Working Document for ***WGHANSA***
Lisbon, 26-30 June.2018

Direct assessment of small pelagic fish by the PELGAS18 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 with two different echosounders, 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 2016). 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:*

Biomass and abundance at length of small pelagic fish during the PELGAS survey has been published in SEANOE: *.Doray Mathieu, Duhamel Erwan, Sanchez Florence, Grellier Patrick, Pennors Laurence, Petitgas Pierre (2018). Biomass and abundance at length of small pelagic fish estimated during the PELGAS survey in the Bay of Biscay in springtime . SEANOE .* http://doi.org/10.17882/53388

- 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 nautical 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.

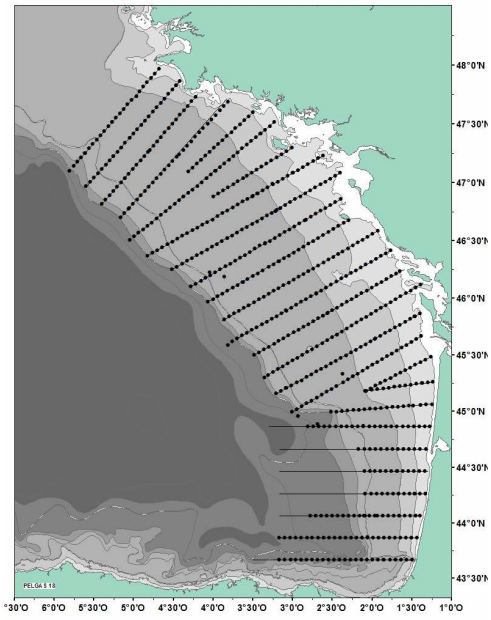


Fig. 1.1.1 - Transects prospected during PELGAS18 by Thalassa.

In 2018, as in previous surveys (since 2009), three modes of acoustic observations were used:

- 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.
- 1 horizontal echo-sounder on the starboard side for surface echo-traces
- this year, the broadband echosounder EK80 was installed and used

Energies and samples provided by all sounders were simultaneously visualised and stored using the 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 good meteorological conditions at the beginning of the survey.

Acoustic data were collected by R/V Thalassa along a total amount of 4836 nautical miles from which 1882 nautical miles on one way transect were used for assessment. A total of 30 077 fishes were measured (including 9752 anchovies and 6507 sardines) and 3 426 otoliths were collected for age determination (1 908 of anchovy and 1 518 of sardine).

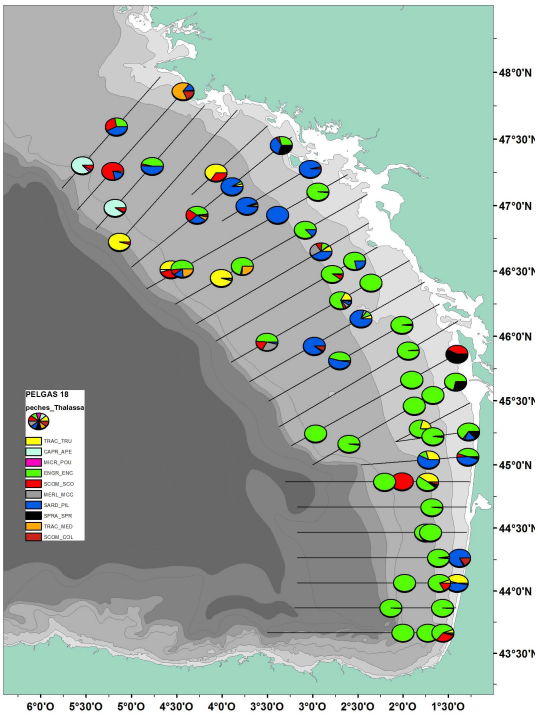


Fig. 1.1.2: Species distribution according to Thalassa identification hauls.

1.2. The consort survey

A consort survey is routinely organised since 2007 with French commercial vessels during 17 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 PELGAS18 survey:

Vessel	Gear	Period	Days at sea
Cintharth / Marilude	Pelagic pair trawl	05/05 to 13/05/2018	9
Papi Paul / Joker	Pelagic pair trawl	16/05 to 23/05/2018	8

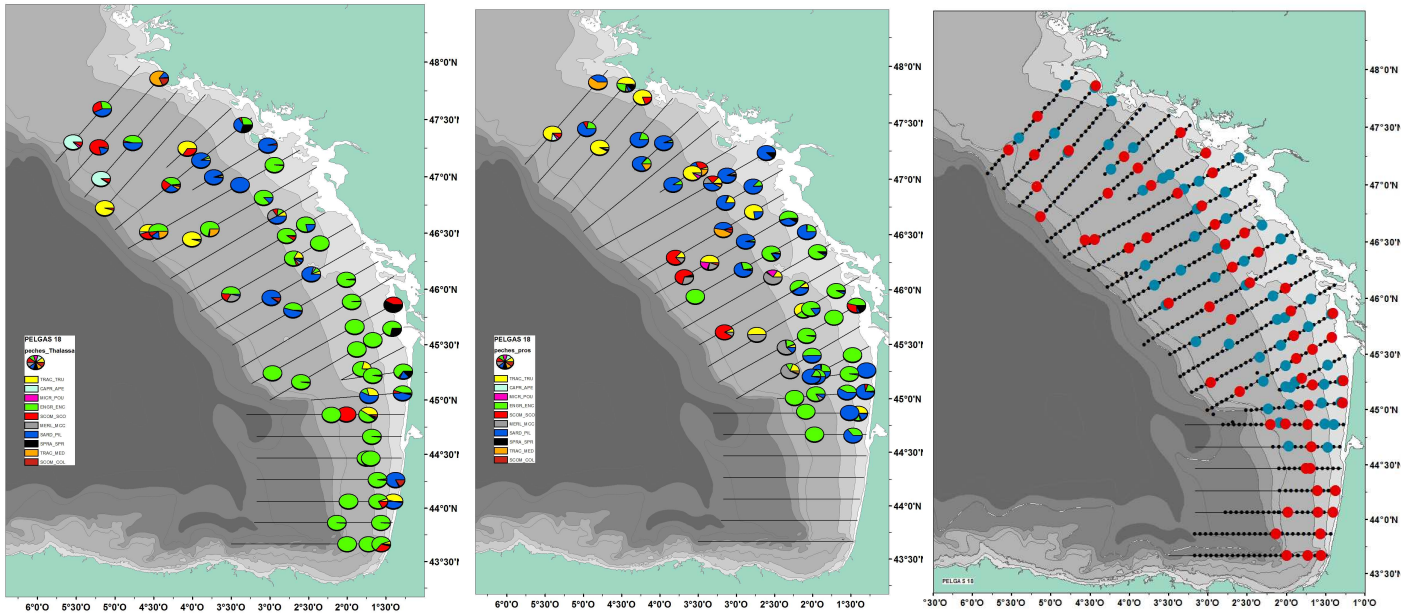
The regular transects network agreed for several years for Thalassa is 12 miles separated in parallel transects. Commercial vessels worked between standard transects and 2 NM northern. Sometimes, they carried out fishing operations on request. Their pelagic trawl was up to 25 m vertical opening and the 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 (200 otoliths of anchovy, 420 of sardine). A total of 11 518 fishes were measured onboard commercial vessels, including 3 053 anchovies and 3 049 sardines.

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

A total of 121 hauls (including 5 not valid) were carried out during the consort survey including 60 hauls by the R/V Thalassa and 61 hauls by commercial vessels.



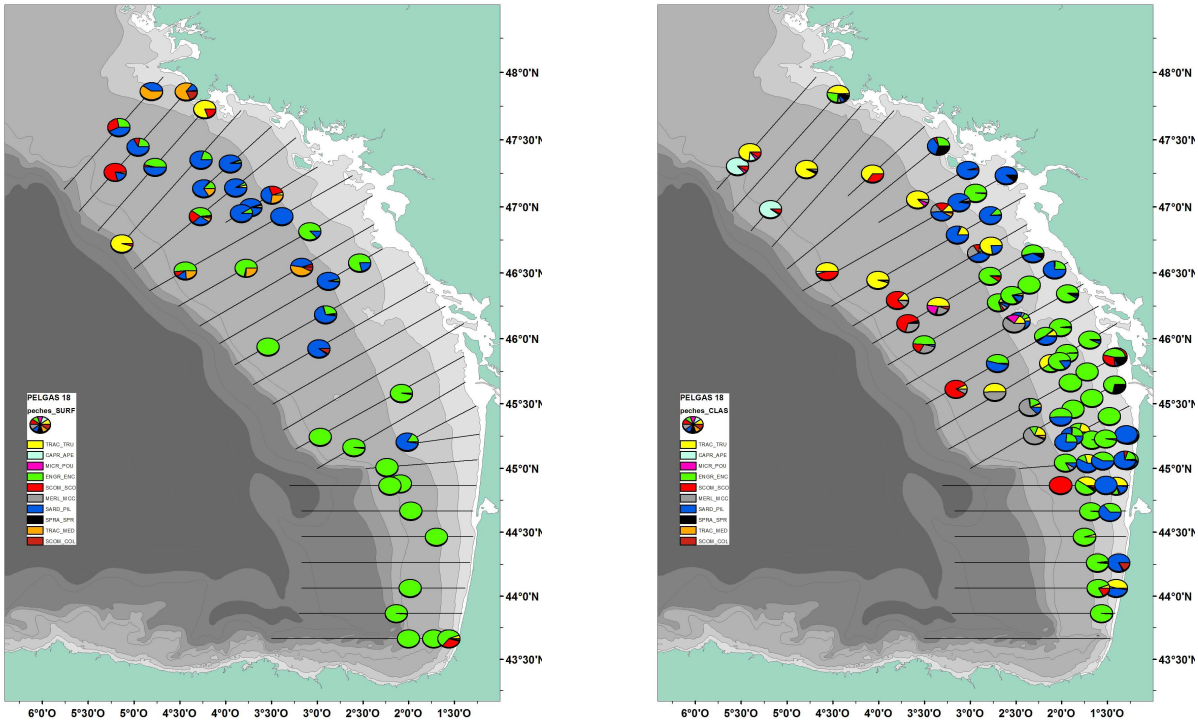
a) Thalassa (nb :60) *b) Commercial vessels (nb : 61)* *c) all fishing hauls (nb :121) Thalassa in red and commercial in blue*

Figure 1.2.2 : fishing operations carried out by Thalassa and commercial vessels during consort survey PELGAS18

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.

