MULTIDISCIPLINARY ACOUSTIC SURVEY PELACUS0314: PRELIMINARY RESULTS ON FISH ABUNDANCE ESTIMATES AND DISTRIBUTION

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Abstract

PELACUS 0314 was characterised by relative stable weather conditions along the surveyed area. Besides, there was an important increase in backscattering energy as compared with the previous year. This resulted in an increase of the biomass estimated for the majority of the fish species, but still sardine is at lowest productivity ever recorded. Good recruitment would be observed in horse mackerel, but for the rest of the fish species, no strong signals for age group 1 have been detected.

The reasons for this increase would be related to the weather stability which could have increased the fish availability either for a change in the behaviour (i.e. spatial pattern distribution) or for an increase in the food availability. This is relevant accounting the increase of the occurrence of mackerel subsurface layers observed this year. As PELACUS is a multidisciplinary survey series (we collect environmental and biological ancillary information, stomach contents, including CTD cats, plankton tows or continuous records of plankton, eggs, S, T and flourometry), we will try to explain this change of behaviour. Our main hypothesis is that these species could follow mackerel when is undertaking vertical migration, probably related with the spawning activity, just for feeding eggs and, therefore, changing the expected schooling behaviour by the dispersed one, used during the feeding activity.

Material and methods

The methodology was similar to that of the previous surveys (see Iglesias et al. 2010 for further details). Survey design consisted in a grid with systematic parallel transects with random start, separated by 8 nm, perpendicular to the coastline, covering the continental shelf from 40 to 1000 m depth and from Portuguese-Spanish border to the Spanish -French one. (Figure 1)

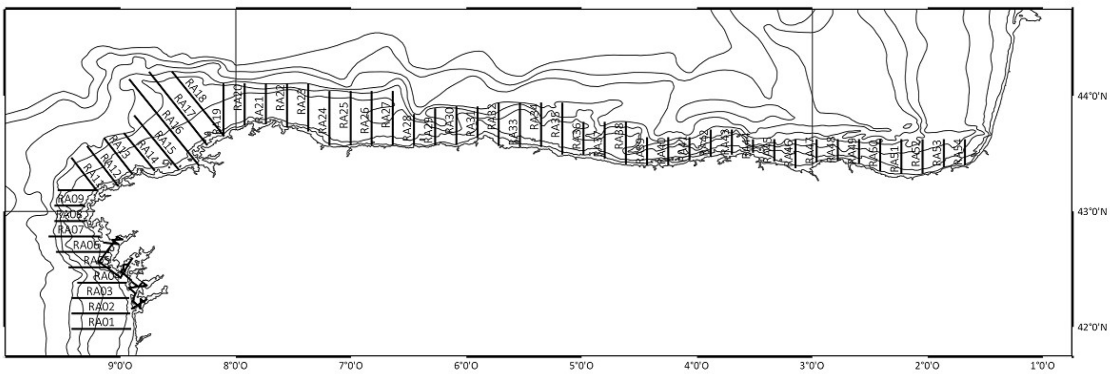


Figure 1 Survey track

The backscattering acoustic energy from marine organisms is measured continuously during daylight. Pelagic trawls are carried out whenever possible to help identify the species (and size classes) that reflect the acoustic energy. A continuous underwater fish egg sampler with an internal water intake located at 5 m depth is used to sample the composition of the ichthyoplankton while trained observers record marine mammal, seabird, floating litter and vessel presence and abundance. At night, data on the hydrography and hydrodynamics of the water masses are collected via the deployment of rosettes and conductivity, temperature and depth sensors. Information on the composition, distribution and biomass of phytoplankton and zooplankton is derived from the analyses of samples taken by plankton nets.

Acoustic equipment

Acoustic equipment consisted on a Simrad EK-60 scientific echosounder, operating at 18, 38, 120 and 200 kHz. All frequencies were calibrated according to the standard procedures (Foote et al 1987). The elementary distance sampling unit (EDSU) was fixed at 1 nm. Acoustic data were obtained only during daytime at a survey speed of 8-10 knots. Data were stored in raw format and post-processed using SonarData Echoview software (Myriax Ltd.) (Higginbottom et al , 2000). All echograms were first scrutinized and also background noise was removed according to De Robertis and Higginbottom (2007). Fish abundance was calculated with the 38 kHz frequency as recommended at the PGAAM (ICES 2002), although echograms from 18, 120 and 200 kHz frequencies were used to visually discriminate between fish and other scatter-producing objects such as plankton or bubbles, and to distinguish different fish species according to the strength of their echo at each frequency. The 18, 120 and 200 kHz frequencies have been also used to create a mask allowing a better discrimination between fish species and plankton. The threshold used to scrutinize the echograms was –70 dB. The integration values were expressed as nautical area scattering coefficient (NASC) units or s_A values (m^2 nm^{-2}) (MacLennan *et al*., 2002).

