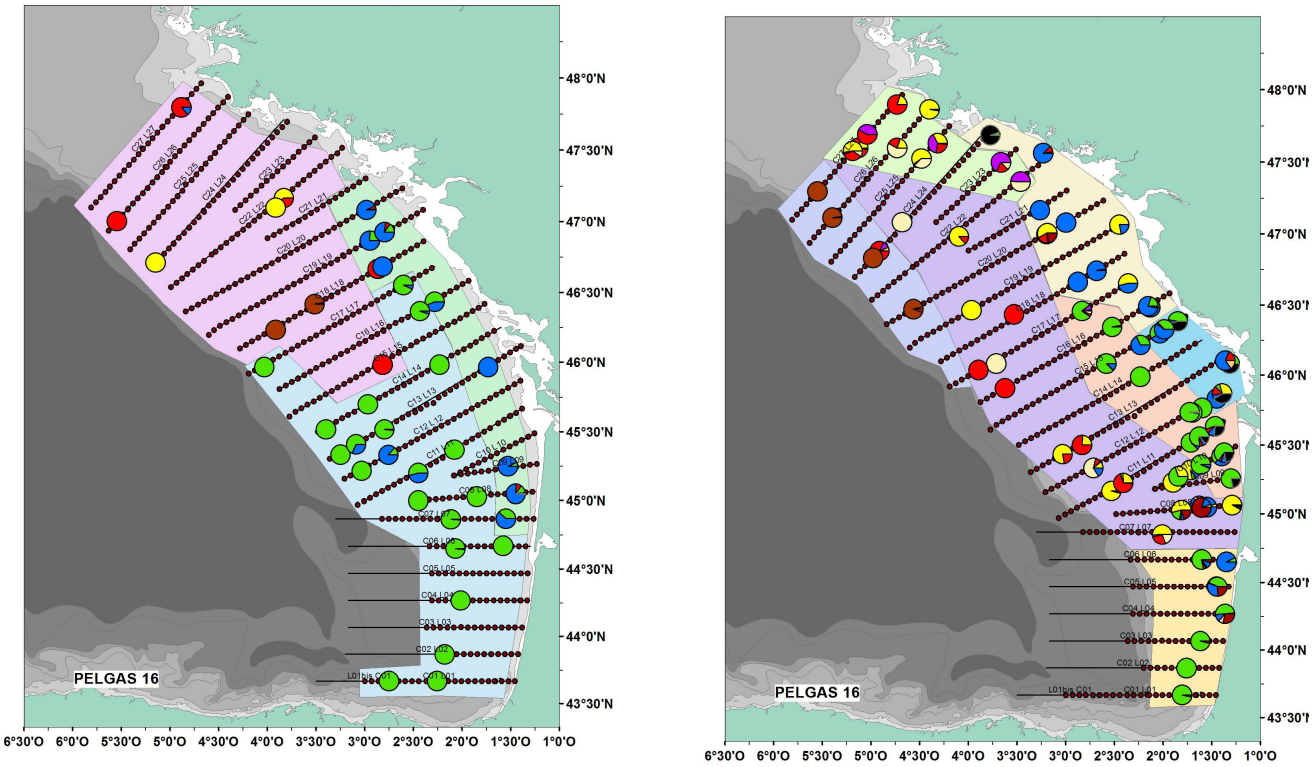
D3 – energies attributed to scattered detection corresponding to blue whiting, myctophids, boarfish, mackerel and horse mackerel.

D4 – energies attributed to sardine, mackerel and anchovy corresponding to echoes very close to the surface. This year, horse mackerel was also allocated 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 different species assemblages. Figure 2.2 shows the strata considered to evaluate biomass of each species. For each stratum, 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 PELGAS16 survey.

2.3. Biomass estimates

The fishing strategy has been followed all along the survey in order to benefit of each vessel's efficiency and maximise the number of samples (in term of identification and biological parameters). Therefore, the commercial vessels carried out mostly surface hauls when Thalassa fished preferably in the bottom layer. According to previous strata (Figure 2.2), using both Thalassa and consort fishing operations, biomass estimates were calculated for each main pelagic species in the surveyed area.

Biomass indices are presented in tables 2.3.1 and 2.3.2 and in figure 2.3.1. No estimate is 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 were much less abundant than last year and their abundance was estimated this year at a medium level compared to the historical time series (around 90 000 tonnes). Soft densities were observed in the Gironde area. It must be noticed that we observed anchovy on the first transect along the Spanish coast in relatively high densities, mainly close to the surface.

Sardine were also less present this year compared to 2015, almost exclusively in coastal waters from the South until the Loire river, and they were rather absent in surface along the shelfbreak.

About other species, another characteristic of this year was that horse mackerel showed a small increase of the biomass for another year in a raw, and reached now a medium level, after 10 years of low biomass at this period of the year in this area.

Mackerel appeared much dispersed all over the area and seemed to be relatively well present this year, particularly offshore, close to the bottom, and sometimes near the surface.

Table 2.3.1. Acoustic biomass index for the main species by strata during PELGAS16

	classic	surface	total
anchovy	71 168	18 558	89 727
sardine	228 308	1 435	229 742
blue whiting	17 934	162	18 096
horse mackerel	115 840	3 390	119 230
sprat	36 593	0	36 593
chub mackerel	111 197	183 452	294 649
hake	16 780	0	16 780
boarfish	4 475	0	4 475

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

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
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**	**89 727**
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	0.13
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**	**229 742**
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	0.08
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**	**36 593**
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	0.44
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**	**119 230**
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	0.3
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**	**11 852**
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*	*0.15*

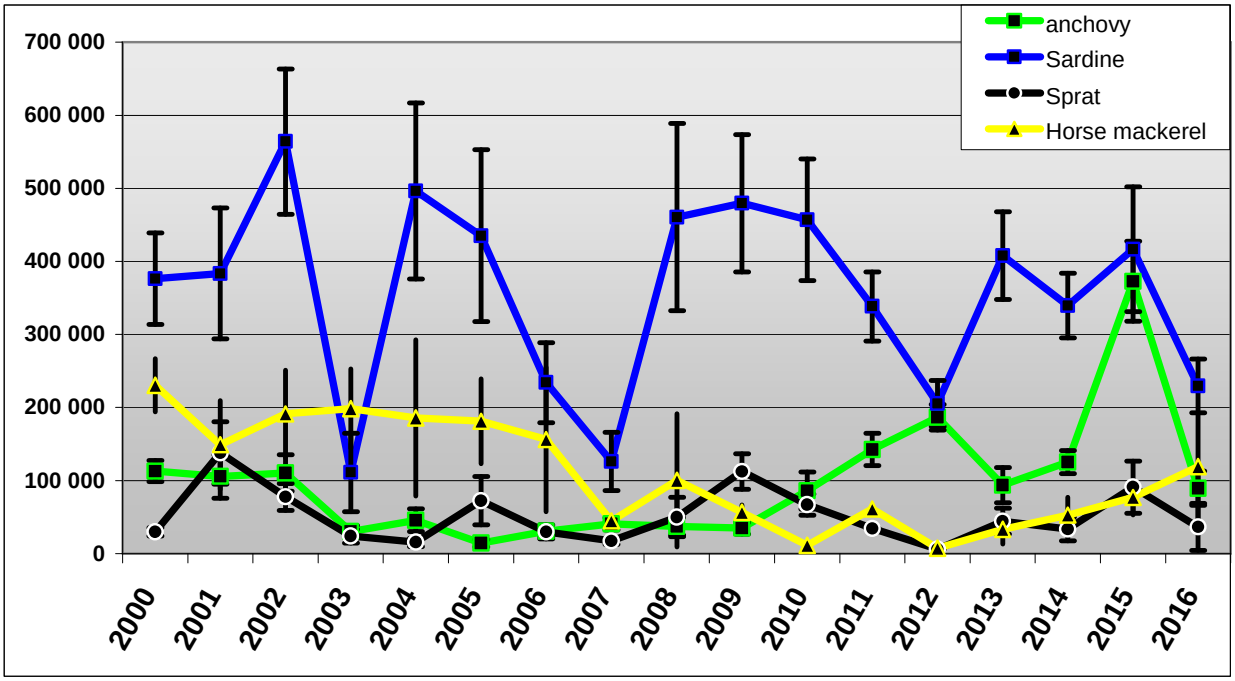


figure 2.3.3. – biomass estimate using Thalassa acoustic data along transects and all the consort identification fishing operations (Thalassa + commercial vessels) and associated coefficients of variation.