Table 1.2.3. : Number of fishing operations carried out by Thalassa and commercial vessels during consort survey PELGAS18

	thalassa	commercial	total
classic	35	41	76
surface	24	16	40
null	1	4	5
total	60	61	121



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 PELGAS18 survey

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 6 categories of echo-traces this year:

D1 – energies attributed to mackerel, chub mackerel, horse mackerel, Mediterranean horse mackerel blue whiting, hake, 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, chub mackerel, horse mackerel, mediterranean horse mackerel, and hake.

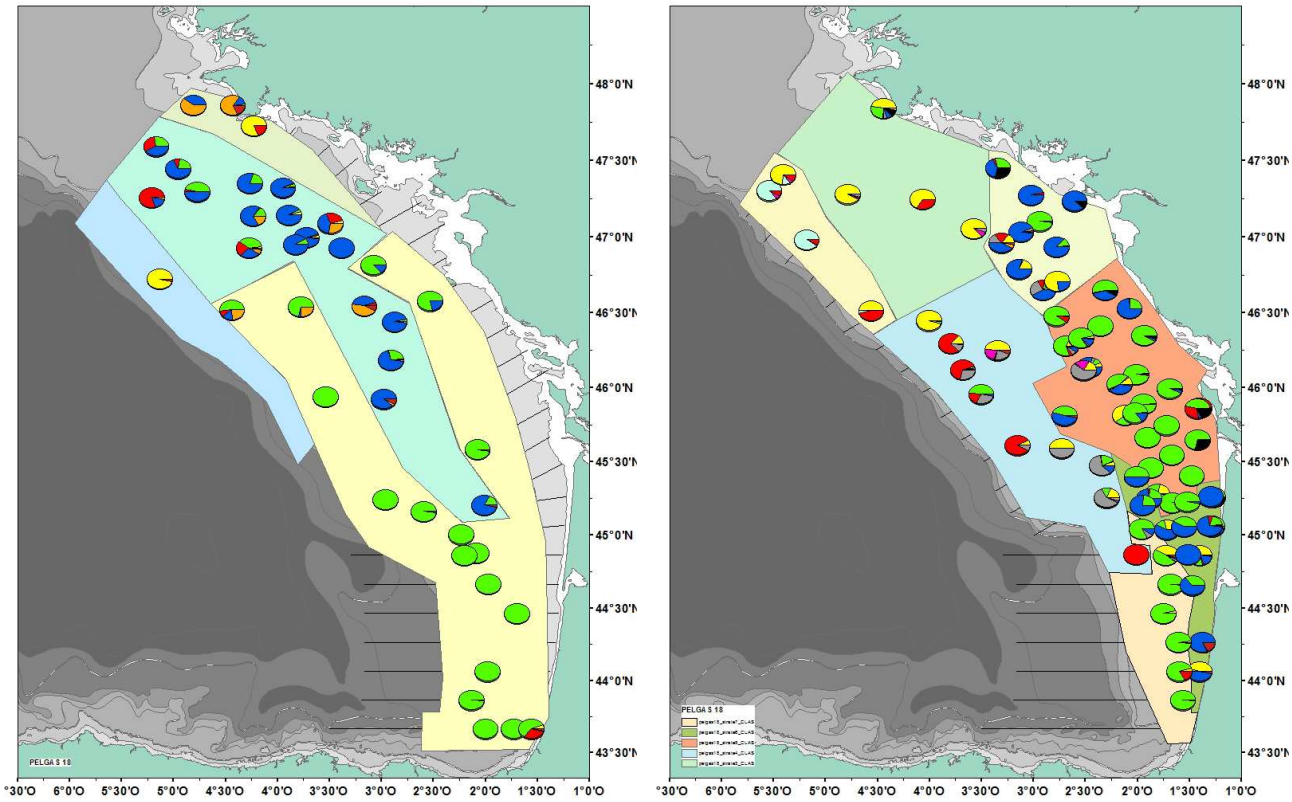
D4 – energies attributed to sardine, mackerel and anchovy corresponding to echoes very close to the surface. This year, horse mackerel was also allocated in this category

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

D9 – energies attributed exclusively to anchovy.

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 PELGAS18 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 was more abundant than last year and their abundance was estimated this year at a high level compared to the historical time series (around 185 000 tonnes). Strong densities were observed in the Gironde area. It must be noticed that we observed anchovy on every transects from the Spanish coast untill the North West of the Bay on Biscay.

Sardine was less present this year compared to 2017, mainly in coastal waters in the South (where an upwelling occured) and it was also present in variable densities in surface or close to the bottom on the shelfbreak in the North.

Even the densities were not that important, the presence at the surface of a mix sardine/anchovy/horse mackerel on the middle part of the Northern part of the bay (the great mud bank) must be noticeable. Northern than 46°30 N, no sardine or anchovy were detected at the shelfbreak

About other species, another characteristic of this year was that horse mackerel showed a increase of the biomass again, after 3 years of increasing and one of decreasing. The biomass reached again a medium level compared to the abundance calculated in recent years, but far away of the biomasses calculated at the beginning of the serie. Small horse mackerel were detected in the South until the Gironde, and large fishes were present dispersed closed to the surface in the North.

Mackerel appeared abundant this year, particularly in the middle of the bay of Biscay, and scattered close to the bottom in the Northern part.

Blue whiting was more or less absent from the bay of Biscay during Pelgas18

Table 2.3.1. Acoustic biomass index for the main species by strata during PELGAS18

	Classic	**Surface**	**total**
boarfish	3 378		3 378
anchovy	**160 906**	**24 619**	**185 524**
hake	42 797	1 256	44 053
blue whiting	2 560	941	3 501
sardine	**240 825**	**24 679**	**265 504**
chub mackerel	62 980	2 809	65 789
mackerel	403 564	14 990	418 555
sprat	16 321		16 321
mediterranean horse mackerel	22 739	8 752	31 491
horse mackerel	87 717	4 042	91 759

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**	**2017**	**2018**
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**	**134 500**	**185 524**
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*	0.073551	0.13	0.154339	0.0699
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**	**465 022**	**265 504**
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*	0.102315	0.08	0.060653	0.0620727
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**	**15 778**	**16 321**
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*	0.19534	0.44	0.52701	0.5879399
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**	**61 919**	**93 728**
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*	0.15498	0.3	0.288318	0.1443578
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**	**23 944**	**3 585**
CV BW	-	-	*0.386*	*0.131*	*0.202*	*0.593*	*0.210*	*0.147*	*0.253*	*0.219*	*0.074*			*0.1542*	*0.337606*	*0.223479*	*0.15*	*0.147063*	*0.30485*

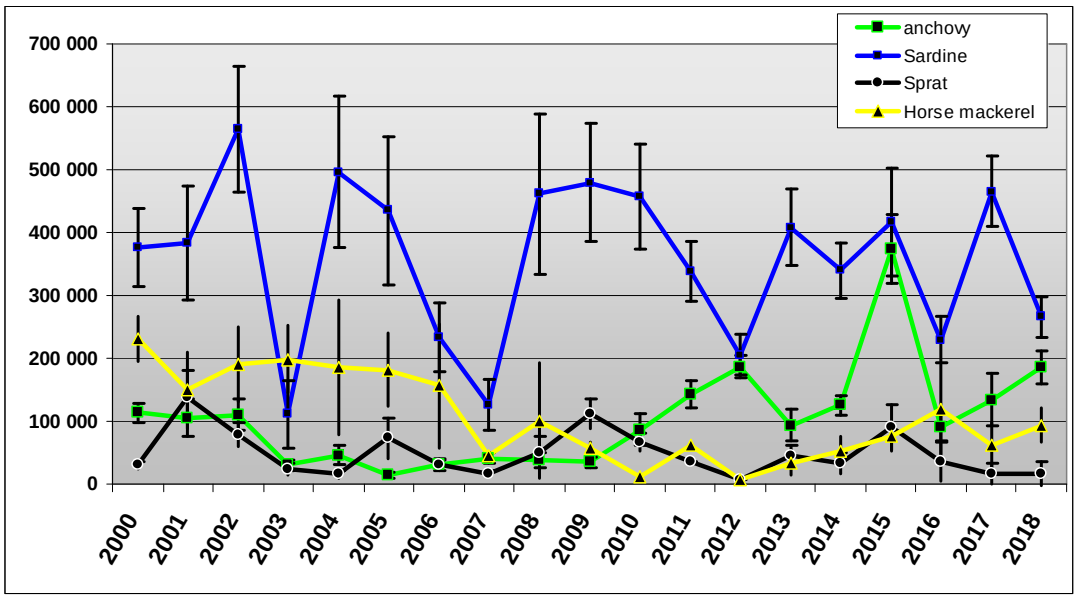


figure 2.3.3. – biomass estimates using Thalassa acoustic data along transects and all the consort identification fishing operations (Thalassa + commercial vessels) and associated coefficients of variation.

3. ANCHOVY DATA

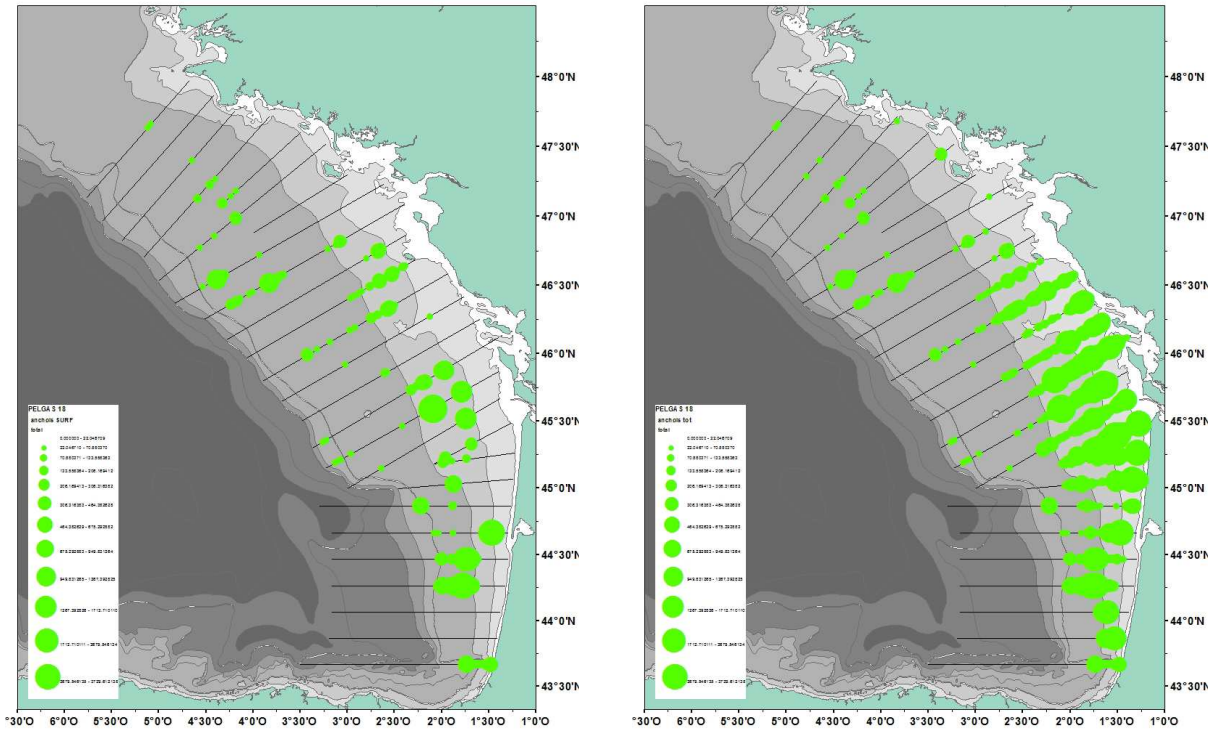
3.1. anchovy biomass

The biomass estimate of anchovy observed during PELGAS2018 is **185 500** tons. (table 2.3.2.), which seems to be a (very) high biomass compared to the serie, and comparable to 2012.

In the Gironde area, the configuration was usual in terms of energy compared to what was observed last years, with a high energy attributed to anchovy.

The one year old anchovies were mostly present front of the Gironde (in terms of energy and, as well, biomass) but they were still well present on the platform, till Brittany along the bathymetric line of 100m. The average size of one year old fish was comparable the average size in recent years (two years really differed from the average: 2012 and particularly 2015 where fishes were much smaller) but shows a clear decreasing trend, year after year. bigger (and older) fish appeared close to the surface in the north-West, at the surface on the great mud bank, mixed with sardine

One years old anchovies were also present, in lower quantities, mixed with older fish, even offshore.



Surface distribution Total distribution

Figure 3.1. – Anchovy distribution according to PELGAS18 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.

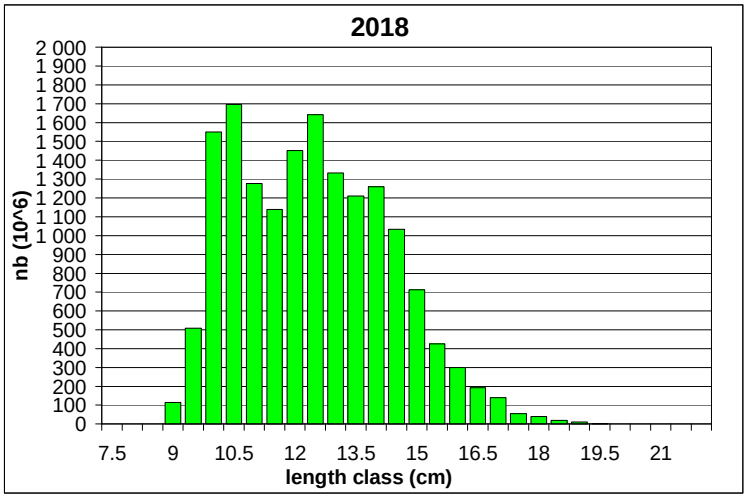


Figure 3.2: length distribution of global anchovy as observed during PELGAS18 survey

Globally we observe that length structure shows a classic distribution, with fish from 8 to 18 centimetres. It must be noticed that even if some individuals were small (less than 10 cm), almost all fishes were mature and in their spawning period. This observation on maturity contrasted with the 2015 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 40 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 (1908 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. PELGAS2018 anchovy Age/Length key.

Nombre de age	age				
length	1	2	3	4	Total
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	100.00%	0.00%	0.00%	0.00%	100.00%
10	100.00%	0.00%	0.00%	0.00%	100.00%
10.5	100.00%	0.00%	0.00%	0.00%	100.00%
11	98.77%	1.23%	0.00%	0.00%	100.00%
11.5	93.64%	6.36%	0.00%	0.00%	100.00%
12	92.80%	7.20%	0.00%	0.00%	100.00%
12.5	88.55%	11.45%	0.00%	0.00%	100.00%
13	84.83%	13.10%	2.07%	0.00%	100.00%
13.5	71.32%	27.94%	0.74%	0.00%	100.00%
14	39.16%	57.34%	3.50%	0.00%	100.00%
14.5	36.24%	62.42%	0.67%	0.67%	100.00%
15	17.68%	81.10%	1.22%	0.00%	100.00%
15.5	8.05%	87.92%	3.36%	0.67%	100.00%
16	4.55%	88.64%	6.06%	0.76%	100.00%
16.5	3.09%	86.60%	9.28%	1.03%	100.00%
17	0.00%	86.49%	9.46%	4.05%	100.00%
17.5	0.00%	72.34%	27.66%	0.00%	100.00%
18	0.00%	84.62%	7.69%	7.69%	100.00%
Total	52.78%	43.92%	2.88%	0.42%	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 2018 are shown in figure 3.3.3.

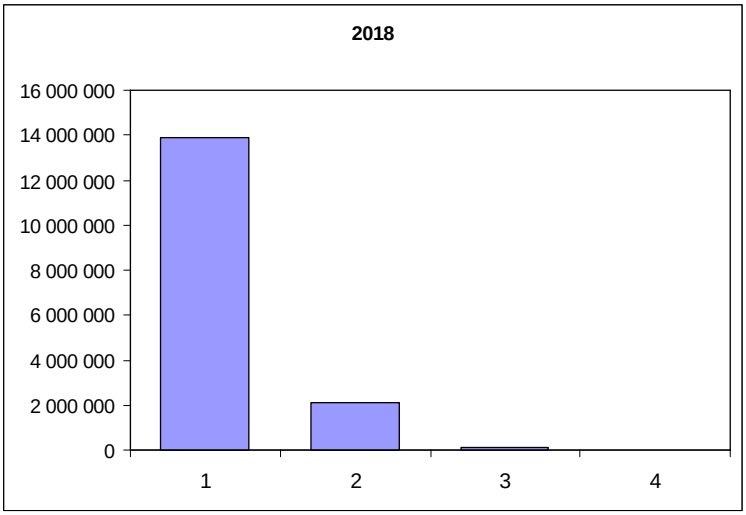


Figure 3.3.2– global age composition (numbers) of anchovy as observed during PELGAS18.

Looking at the numbers at age since 2000 (fig 3.3.3.), the number of 1 year old anchovies this year seems to be equivalent to 2011, 2012 or 2017, far away from the very best recruitment observed in 2015.

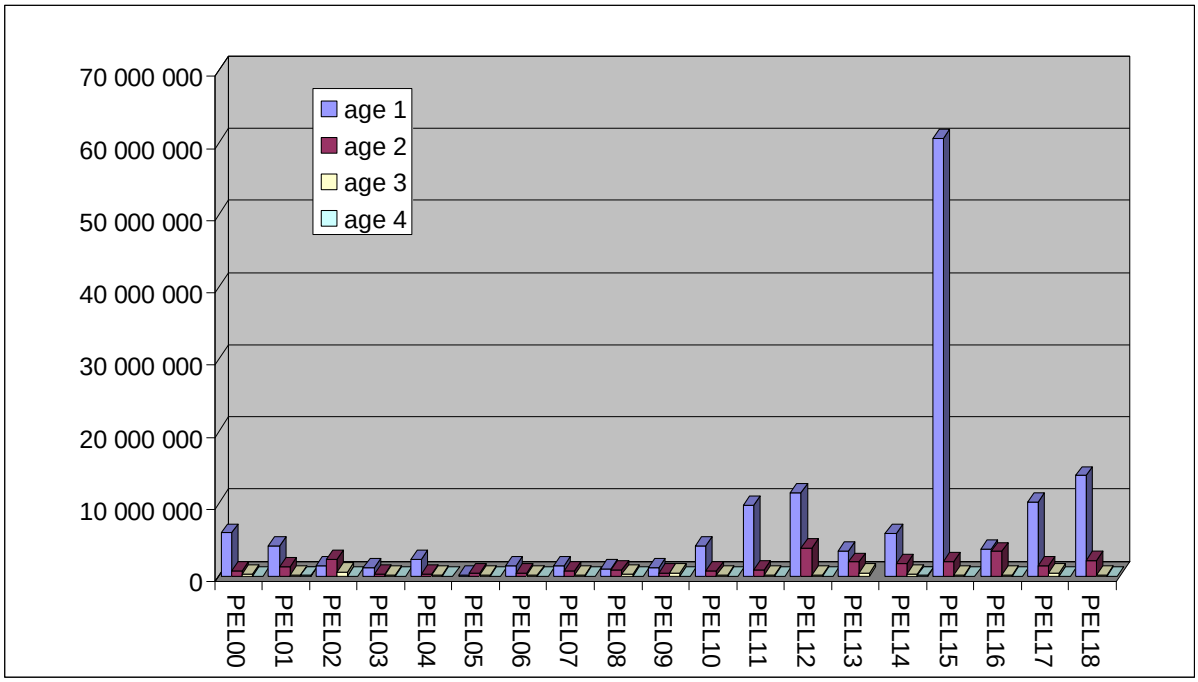


Figure 3.3.3 Anchovy numbers at age as observed during PELGAS surveys since 2000

The huge 2015 age class is not followed in 2016 and in 2017 as well. Once again, it could indicate that an overestimation occurred on the recruitment in 2015. Several investigation have been done to explain, without results for the time being.