3. ANCHOVY DATA

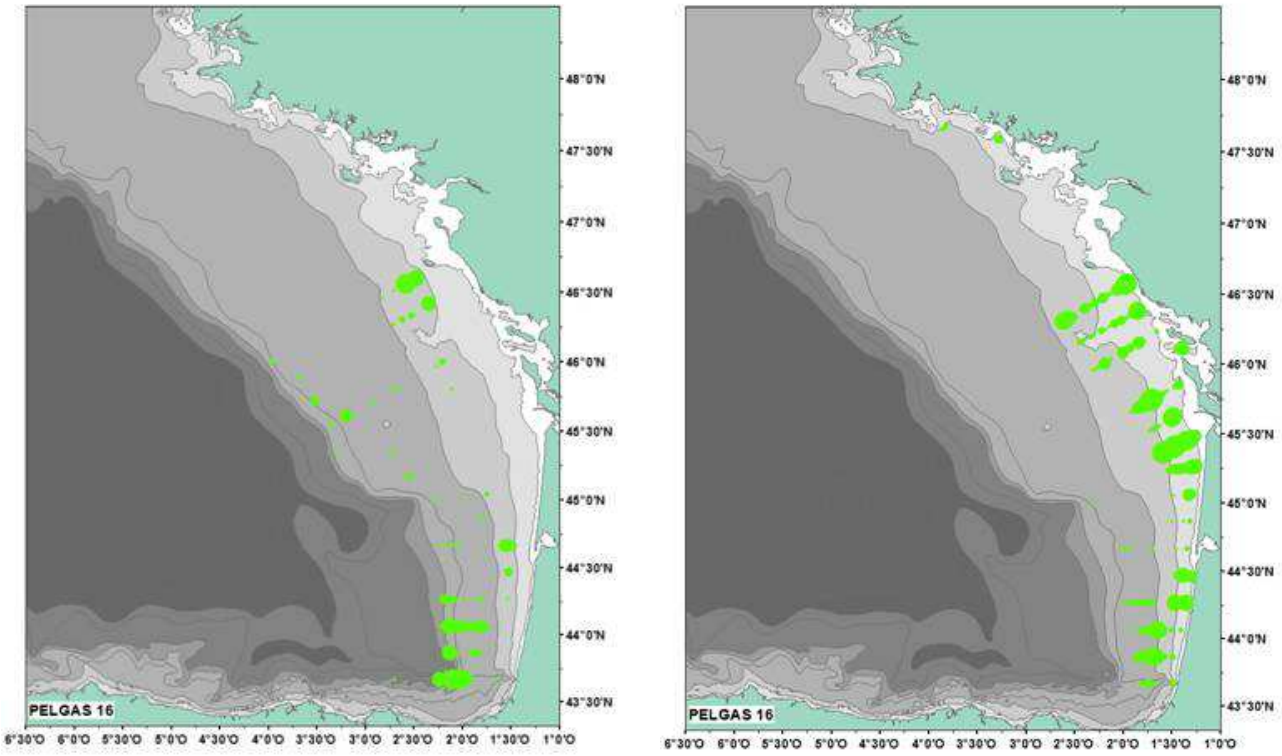
3.1. anchovy biomass

The biomass estimate of anchovy observed during PELGAS2016 is **89 727** tons. (table 2.3.2.), which seems to be a medium biomass compared to previous year's, comparable to 2010 and far away from the 2015 biomass.

In the Gironde area, the configuration was unusual in terms of energy compared to what was observed last years, with a low energy attributed to anchovy, far away from the huge abundance calculated in 2015 in this area. 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, in the southern part of the Bay of Biscay. The most part of the age 1 anchovy was there. The average size of one old fish was comparable the average size (two years really differed from the average: 2012 and particularly 2015 where fishes were much smaller).

Figure 3.1 shows the vertical distribution of anchovy. Offshore, anchovies were so closed to the surface that their abundance was probably underestimated in that area, given to the quantity of eggs counted (for more detail, see chapter 3.7 "Coherence between CUFES and Acoustic survey indices").



Surface distribution

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

Figure 3.1. – Anchovy distribution according to PELGAS16 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) were 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.

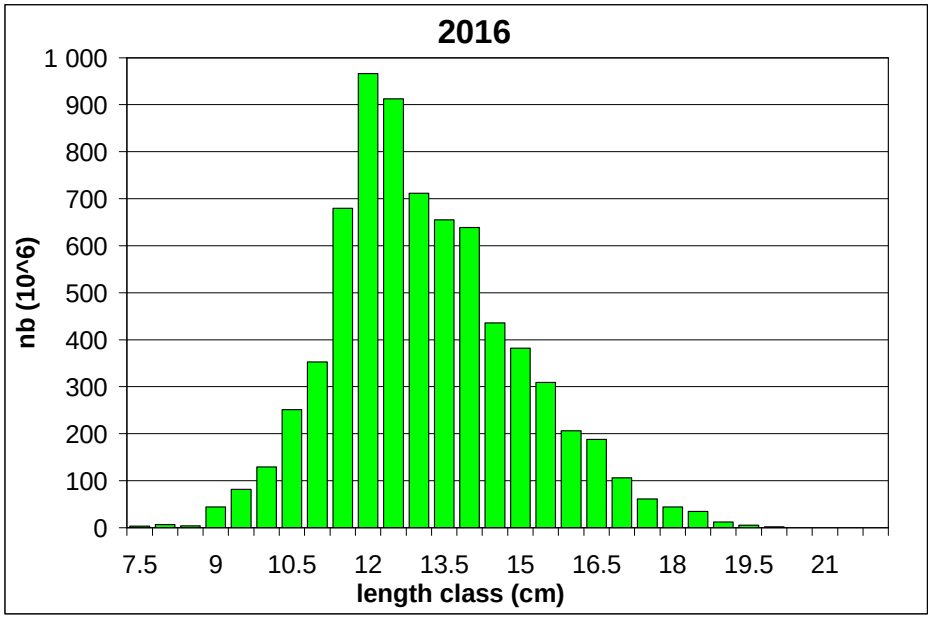


Figure 3.2: length distribution of global anchovy as observed during PELGAS16 survey

Globally we observe that length structure shows an unimodal distribution, with a mode around 12 centimetres (constituted by age 1 and Age 2 fishes). It must be noticed that even if some individuals were small (less than 10centimeters), almost all fishes were mature and in their spawning period. This observation on maturity contrasted with last year observation where a large proportion of the population was not spawning at the period of the 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 given number of fishes per length class (4 to 6 / half-cm), for a total amount of around 50 fishes per haul. As there was a lot of fishing operations where anchovy was present (as previous surveys), the number of otoliths taken during the survey was still important (1587 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.

Table 3.3.1. PELGAS2016 anchovy Age/Length key.

Nombre de Age	Age				
Taille	1	2	3	4	Total
7	100.00%	0.00%	0.00%	0.00%	100.00%
7.5	100.00%	0.00%	0.00%	0.00%	100.00%
8	100.00%	0.00%	0.00%	0.00%	100.00%
8.5	100.00%	0.00%	0.00%	0.00%	100.00%
9	100.00%	0.00%	0.00%	0.00%	100.00%
9.5	96.67%	3.33%	0.00%	0.00%	100.00%
10	70.45%	29.55%	0.00%	0.00%	100.00%
10.5	69.23%	30.77%	0.00%	0.00%	100.00%
11	67.44%	32.56%	0.00%	0.00%	100.00%
11.5	54.74%	45.26%	0.00%	0.00%	100.00%
12	62.86%	37.14%	0.00%	0.00%	100.00%
12.5	45.19%	54.81%	0.00%	0.00%	100.00%
13	33.61%	66.39%	0.00%	0.00%	100.00%
13.5	36.11%	63.89%	0.00%	0.00%	100.00%
14	28.46%	69.11%	1.63%	0.81%	100.00%
14.5	15.63%	80.47%	3.91%	0.00%	100.00%
15	10.83%	87.50%	1.67%	0.00%	100.00%
15.5	2.73%	86.36%	10.91%	0.00%	100.00%
16	4.95%	67.33%	26.73%	0.99%	100.00%
16.5	1.47%	58.82%	39.71%	0.00%	100.00%
17	0.00%	46.67%	50.00%	3.33%	100.00%
17.5	0.00%	35.00%	65.00%	0.00%	100.00%
18	0.00%	18.18%	81.82%	0.00%	100.00%
18.5	0.00%	22.22%	77.78%	0.00%	100.00%
19	0.00%	0.00%	100.00%	0.00%	100.00%
19.5	0.00%	0.00%	100.00%	0.00%	100.00%
Total	33.14%	56.40%	10.21%	0.25%	100.00%

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 2016 are shown in figure 3.3.3.

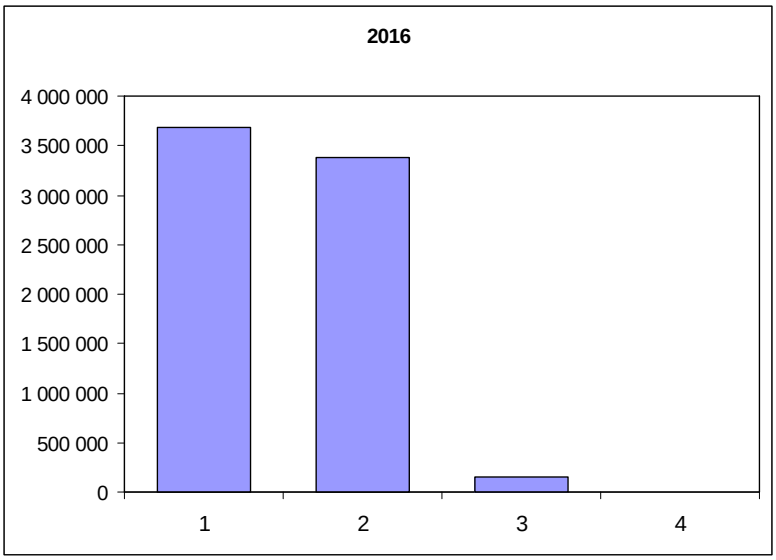


Figure 3.3.2– global age composition (numbers) of anchovy as observed during PELGAS16.

Looking at the numbers at age since 2000 (fig 3.3.3.), the number of 1 year old anchovies this year seemed equivalent to 2010 or 2013, far away from the very best recruitment observed last year. As it is described in chapter 3.7, we probably underestimated the number of age 2 & 3 this year, as they were present very closed to the surface offshore in the middle part of the bay of Biscay, in the blind layer of vertical echosounders but observed by the lateral echosounder. The lateral echosounder is not used for assessment purpose.

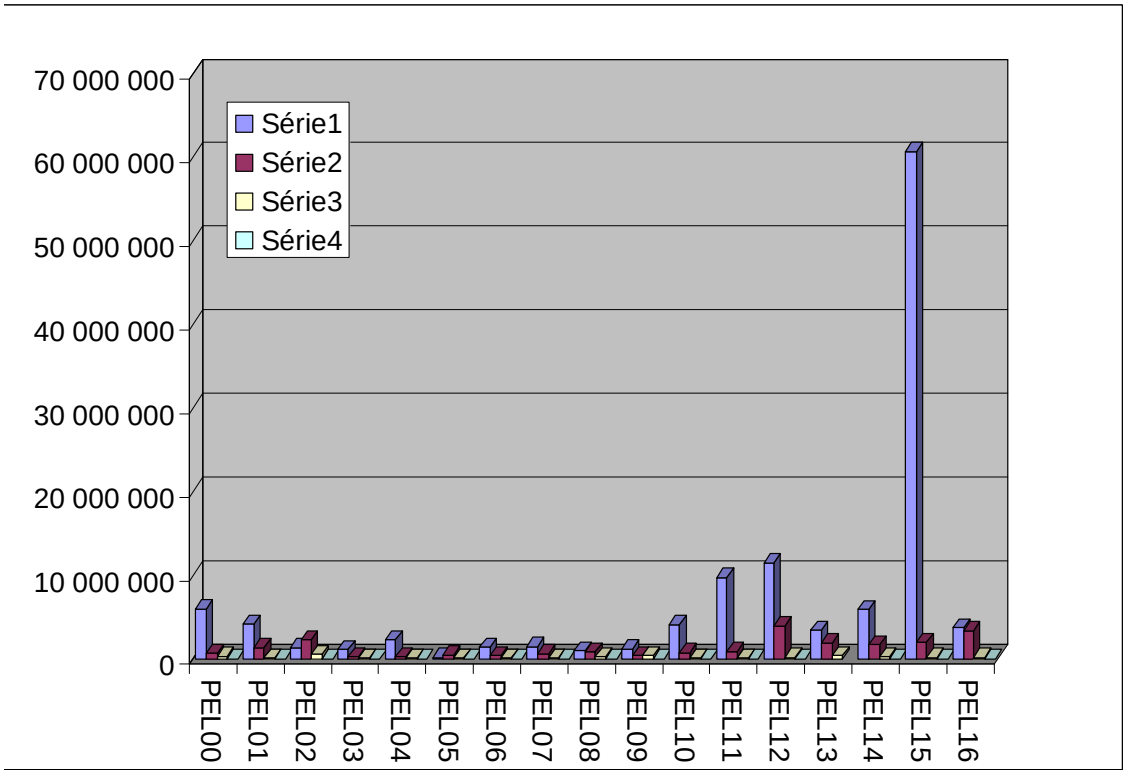


Figure 3.3.3 Anchovy numbers at age as observed during PELGAS surveys since 2000

The huge 2015 age class last year is not fully followed in a high abundance of age 2 this year (see before and in chapter 3.7).

In 2016, the number of age 1 and 2 seemed to be equivalent in numbers.

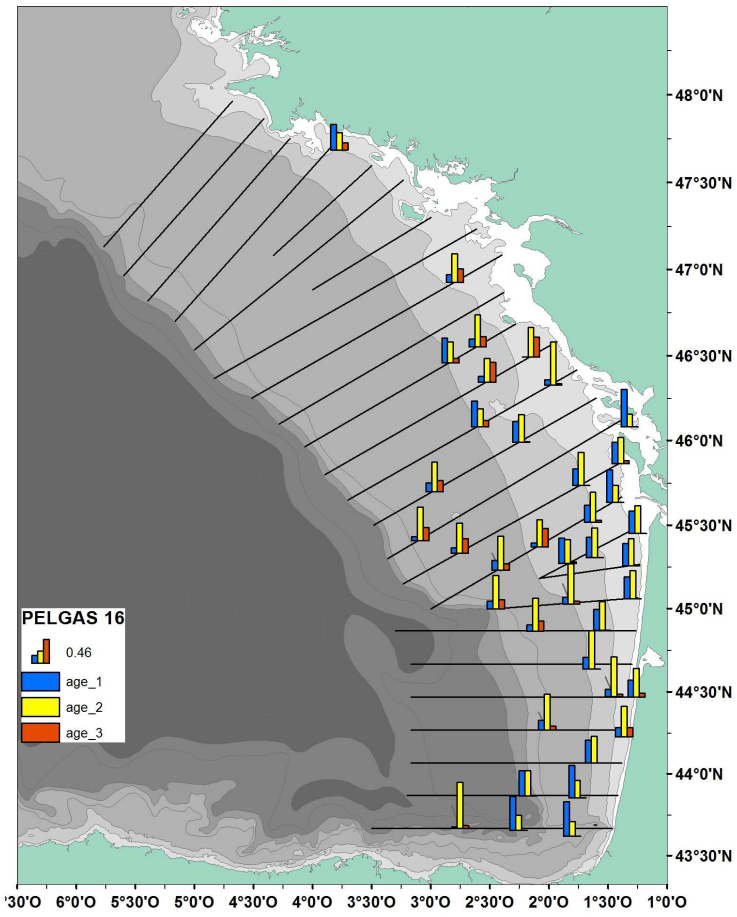


Figure 3.3.4 Anchovy proportion at age in each haul as observed during PELGAS16 survey (blue = age 1, yellow = age 2).

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 age2 were present all over the area where anchovy was present, even in the Gironde area where usually age 1 is almost pure. Offshore and closed to the surface, older fishes (age 2 and 3) were detected and caught

	PEL16 - % - N
age 1	51.06%
age 2	46.71%
age 3	2.14%
age 4	0.08%

	Pel16 - % - W
age 1	39.68%
age 2	54.71%
age 3	5.46%
age 4	0.15%

Figure 3.3.5 percentage by age of the Anchovy population observed during PELGAS16 in numbers (left) and biomass (right).