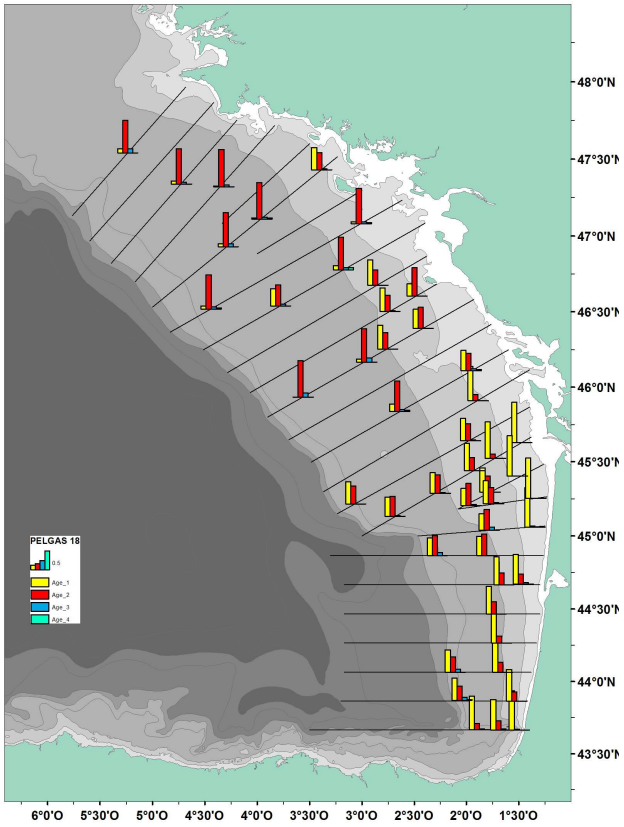


Figure 3.3.4 Anchovy proportion at age in each haul as observed during PELGAS18 survey (yellow = age 1, red = age 2).

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 recent years, as age 1 were present all over the area where anchovy was present. This one year old anchovy is almost pure front of the Gironde, and mixed with older individuals elsewhere except on the great mud bank (North-West of the bay of Biscay) where almost pure anchovy of age 2 appeared close to the surface.

	PEL18 - N - %
1	86.3%
2	13.1%
3	0.6%
4	0.05%

age	PEL18 - W - %
1	73.52%
2	25.10%
3	1.24%
4	0.14%

Figure 3.3.5 percentage by age of the Anchovy population observed during PELGAS18 in numbers (left) and biomass (right).

3.4. Weight/Length key

Based on 1921 weights of individual fishes, the following weight/length key was established (figure 4.5.):

$W = 0.003363L^{3.267418}$ with R2 = 0.9682 *(with W in grams and L in cm)*

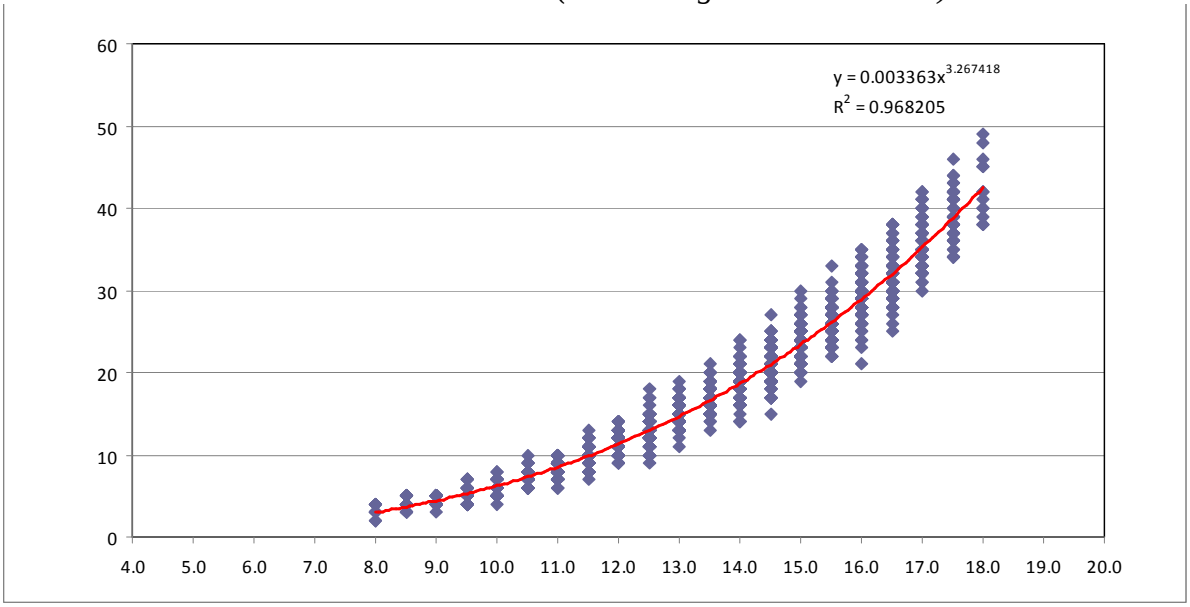


Fig. 3.4 – Weight/length key of anchovy established during PELGAS18

3.5. Mean Weight at age

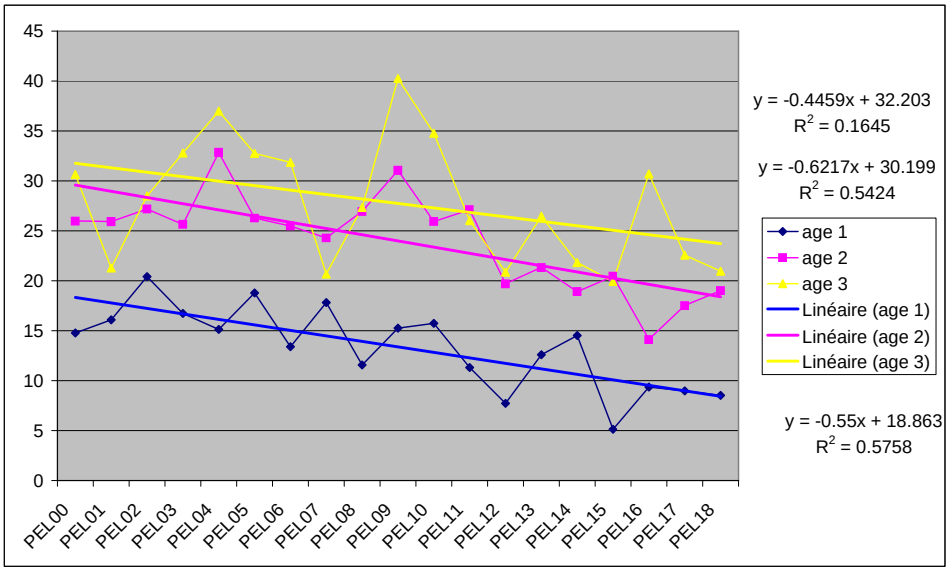


Fig. 3.5. – evolution of mean weight at age (g) of anchovy along PELGAS series

As previous years, we observe that globally the trend of the mean weight at age is a decrease. This trend is almost 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, 681 CUFES samples were collected and counted, 64 vertical plankton hauls and 97 vertical profiles with CTD were carried out. Eggs were sorted and counted automatically with the zoocam system, and staged during the survey.

2018, as from 2011, was marked by a large quantity of collected and counted anchovy eggs (Fig 3.6.2), with the same magnitude as previous values of the on-going decade. Their spatial pattern of distribution was quite usual, with major part of the abundance South of 46°N. However, eggs are also abundant on 3 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 almost everywhere. The weather and hydrology conditions were slightly delayed as compared to climatologies, which may explain the relatively lower spawning as compared to previous years. Spawning distribution was strongly dispersed, probably in relation to the large extension of the plumes over the shelf.

Spawning occured over the mid-shelf in the north, an area where no egg is observed usually.

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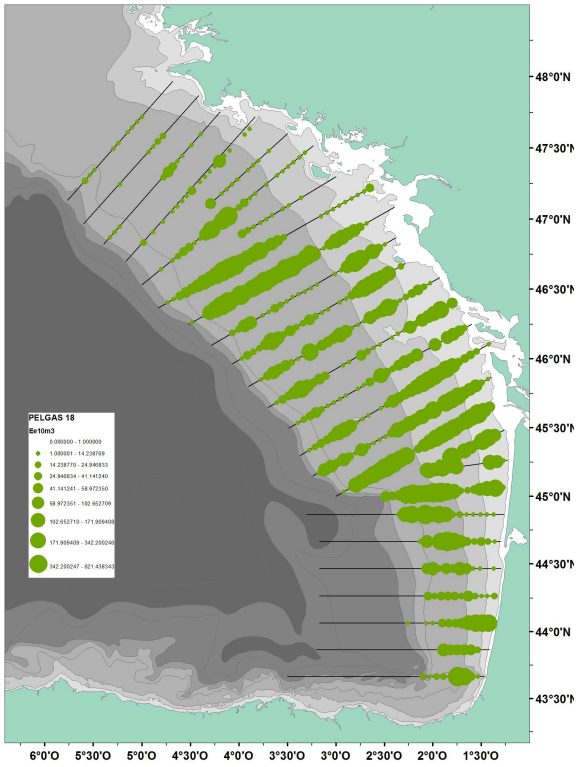

Figure 3.6.1 – Distribution of anchovy eggs observed with CUFES during PELGAS18.

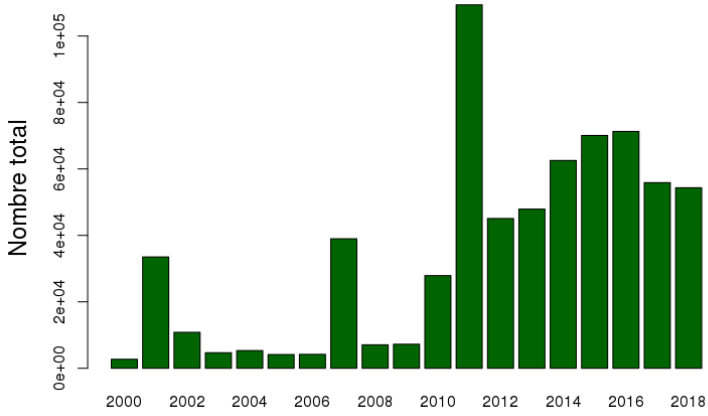

Figure 3.6.2 – Number of eggs observed during PELGAS surveys from 2000 to 2018

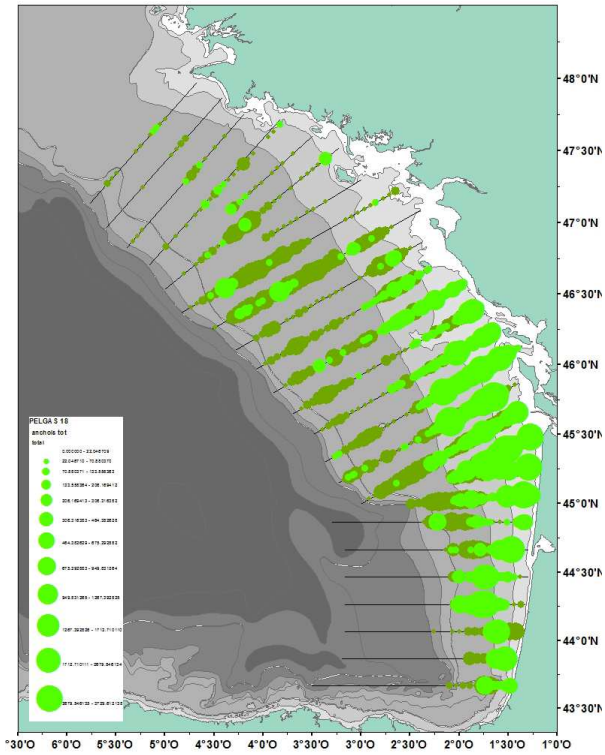

Figure 3.6.3 – Coherence between spatial distribution of adults and eggs. light green = biomass of adults per ESDU, dark green = eggs

We can see that globally the spatial distribution of eggs match with the adult's one along the coast. But more offshore between 45°N and 47°N, eggs were counted in important quantity with low echoes attributed to anchovy. It could be due to the presence of fish completely closed to the surface, in the blind layer of echosounders.

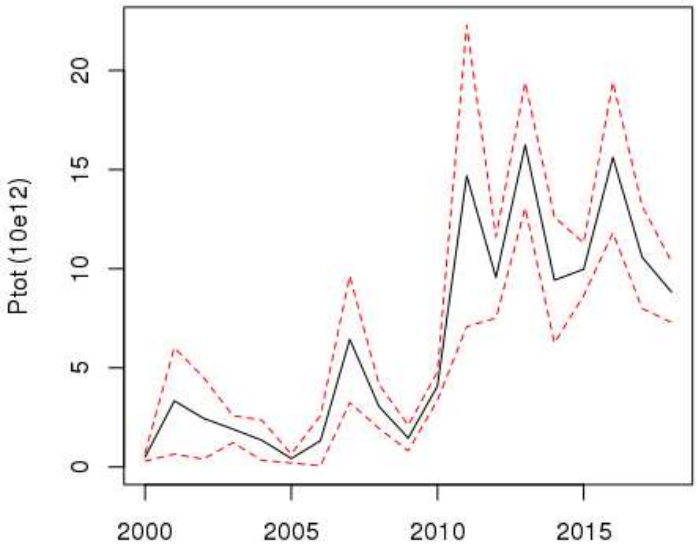

Figure 3.6.4 – total number of anchovy eggs corrected by the vertical model (Ptot)

4. SARDINE DATA

4.1. Adults

The biomass estimate of sardine observed during PELGAS18 is **265 500** tons (table 2.3.), which constitutes an decrease from last year, the biomass reaching a medium level of the PELGAS series. It must be noticed that the sardine abundance index is very variable, and it could be explained 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. 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. The small sardine was present this year, pure along the Lande's coast where an upwelling occurred, rarely mixed with other species along the coast. Sardine appeared also present close to the surface in the middle of the platform in the Northern part of the Bay of Biscay (on the great mud bank) which is not his regular habitat. Offshore, close to the surface, along the shelfbreak, sardine was totally absent this year.

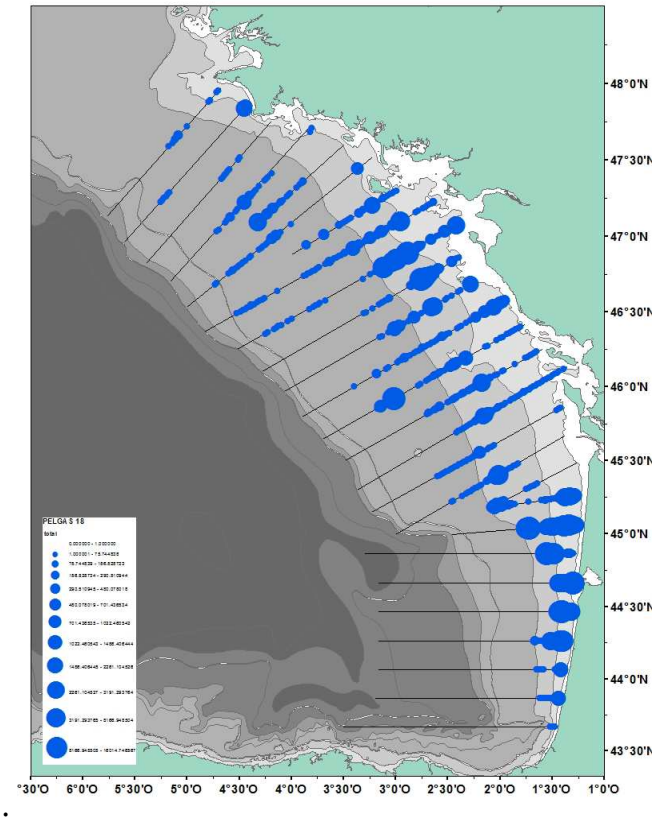

Figure 4.1.1 – distribution of sardine observed by acoustics during PELGAS18

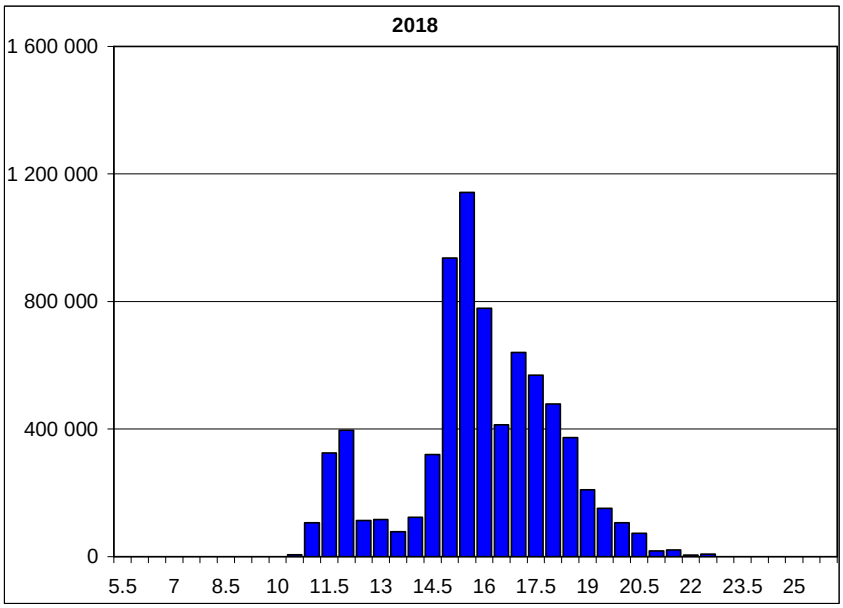

Figure 4.1.2. – length distribution of sardine as observed during PELGAS18

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.