3.4. Weight/Length key

Based on 1781 weights of individual fishes, the following weight/length key was established (figure 4.5.):

$W = 0.004L^{3.199}$ with R2 = 0.9697 *(with W in grams and L in mm)*

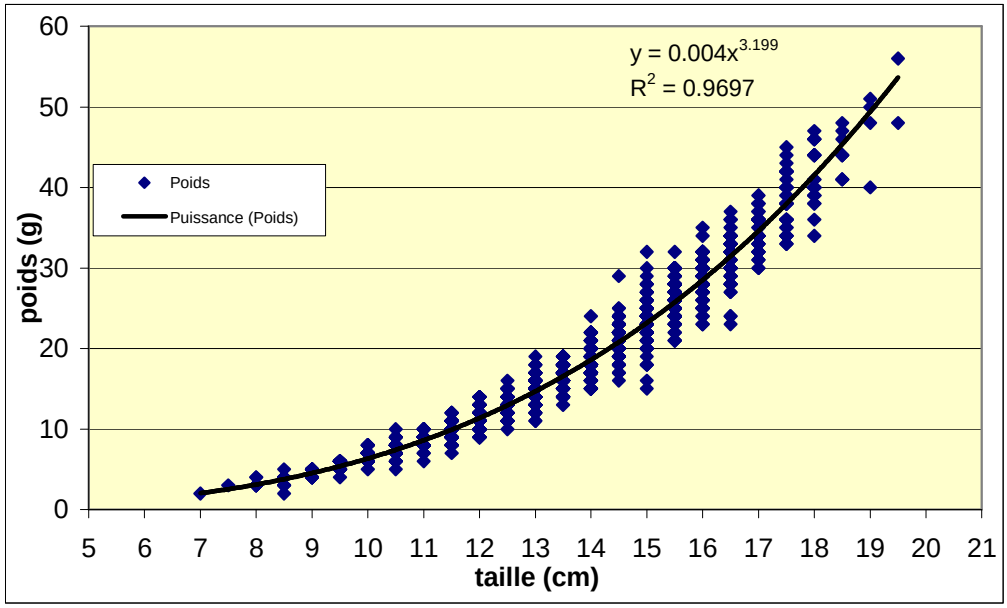


Fig. 3.4 – Weight/length key of anchovy established during PELGAS16

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
PEL16	9.37	14.12	30.70	23.97	

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, 538 CUFES samples were collected and counted, 82 vertical plankton hauls and 114 vertical profiles with CTD were carried out. Eggs were sorted and counted during the survey.

2016, as from 2011, was marked by a large quantity of collected and counted anchovy eggs (Fig 3.6.2).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.

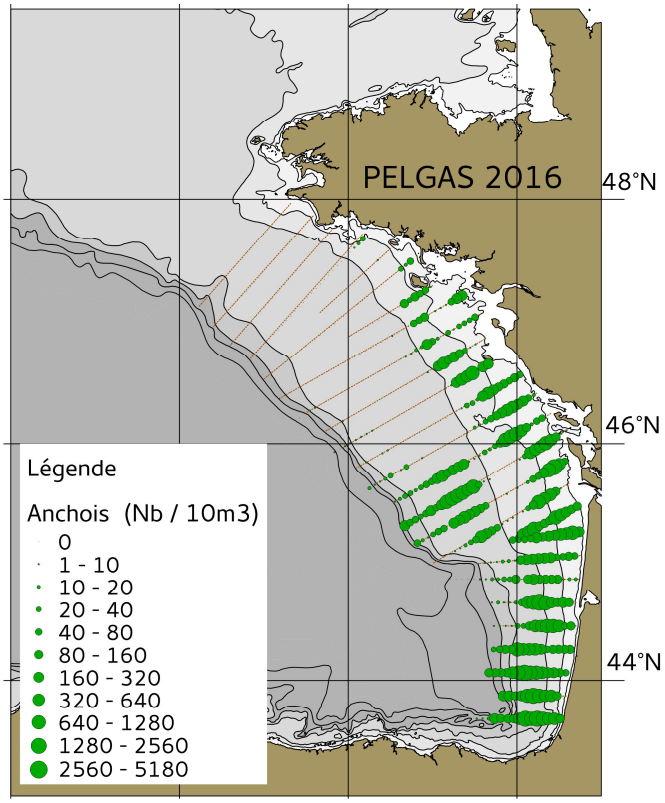


Figure 3.6.1 – Distribution of anchovy eggs observed with CUFES during PELGAS16.

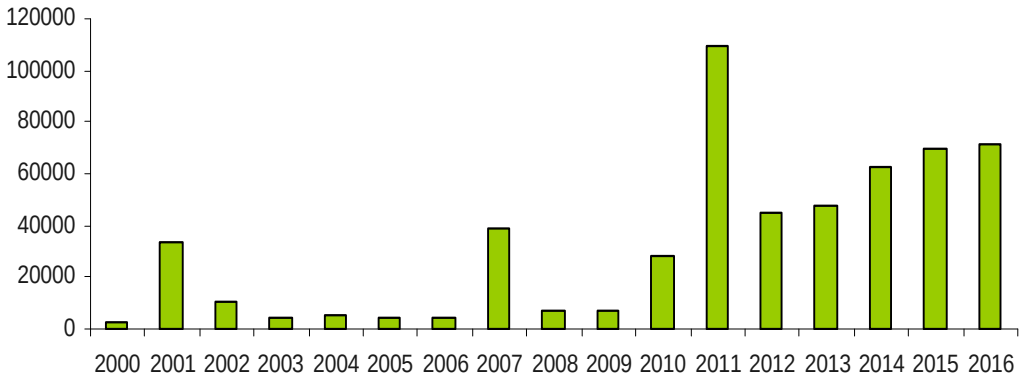


Figure 3.6.2 – Number of eggs observed during PELGAS surveys from 2000 to 2016

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.

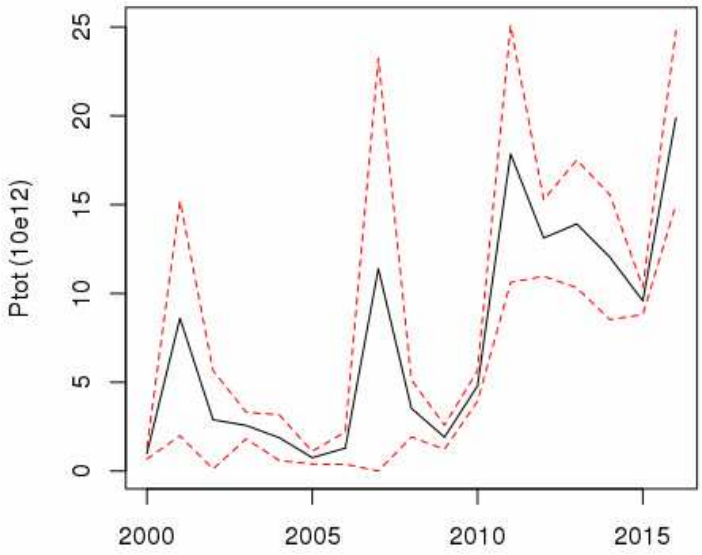


Figure 3.7.1 – Ptot serie from the CUFES index

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 3.7.2.). 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 some years.

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.

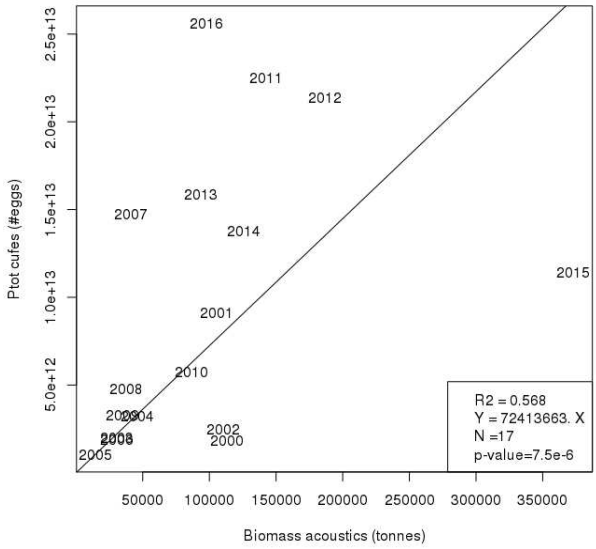


Figure 3.7.2 – Coherence between CUFES and Acoustic PELGAS survey indices

It must be noticed that with such a high acoustic biomass in 2015, this year's point drives the linear regression. It must be simply explained by the fact that a high proportion of in 2015 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. Once again, if the biomass this year in slightly underestimated according to the presence of large anchovies in the blind layer of vertical echosounder, the point should be closer to the slope.

An other important thing is that this year is the second 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.

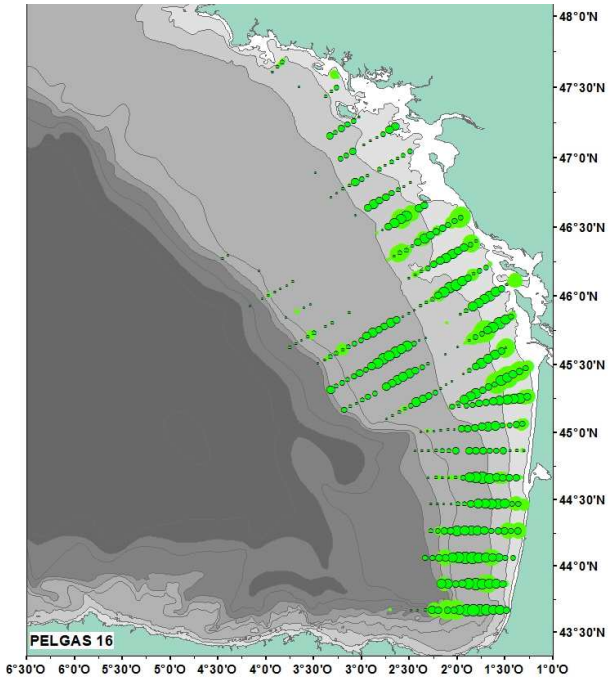


Figure 3.7.3 – Coherence between spatial distribution of adults and eggs. circled point = eggs, without circle = biomass of adults per ESDU

We can see that globally the spatial distribution of eggs match with the adult's one. but in the center of the bay, a lot of eggs were counted despite a low abundance of adults. In this area particularly, anchovy was very closed to the surface, in the blind layer of vertical echosounders. This lead a probable underestimation of adults biomass in this area.