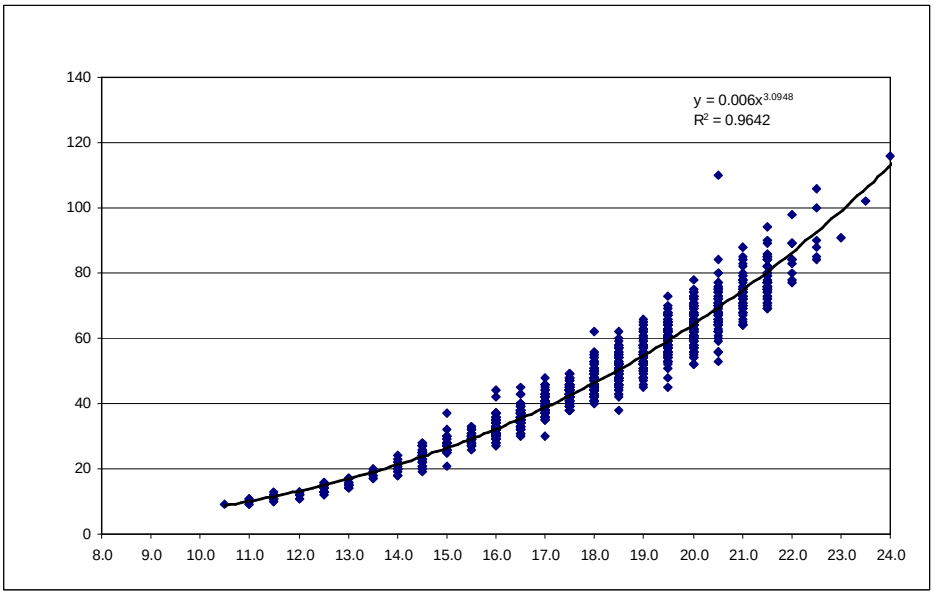

Figure 4.1.3 – Weight/length key of sardine established during PELGAS18

Nombre de age	age										
length	1	2	3	4	5	6	7	8	10	(vide)	Total
10.5	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
11	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
11.5	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
12	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
12.5	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
13	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
13.5	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
14	90.00%	10.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
14.5	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
15	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
15.5	98.72%	1.28%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
16	96.63%	3.37%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
16.5	58.43%	41.57%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
17	23.48%	75.65%	0.87%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
17.5	3.73%	94.03%	0.75%	1.49%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
18	0.00%	84.51%	10.56%	4.23%	0.00%	0.70%	0.00%	0.00%	0.00%	0.00%	100.00%
18.5	0.00%	64.86%	17.57%	14.86%	2.70%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
19	0.00%	53.33%	16.67%	23.33%	5.83%	0.83%	0.00%	0.00%	0.00%	0.00%	100.00%
19.5	0.00%	22.32%	20.54%	43.75%	11.61%	1.79%	0.00%	0.00%	0.00%	0.00%	100.00%
20	0.00%	9.65%	14.91%	50.88%	20.18%	3.51%	0.88%	0.00%	0.00%	0.00%	100.00%
20.5	0.00%	3.30%	3.30%	58.24%	26.37%	5.49%	1.10%	2.20%	0.00%	0.00%	100.00%
21	0.00%	0.00%	1.61%	40.32%	48.39%	9.68%	0.00%	0.00%	0.00%	0.00%	100.00%
21.5	0.00%	0.00%	2.13%	31.91%	46.81%	17.02%	2.13%	0.00%	0.00%	0.00%	100.00%
22	0.00%	0.00%	0.00%	33.33%	44.44%	11.11%	11.11%	0.00%	0.00%	0.00%	100.00%
22.5	0.00%	0.00%	0.00%	0.00%	66.67%	33.33%	0.00%	0.00%	0.00%	0.00%	100.00%
23	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
23.5	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
24	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100.00%
24.5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	100.00%
(vide)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Total	26.61%	37.81%	7.11%	17.19%	8.76%	2.04%	0.26%	0.13%	0.07%	0.00%	100.00%

Table 4.1.4 : sardine age/length key from PELGAS18 samples (based on 1518 otoliths from Thalassa and commercial vessels)

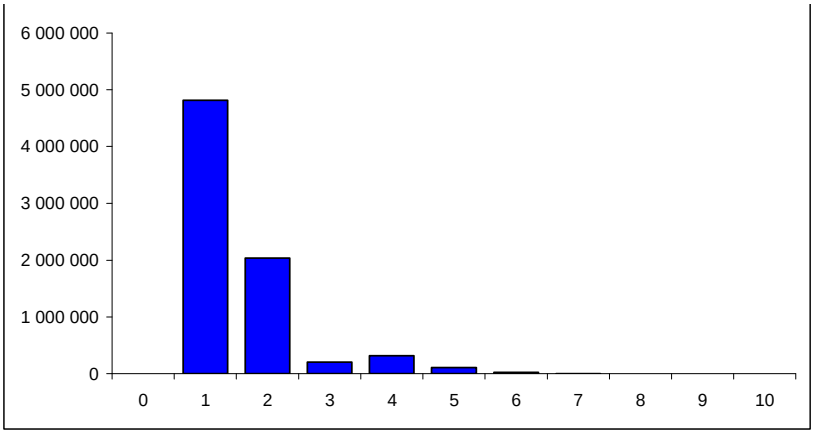

Figure 4.1.5.- Global age composition (nb) of sardine as observed during PELGAS 18

	PEL18 - N - %
1	64.14%
2	27.10%
3	2.68%
4	4.25%
5	1.44%
6	0.32%
7	0.04%
8	0.02%
10	0.00%

age	PEL18 - W- %
1	48.20%
2	36.20%
3	4.50%
4	7.46%
5	2.86%
6	0.66%
7	0.08%
8	0.05%
9	0.00%
10	0.00%

Figure 4.1.6 percentage by age of the sardine population observed during PELGAS18 in numbers (left) and biomass (right).

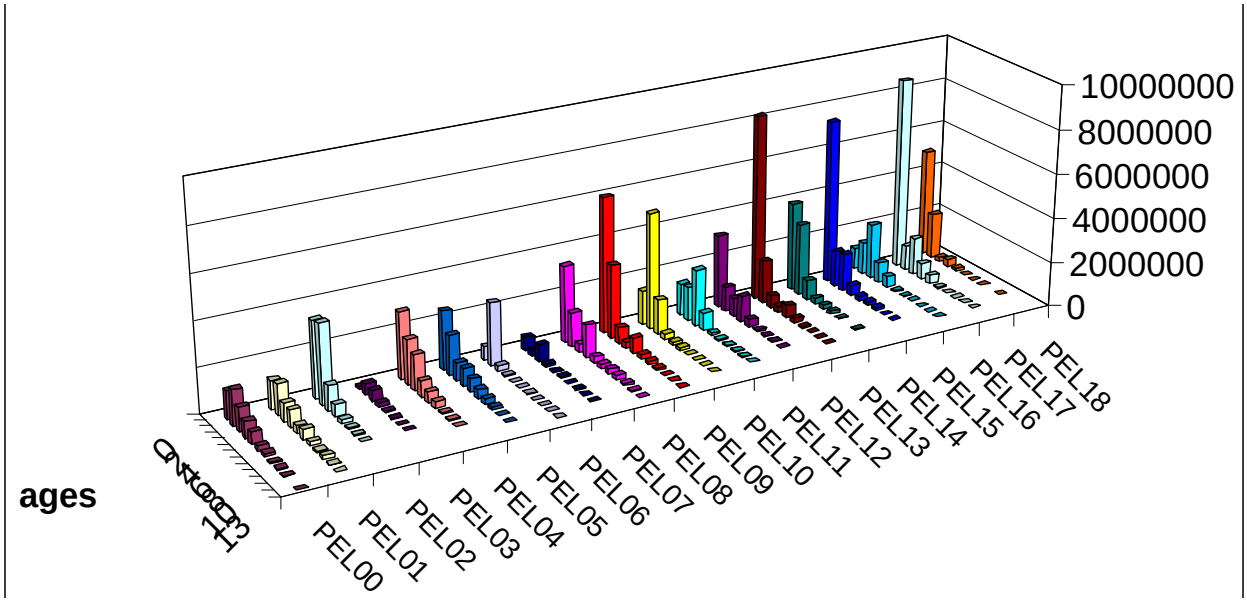

Figure 4.1.7- Age composition of sardine as estimated by acoustics since 2000

PELGAS serie of sardine abundances at age (2000-2018) 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, or the 2017 year class which seems to be the best recruitment ever and who seems to contribute not that much to the total abundance of sardine in 2018 in the bay of Biscay.

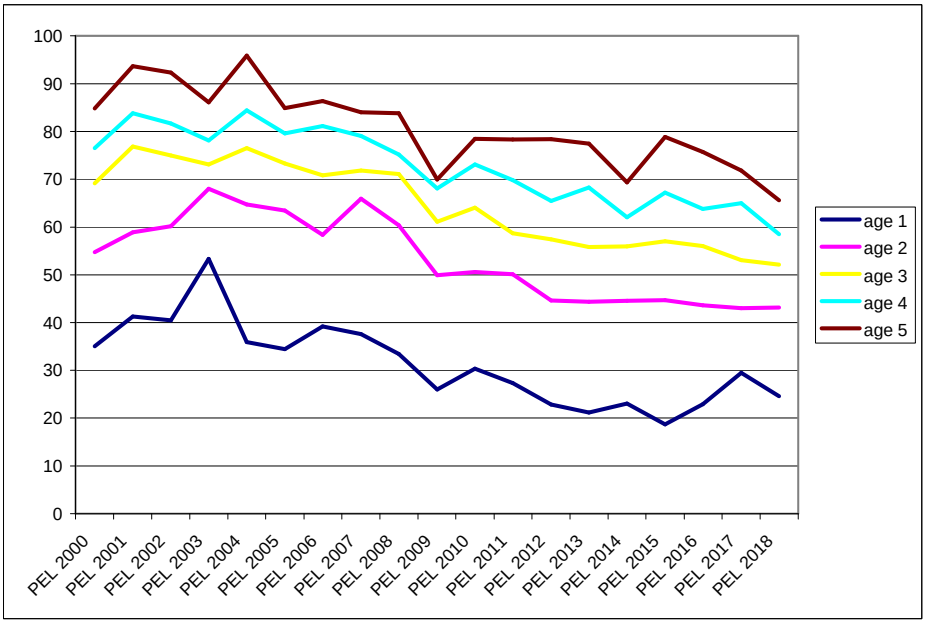

Figure 4.1.8- evolution of mean weight at age (g) of sardine along pelgas series

The PELGAS sardine mean weights at age series (Figure 4.1.8) shows a clear decreasing trend, whose biological determinant is still poorly understood. It must be noticed that after two years when the mean weight at age 1 seems increasing, 2018 shows a decrease again. For older ages, (particularly age 2), there is no real evolution since 2011.

Further work must be conducted to explore the causes of the fluctuation of mean weights at ages.

4.2. Eggs

The spatial pattern of sardine eggs overlaps with the one of anchovy, without any distribution along the shelf break this year.

Sardine egg production was quite low (third lowest of the series), despite the delayed warming and stratification more favorable to sardine. Sardine eggs were indeed really low in the south of the Bay, and did not extend much in the north excepts along the coast until the latitude of the Loire.

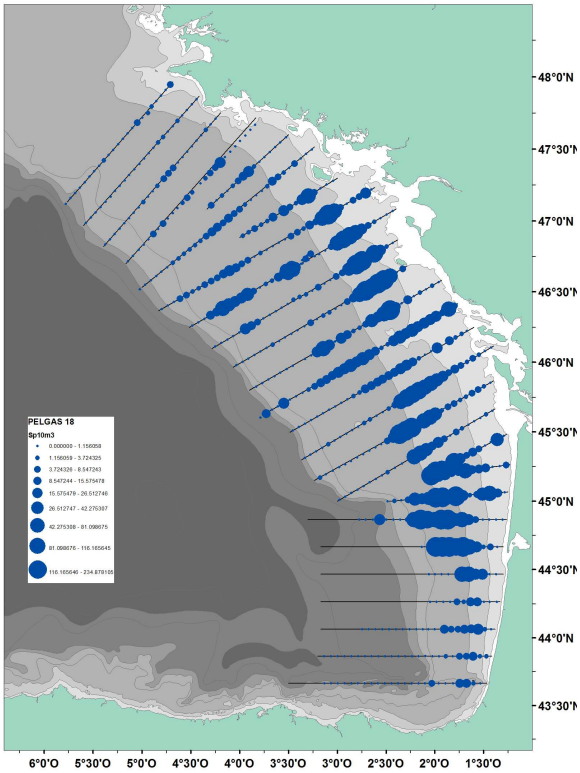

Figure 4.2.1. Distribution of sardine eggs observed with CUFES during PELGAS18.