4. SARDINE DATA

4.1. Adults

The biomass estimate of sardine observed during PELGAS15 is **229 742** tons (table 2.3.), which is is at a low average level of the PELGAS series, and constituting a real decrease of the biomass compared to the 4 last years. 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. It seems to be the case along the coast of Brittany this year where eggs were counted along the coast but without real energy attributed to sardine.

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. Sardine was present, often mixed with anchovy and sometimes with sprat, from the Gironde to the South coast of Brittany. Sardine appeared rather absent offshore, close to the surface, along the shelf break, contrary to previous years when sardine was well present along the shelfbreak.

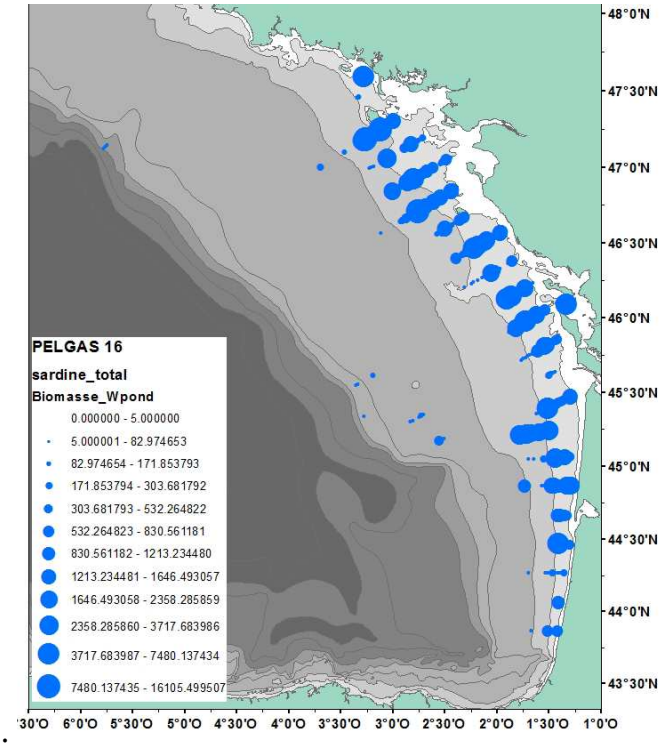


Figure 4.1.1 – distribution of sardine observed by acoustics during PELGAS16

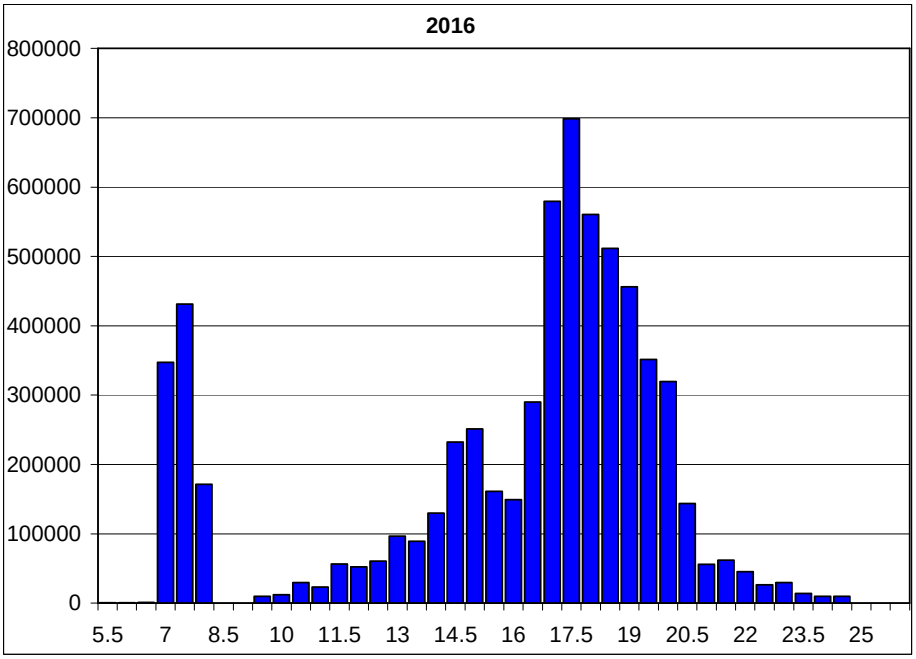


Figure 4.1.2. – length distribution of sardine as observed during PELGAS16

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.

This year, sardine shows a trimodal length distribution, the first one (about 7 cm), corresponding to the age 0, and present for the first time this year at this period front of the Gironde and in the extrem south of the bay of Biscay). The second , about 14cm, corresponds to age 1 and the third, about 18cm, 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. The older individuals (age 5 and more) seems to be rather absent of the bay of Biscay this year.

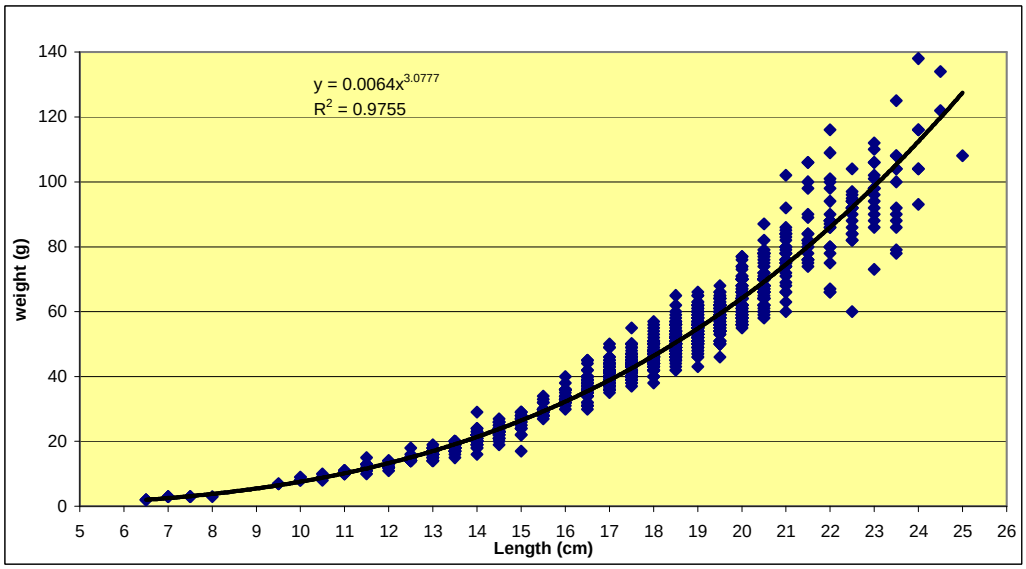


Figure 4.1.3 – Weight/length key of sardine established during PELGAS16

Nombre de Age	Age											
Taille	0	1	2	3	4	5	6	7	8	9	10	Total
6.5	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
7	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
7.5	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
8	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
9.5	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
10	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
10.5	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
11	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
11.5	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
12	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
12.5	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
13	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
13.5	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
14	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
14.5	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
15	0.00%	94.74%	5.26%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
15.5	0.00%	95.24%	4.76%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
16	0.00%	44.44%	55.56%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
16.5	0.00%	23.64%	76.36%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
17	0.00%	8.51%	89.36%	2.13%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
17.5	0.00%	6.48%	87.04%	4.63%	1.85%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
18	0.00%	0.00%	83.04%	16.07%	0.89%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
18.5	0.00%	0.00%	58.77%	34.21%	7.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
19	0.00%	0.00%	41.46%	42.28%	16.26%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
19.5	0.00%	0.00%	20.59%	55.88%	23.53%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
20	0.00%	0.00%	6.33%	46.84%	37.97%	6.33%	2.53%	0.00%	0.00%	0.00%	0.00%	100.00%
20.5	0.00%	0.00%	2.00%	28.00%	62.00%	6.00%	0.00%	2.00%	0.00%	0.00%	0.00%	100.00%
21	0.00%	0.00%	0.00%	31.25%	34.38%	28.13%	0.00%	6.25%	0.00%	0.00%	0.00%	100.00%
21.5	0.00%	0.00%	0.00%	15.79%	57.89%	15.79%	0.00%	10.53%	0.00%	0.00%	0.00%	100.00%
22	0.00%	0.00%	0.00%	4.55%	54.55%	13.64%	4.55%	18.18%	4.55%	0.00%	0.00%	100.00%
22.5	0.00%	0.00%	0.00%	5.56%	27.78%	33.33%	16.67%	11.11%	0.00%	5.56%	0.00%	100.00%
23	0.00%	0.00%	0.00%	0.00%	6.67%	13.33%	40.00%	33.33%	6.67%	0.00%	0.00%	100.00%
23.5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	41.67%	25.00%	25.00%	0.00%	8.33%	100.00%
24	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	50.00%	33.33%	16.67%	0.00%	100.00%
24.5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	100.00%
25	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	100.00%
Total	0.82%	21.39%	38.78%	19.51%	12.73%	2.53%	1.39%	1.96%	0.57%	0.16%	0.16%	100.00%

Table 4.1.4 : sardine age/length key from PELGAS16 samples (based on 1225 otoliths)

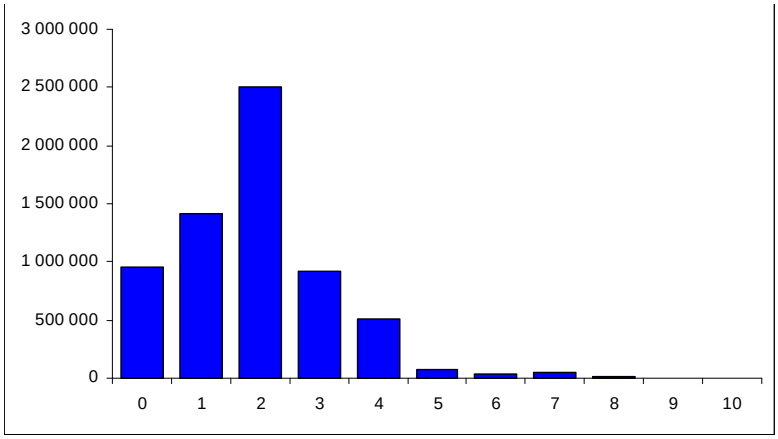


Figure 4.1.5.- Global age composition (nb) of sardine as observed during PELGAS 16

	pel16 - % - N
age 0	14.70%
age 1	21.85%
age 2	38.68%
age 3	14.22%
age 4	7.89%
age 5	1.13%
age 6	0.50%
age 7	0.80%
age 8	0.16%
age 9	0.05%
age 10	0.02%

	PEL16 - W - %
age 0	1.18%
age 1	13.31%
age 2	44.86%
age 3	21.17%
age 4	13.37%
age 5	2.28%
age 6	1.17%
age 7	2.03%
age 8	0.45%
age 9	0.13%
age 10	0.05%

Figure 4.1.6 percentage by age of the sardine population observed during PELGAS16 in numbers (left) and biomass (right).

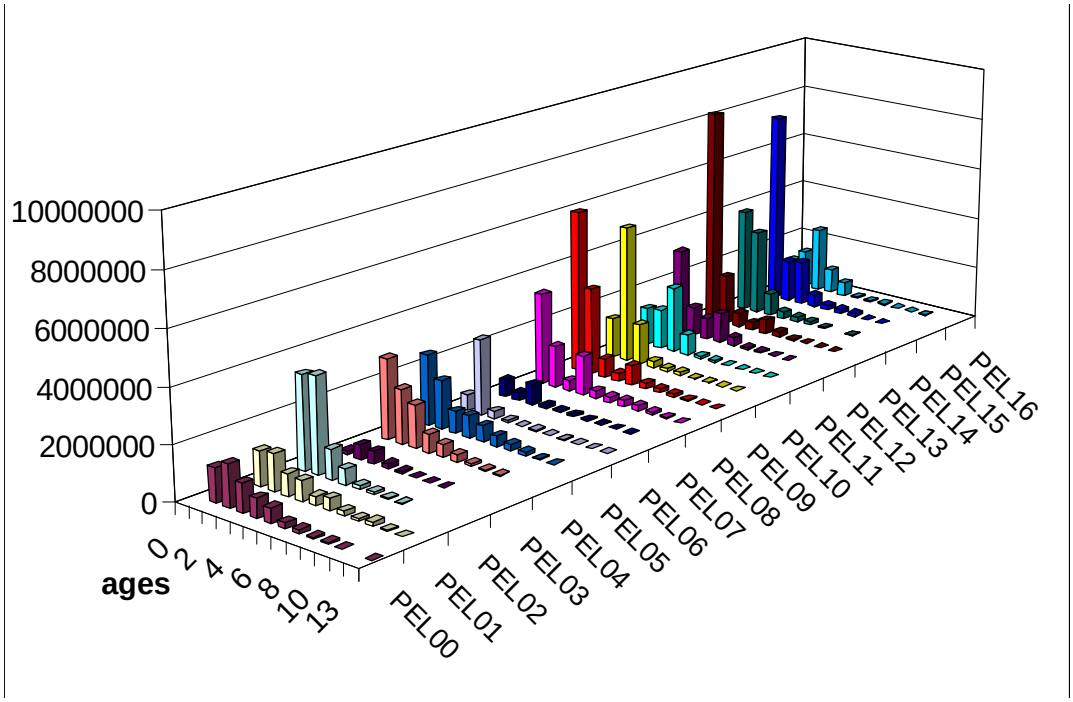


Figure 4.1.7- Age composition of sardine as estimated by acoustics since 2000

PELGAS serie of sardine abundances at age (2000-2016) is shown in Figure 4.1.7. Cohorts can be visually tracked on the graph particularly in the past : 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. this is less true in recent years, with the good recruitment in 2013 which doesn't profit to incoming years.

The 2016 recruitment at age 1 seems to be low. But the real new event is that juveniles appearance particularly front of the Gironde. Otoliths were extracted and read and they show a full opaque pattern, without any winter ring. So it was decided to attribute age 0 to these fish.

	age										
survey	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
PEL 2000	-	35.05	54.74	69.15	76.46	84.82	89.93	98.83	110.18	105.04	112.87
PEL 2001	-	41.28	58.85	76.83	83.84	93.68	96.92	103.41	105.35	112.71	120.97
PEL 2002	-	40.48	60.2	74.94	81.7	92.31	99.42	106.68	118.05		
PEL 2003	-	53.35	68.04	73.15	78.11	86.04	93.33	88.74	96.09		
PEL 2004	-	35.94	64.73	76.54	84.39	95.87	98.83	104.34	109.19	106.15	
PEL 2005	-	34.44	63.45	73.29	79.62	84.88	88.96	90.04	105.42	109.45	98.35
PEL 2006	-	39.17	58.37	70.78	81.18	86.37	82.48	91.25	97.22	107.02	112.02
PEL 2007	-	37.55	65.96	71.77	79.05	84.02	94.45	100.37	96.93	101.27	114.86
PEL 2008	-	33.44	60.33	71.1	75.18	83.82	92.84	90.45	95.67	99.48	101.41
PEL 2009	-	29.51	57.13	73.62	81.28	83.26	88.35	95.67	91.44	96.50	106.67
PEL 2010	-	30.33	50.55	64.04	73.05	78.43	87.58	93.16	105.88	106.96	116.01
PEL 2011	-	27.37	50.13	58.69	69.84	78.35	83.00	84.28	108.17	105.38	108.33
PEL 2012	-	22.88	44.66	57.40	65.45	78.42	87.83	95.26	92.27	99.83	
PEL 2013	-	21.16	44.33	55.82	68.30	77.42	84.27	89.28	99.10	113.27	89.17
PEL 2014	-	23.02	44.53	55.93	62.07	69.35	76.11	78.46		86.50	
PEL 2015	-	18.75	44.73	56.98	67.22	78.86	87.07	94.81	95.23	90.01	
PEL 2016	3.01	22.94	43.64	56.03	63.76	75.71	88.48	95.36	102.21	102.39	105.47

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 with the one of anchovy, with a further north distribution along the coast though, and a lack of eggs along the slope in the North, which was the case only one year in the past in 2010.

For sardine, egg abundances are at a mean level with regard to the whole Pelgas time-series.