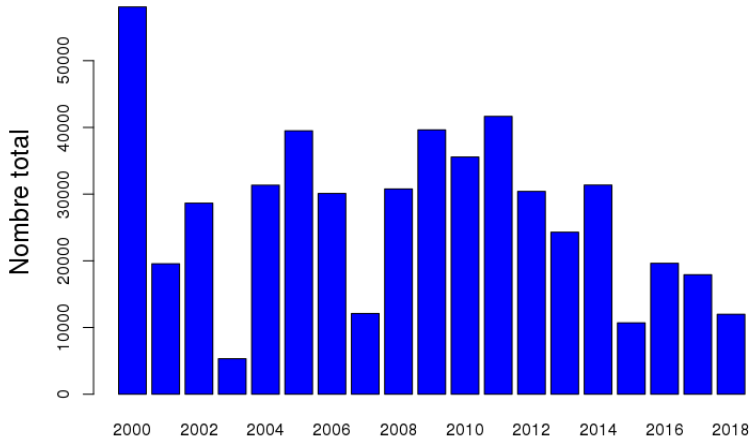

Figure 4.2.2. Number of eggs observed during PELGAS surveys from 2000 to 2018

2018 was marked by a low 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, except very few fishing hauls in the South along the coast where 1 year old sardine was present in a zone where an upwelling occured. This fish was just starting his maturation.

5. TOP PREDATORS

For the sixteenth 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.

A total of 270 hours of sighting effort were performed for 31 days (Figure 5.1.), with an average of 8 hours and 4à minutes of sighting effort per day. Weather conditions were globally very good with 86% of the time with good conditions (wind speed equal or less than 3 on the Beaufort scale).

During the survey, 4362 sightings of animals or objects were recorded. Seabirds constitute the majority of sightings (69%). Second most important sightings in numbers are litters drifting at sea (16%), then human activities (10 %). Cetaceans represents 5% of sightings (2% last year) and large fishes (sunfishes, sharks).

5.1 – Sighting effort and conditions

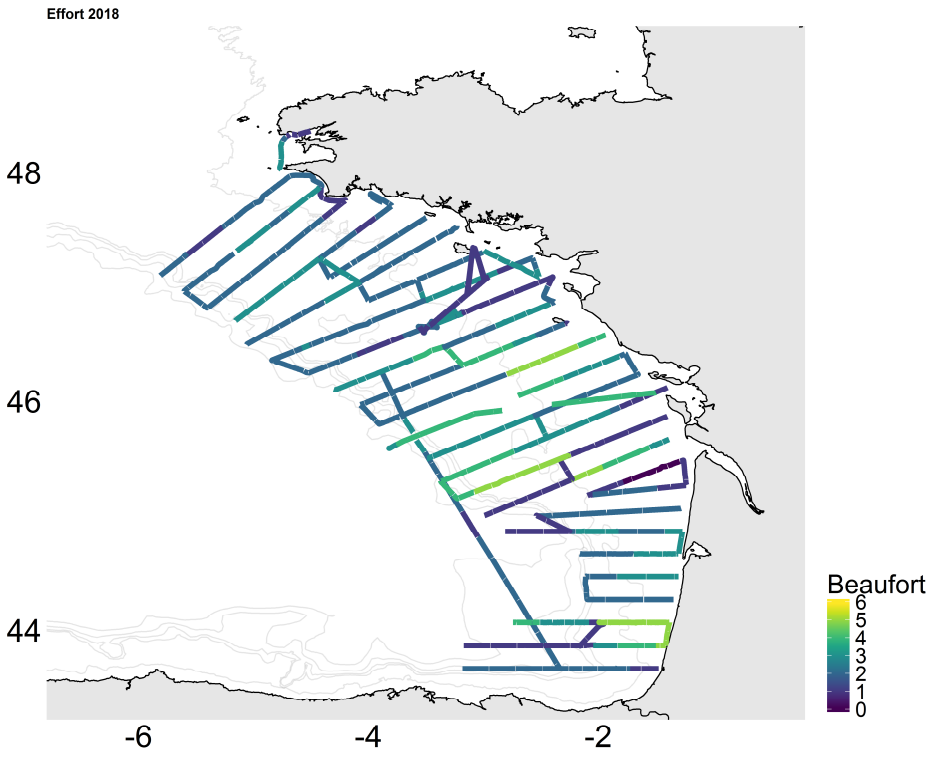

Figure 5.1. Sighting effort and conditions

The worst conditions were met in the central part of the bay of Biscay, and are mainly due to rain and fog. Globally, conditions of sightings during PELGAS2018 (including rain, fog and wind) were considered as very good.

5.2 – Birds

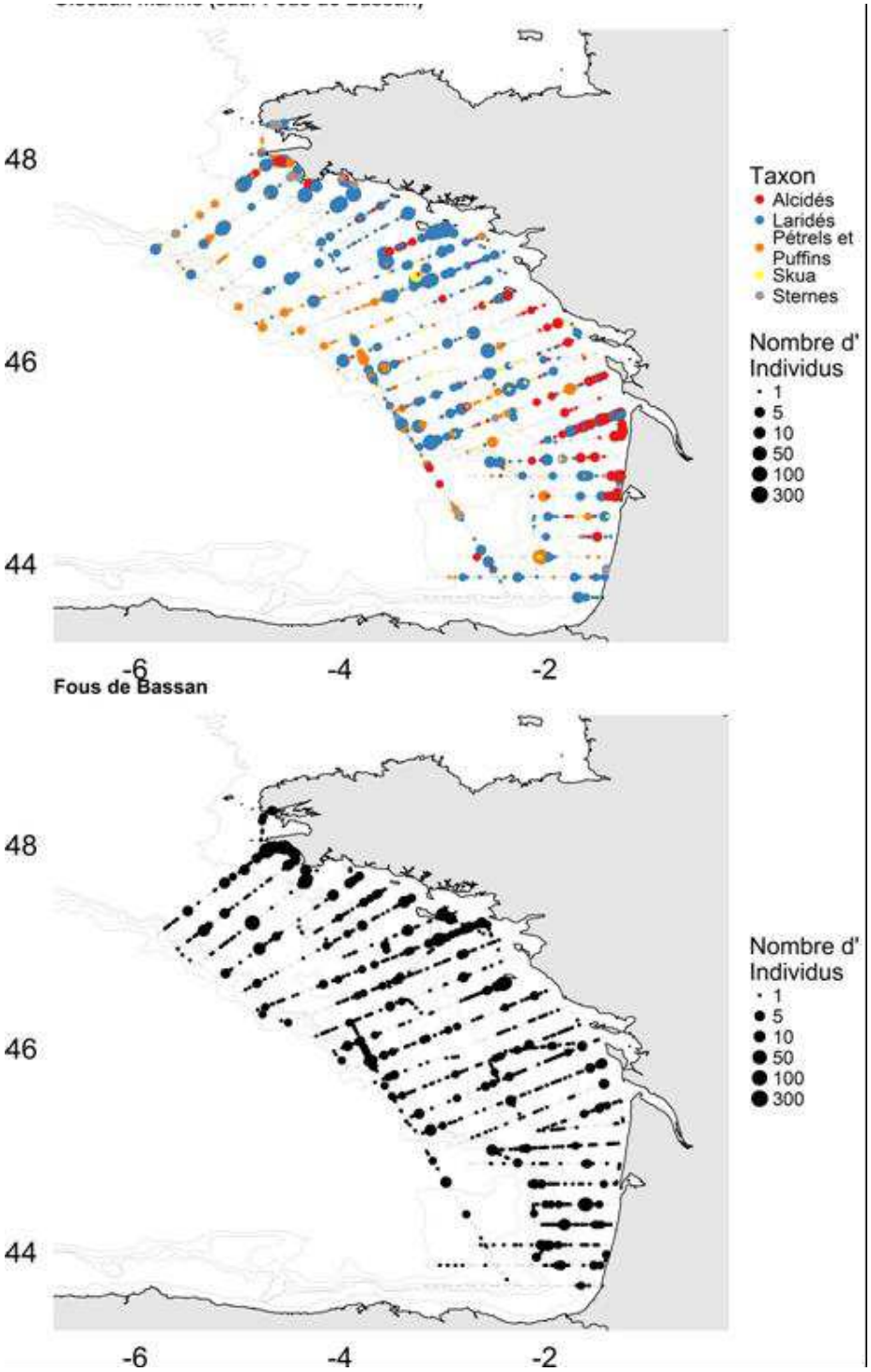

Figure 5.2. Distribution of birds observed during the PELGAS18 survey. On top : all marine birds without gannets. Bottom : gannets

Birds constitute the vast majority of sightings. Shorebirds and passerines accounted for less than 4% of bird sightings. 3009 sightings of seabirds were found all over the Bay of Biscay (Figure 5.2), divided into 26 identified species and a raw estimate of 7716 individuals (against 14 697 individuals in 2017), and constitutes a come back to the numbers observed until 2016.

Northern gannets accounted for 36% of all seabird sightings: its distribution is homogeneous across the Bay of Biscay.

The larids, principally including the sea gulls are mainly located (sometimes in very numerous groups) from the coast to the middle of the platform.