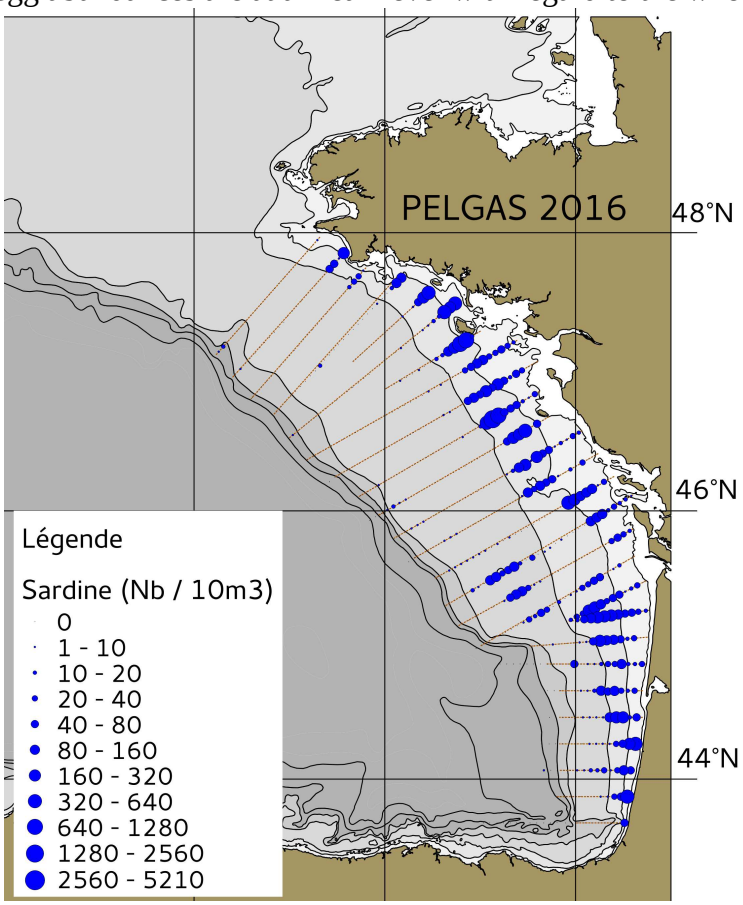


Figure 4.2.1. Distribution of sardine eggs observed with CUFES during PELGAS16.

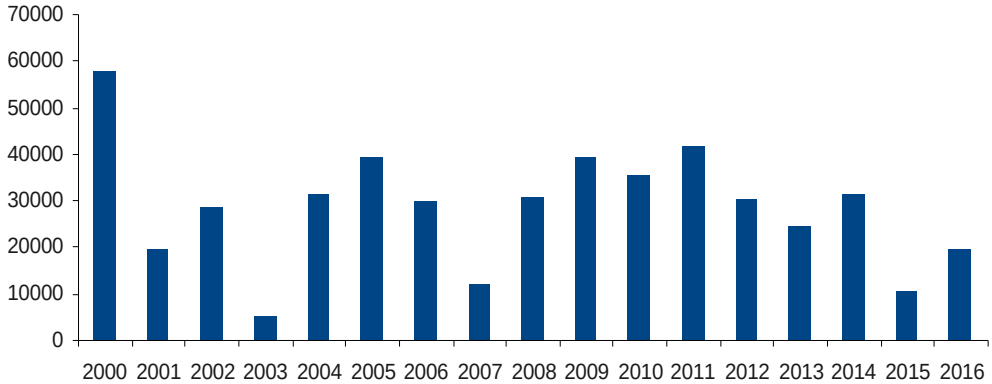


Figure 4.2.2. Number of eggs observed during PELGAS surveys from 2000 to 2016

2016 was marked by a medium abundance of sardine eggs as compared to the PELGAS time-series. It must be noticed that this year almost all sardines were mature and in spawning period, compared to 2015 when the small sardine at age 1 were not spawning 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 236 hours of sighting effort were performed for 31 days (Figure 5.1.), with an average of 7.6 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 – Sighting effort and conditions

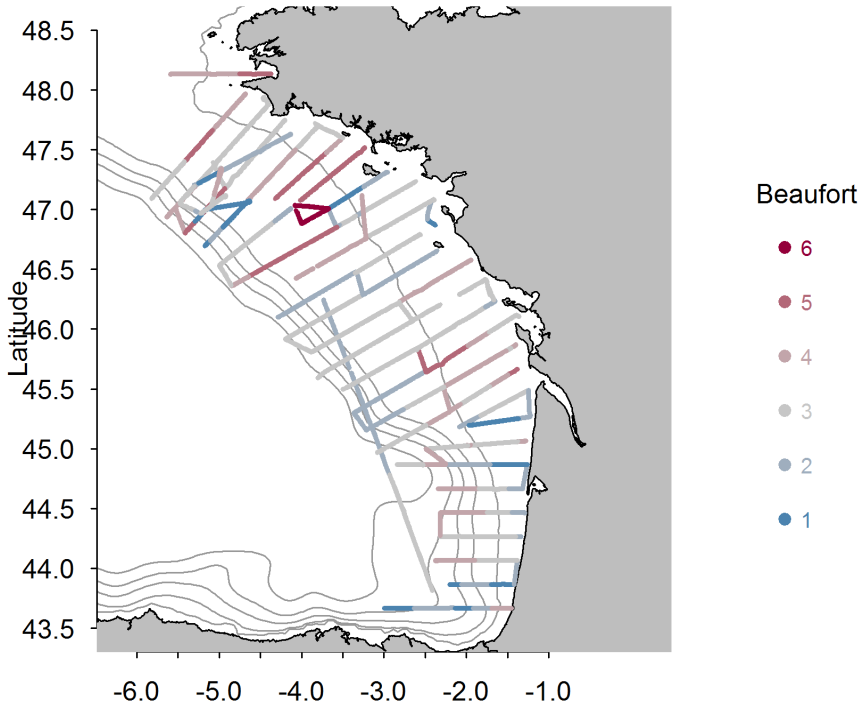


Figure 5.1. Sighting effort and conditions

The better conditions were met in the central part of the bay of Biscay, and the worst in the North. Globally conditions of sightings were considered as "good", 8% as medium and 31 % as bad, due to wind or fog

5.2 – Birds

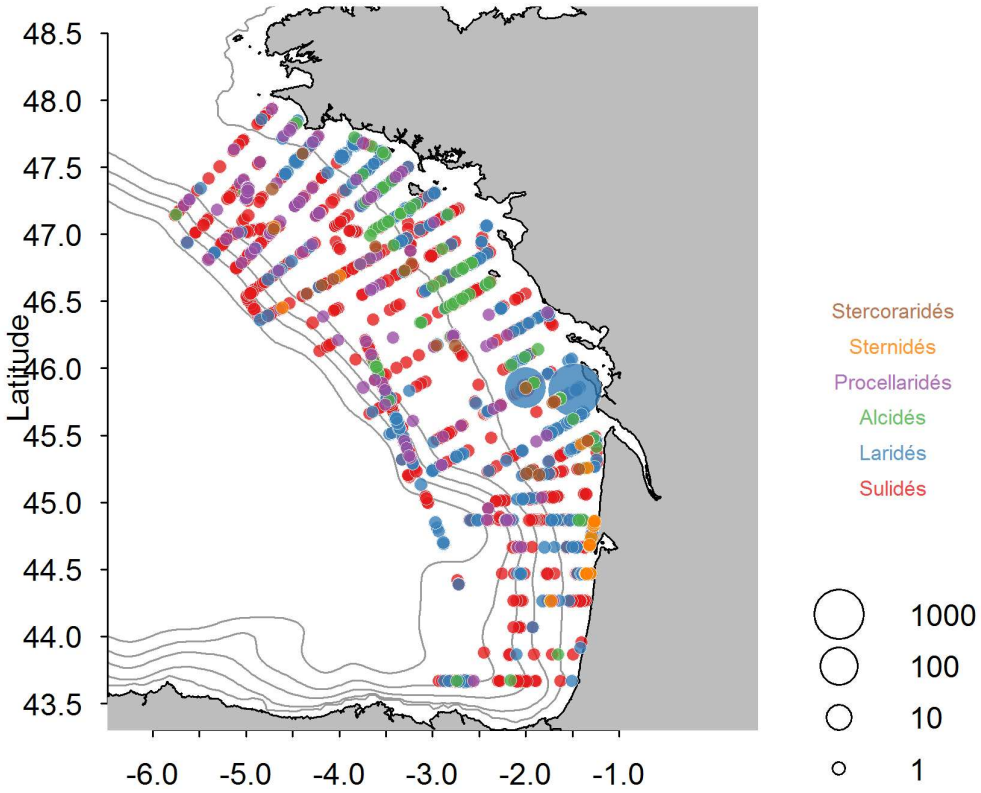


Figure 5.2. Distribution of birds observed during the PELGAS16 survey

Birds constitute the vast majority of sightings. Shorebirds and passerines accounted for less than 4% of bird sightings. 1,505 sightings of seabirds were found all over the Bay of Biscay (Figure 5.2), divided into 22 identified species and a raw estimate of 5577 individuals.

Northern gannets accounted for 55% of all seabird sightings: its distribution is homogeneous across the Bay of Biscay.

An other group of species was also well met : the larids, including the sea gulls and Black-legged Kittiwake (4 species observed this year in this family). They represent the most important number of individuals observed during the survey, with a total of 4805 birds. Some groups are really huge in terms of numbers of fish, with a strong maximum this year of almost 500 individuals, observed in the Gironde area.