5.2 – Mammals

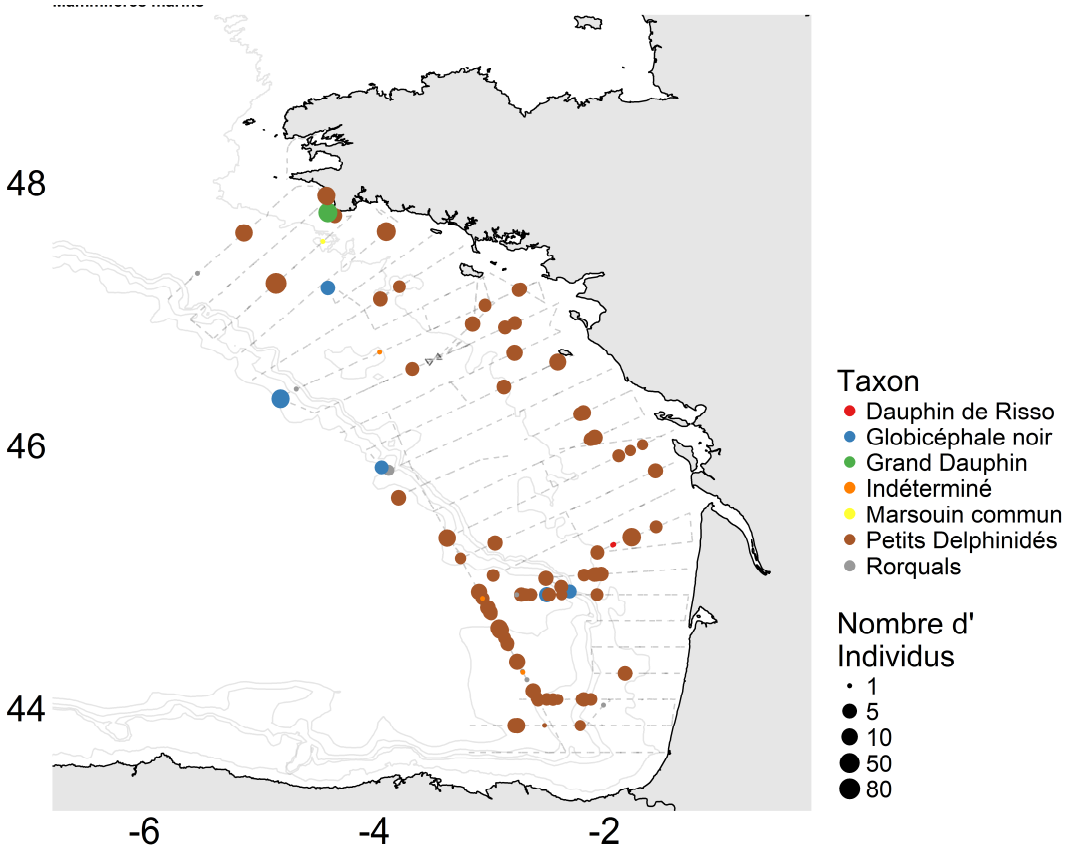

Figure 5.2. Distribution of mammals during the PELGAS18 survey.

A total of 188 sightings (against 88 last year) were recorded corresponding to a raw estimate of 794 individuals and 7 species of cetaceans clearly identified (Figure 5.2). 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.

The raw number of cetacean observed this years is similar as last year's number while the number of sightings strongly increased, because the most part of delphinids groups were constituted of 5 individuals or less.

Common dolphin is the most recorded species (74% of total observations, 629 individuals). Common dolphins were present on the continental shelf, particularly in the northern part of the Bay of Biscay. Offshore, there were located around the "fer à cheval" area.

No Striped dolphins were sighted this year again. However, few long-finned pilot whales were sighted on the continental slope in the central part of the Bay of Biscay and at the shelfbreak.

Very few bottlenose dolphins were detected this year (2 sightings), located close to the coast in the North of the bay of Biscay.

6. HYDROLOGICAL CONDITIONS

Winter 2017-2018 has been really humid with a lot of rainfall. Cumulated river discharges (fig 6.1) to the Bay of Biscay have been really large, in second place after 2001 when considering the time-period 2000-2018, and first for the Gironde only.

Winter was also quite windy like early spring, which did not allow real stratification setup before the survey despite some nice days in April. .

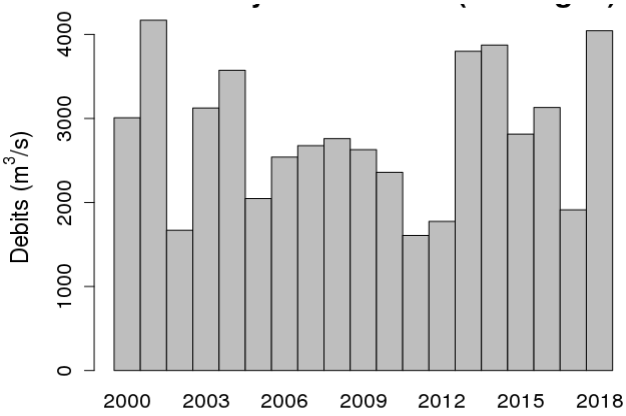

figure 6.1 cumulated river discharges from January to April

Strong river discharges contributed to the haline stratification and shelf enrichment though, which together permitted winter blooms during calm periods as early as February.

During the survey, weather was calm but fresh under a northern flux, before becoming really anticyclonic and warmer during the second leg. Warming and thermal stratification were slow in the beginning but then accelerated in the second fortnight of May.

Salinity was low over the whole shelf especially within the 100m isobath, with values often below 33psu. An upwelling is visible along the Landes coast under the influence of the wind from the north, with a signature of low temperature and higher salinity.

Phytoplanktonic production was continuously high during a large part of the survey, again under the influence of the large river discharges.

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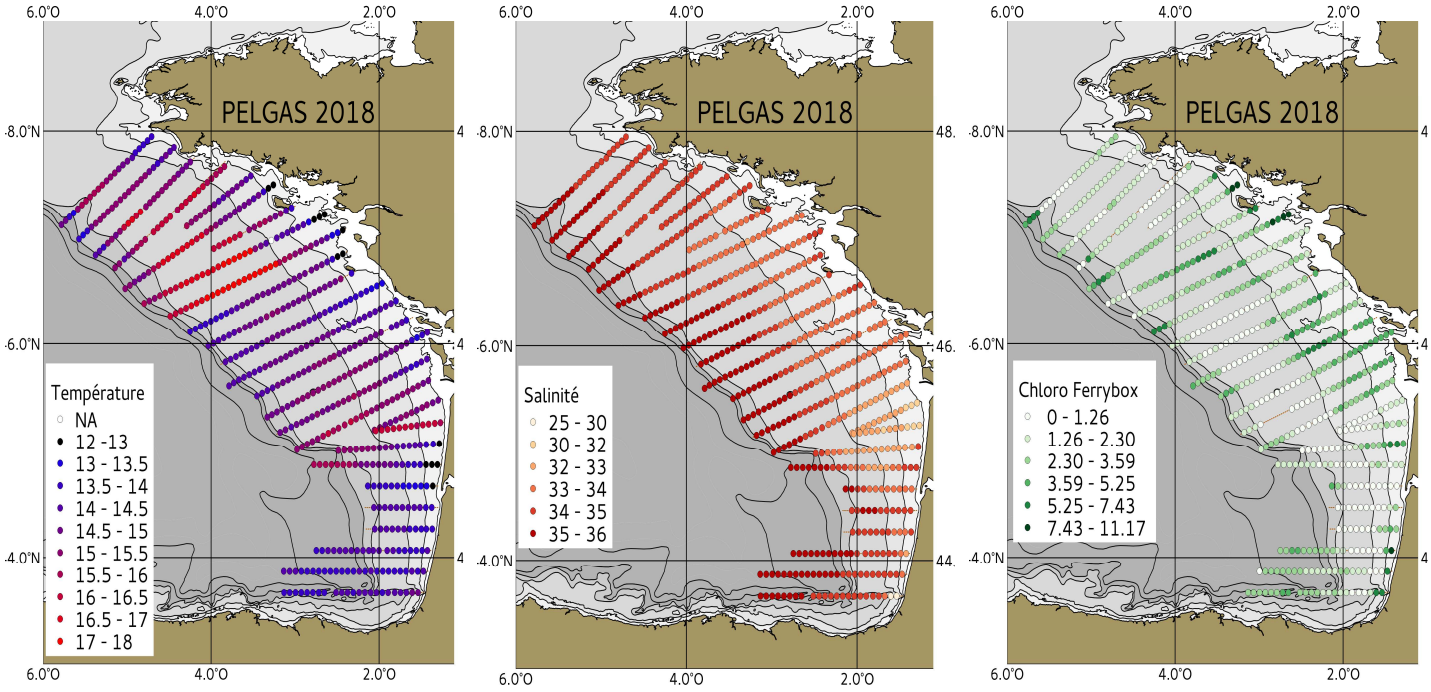

Figure 6.2. – Surface temperature, salinity and fluorescence observed during PELGAS18.

7. CONCLUSION

The Pelgas18 acoustic survey has been carried out with good weather conditions (low wind) 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 17 days provided about 120 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. Vessels (and the scientific observer onboard) are founded by EMFF (European Maritime and Ficheries Found) for the period 2017- 2019, with the financial help of "France Filière Pêche" which is a groupment of French fishing organisations.

Warming and thermal stratification were slow in the beginning but then accelerated in the second fortnight of May. Salinity was low over the whole shelf especially within the 100m isobath, with values often below 33psu. This low salinity is due to a very rainy winter before the survey. Cumulated river discharges to the Bay of Biscay have been really large, in second place after 2001 when considering the time-period 2000-2018

The PELGAS18 survey observed a relatively high level of anchovy biomass (**185 500 tons**), which seems to be higher to previous year, comparable to 2012 and far away from the 2015

biomass (which was probably overestimated but it is not explained for the time being). Offshore, anchovies were present closed to the surface in the South. As previous years, we observe that globally the trend of the mean weight at age is a decrease. This trend is globally 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 PELGAS17 is **265 500** tons, which constitutes an decrease from last year, the biomass reaching a medium level of the PELGAS series.. It confirms that this specie shows a variable abundance in the bay of Biscay at this period.

The population of sardine is still very young, with an age distribution largely dominated age 1 and 2 groups (sum about 91% in numbers). 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 sprat and blue whiting were rather absent in the surveyed area.