Alcids (guillemot, razorbill) are softly present this year, with only 5% of the observations concerning this group.

5.2 – Mammals

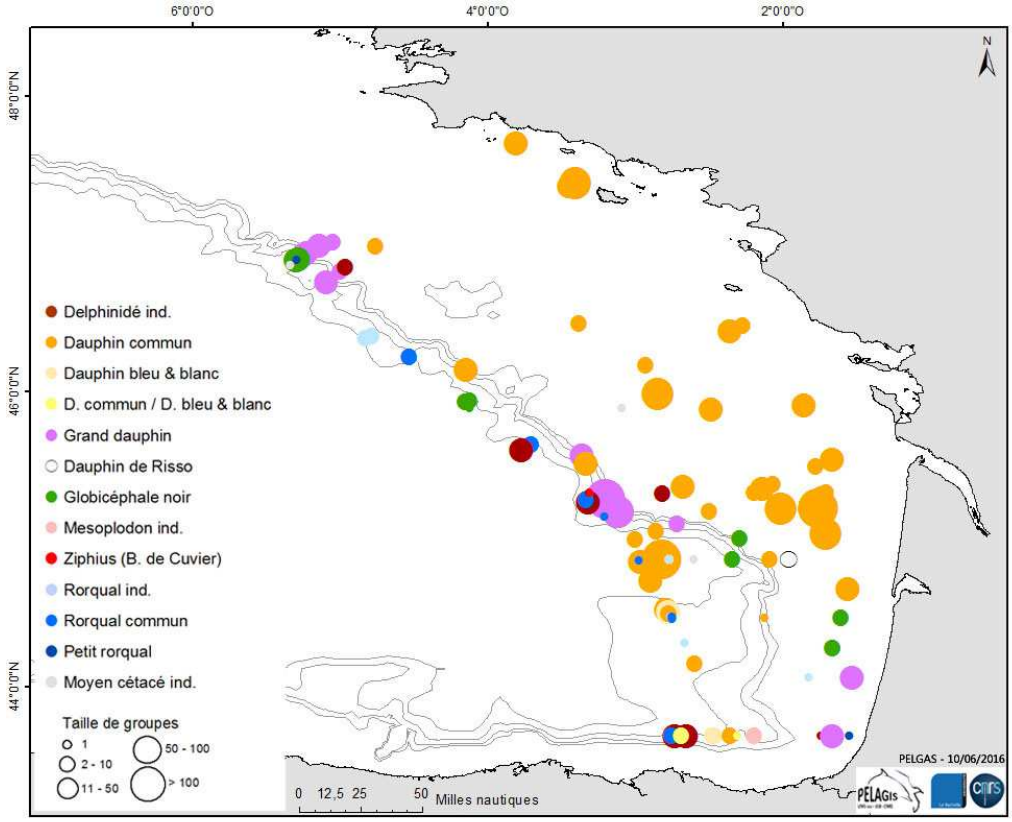


Figure 5.2. Distribution of mammals during the PELGAS16 survey.

A total of 109 sightings were recorded corresponding to a raw estimate of 2122 individuals and 8 species of cetaceans clearly identified (Figure 2). The greatest diversity of marine mammals was observed in the central 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 (44% of total observations, 1375 individuals). Common dolphins were present on the continental shelf, with a maximum front of the Gironde, with large groups someone (until 200 individuals). Striped and Risso's dolphins were sighted this year, but as usual in lower quantities than Bottlenose dolphins. However, some long-finned pilot whales were sighted on the continental slope in the central part of the Bay of Biscay.

Two observations of minke whales were reported after the slope, in the extreme South and the extreme North of the bay of Biscay. Compared to previous years, fin whales were well present in 2016 all along the shelfbreak, with 11 observations reported.

6. HYDROLOGICAL CONDITIONS

The conditions were very similar than 2015, with a well established stratification despite relatively low temperature at surface, around 14°C over the whole bay. The calm but cold weather in April (before the start of the survey) explain these conditions. Thermal stratification

was even more favoured by the river runoffs quite strong during the winter generating a haline stratification over a large part of the continental shelf.

The early spring phytoplankton blooms were important from early March on the shelf. Offshore the typical northward progression of high chlorophyll surface concentration occured during April.

At the start of the survey, stratification is then well established, with a thermocline well marked around a depth of 40m, but surface temperature remain relatively cold just above 14°C. The fresh weather conditions, even if no real wind event occurred during the survey, maintain this temperature between 14°C and 15°C during the whole survey, with not much evolution of the structure of the surface mixed layer.

The surface primary production remain high along the coast in the plumes. More offshore, the chlorophyll maxima are well marked around the thermocline.

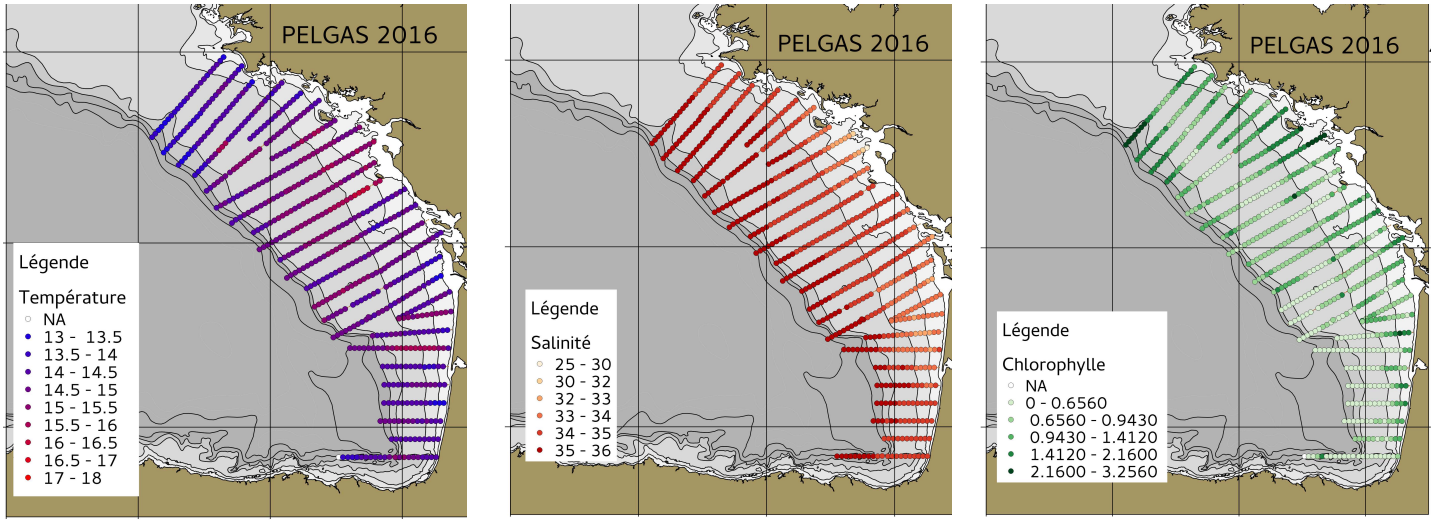


Figure 6.1. – Surface temperature, salinity and fluorescence observed during PELGAS16.

7. CONCLUSION

The Pelgas16 acoustic survey has been carried out with very 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 120 valid identification hauls instead of about 60 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 PELGAS16 were close to the average of the serie, with a surface temperature still relatively cold (just above 14°C) maintained by low atmospheric temperature and an absence of real wind event during the survey and some time before.

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. More offshore, the chlorophyll maxima are well marked around the thermocline.

The PELGAS16 survey observed a medium level of anchovy biomass (**89 727 tons**), which seems to be a medium biomass compared to previous year's, comparable to 2010 and far away from the 2015 biomass. Offshore, anchovies were so closed to the surface that we probably underestimate the abundance in that area, according to the quantity of eggs counted. 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.

The biomass estimate of sardine observed during PELGAS16 is **229 742 tons**, which constitutes a decrease of the last years level of biomass. It confirms that this specie shows a variable abundance in the bay of Biscay at this period. Last years showed a high level of biomass, and the current year a medium one, taken into account the probable light underestimate along the coast in the Northern part. Effectively, eggs were present along the coast without any energy attributed to sardine in this area. It must be explained by fish in very shallow waters, where Thalassa is not allowed to do acoustic acquisition, and then, to fish.

The proportion of age 1 (22% in number, and 13 % in mass) seems to be low compared to high recruitments observed during last 3 years. the relative high proportion of age 2 (39% in number and 44 % in mass) confirms the last year's good recruitment. 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 or other reasons not well known at this time. Old individuals (>5 years old) seems to be less an less present in the bay of Biscay, year after year.

Concerning the other species, mackerel was relatively well present this year compared to recent surveys, while horse mackerel seems to be one more time a bit more abundant for the fourth consecutive year, this index of biomass now reaching a medium level of biomass.