NASC Allocation

Two pelagic gears have been used to identify the species and size classes responsible for the acoustic energy detected and to provide samples. Choice of net was also dependant on the availability of enough unobstructed ground for the net to be deployed and recovered and for effective fishing to occur. Haul duration is variable and ultimately depends on the number of fish that enters the net and the conditions where fishing takes place although a minimum duration of 20 minutes is always attempted. The quality of the hauls for ground-truthing of the acoustic data was classified on account of weather condition, haul performance and the catch composition in numbers and the length distribution of the fish caught as follows:

	0	**1**	**2**	**3**
Gear performance Fish behaviour	Crash	Bad geometry Fish escaping	Bad geometry No escaping	God geometry No escaping
Weather conditions	Swell >4 m height Wind >30 knots	Swell: 2 -4 m Wind: 30-20 knots	Swell: 1-2m Wind 20-10 knots	Swell <1 m Wind < 10 knots
Fish number	total fish caught <100	Main species >100 Second species <25	Main species > 100 Second species< 50	Main species > 100 Second species > 50
Fish length distribu-tion	No bell shape	Main species bell shape	Main species bell shape Seconds: almost bell shape	Main species bell shape Seconds: bell shape

Hauls considered as the best representation of the fish community for a specific area were used to allocate NASC of each EDSU within this area. This process involved the application of the Nakken and Dommasnes (1975, 1977) method for multiple species, but instead of using the mean backscattering cross section, the full length class distribution (1 cm length classes) has been used, as follows:

$$s_{A_i} = s_A \frac{w_{li} \cdot \sigma_{bs}}{\sum_{li} w_{li} \cdot \sigma_{bs}}$$

where w_{li} is the proportion in number of *l* length class and species *i* in the hauls, and σ_{bs} is its correspondent proportion of backscattering cross section. The target strength (TS) is also taken into account as follows:

$$\sigma_{bs} = 10^{TS/10} \quad \text{(in dB)}$$

This is computed from the formula TS =20 $\log L_T + b_{20}$ (Simmonds and MacLennan, 2005), where L_T is the length class (0.5 cm). The b_{20} values for the most important species present in the surveyed area are shown in following table:

Table 1.- b_{20} values from the length target strength relationship of the main fish species assessed in PELACUS survey (WHB is blue whiting; MAC-mackerel; HOM- horse mackerel; PIL-sardine; JAA-blue jack mackerel (Trachurus picturatus); BOG-bogue (Boops boops); MAS-chub mackerel (Scomber colias); BOC-board fish (Capros aper); and HMM-Mediterranean horse mackerel (Trachurus mediterraneus))

Species	**WHB**	**MAC**	**HOM**	**PIL**	**JAA**	**ANE**	**BOG**	**MAS**	**BOC**	**HMM**
b_{20}	-67.5	-84.9	-68.7	-72.6	-68.7	-72.6	-67.0	-68.7	-72.6	-68.7

In addition and according with Fässler et al (2013) a new b_{20} = -66.20 value for boarfish was also used.

When possible, direct allocation was also done, accounting for the shape of the schools and also the relative frequency response (Korneliussen and Ona, 2003, De Robertis et al, 2010).

Echointegration estimates

Once backscattering energy was allocated to fish species, the spatial distribution for each species was analysed taking into account both the NASC values and the length frequency distributions (LFD) to provide homogeneous assessment polygons. These are calculated as follows: an empty track determine the along-coast limit of the polygon, whilst three consecutive empty ESDU determine a gap or the across-coast limit. Within each polygon, the LDF is analysed.

LFD were obtained for all positive hauls for a particular species (either from the total catch or from a representative random sample of 100-200 fish). For the purpose of acoustic assessment, only those LFD which were based on a minimum of 30 individuals were considered. Differences in probability density functions (PDF) were tested using Kolmogorov-Smirnov test. PDF distributions without significant differences were joined, providing a homogeneous PDF strata. Spatial distribution was then analysed within each stratum and finally mean s_A value and surface (square nautical miles) were calculated using a GIS based system. These values, together with the length distributions, are used to calculate the fish abundance in number as described in Nakken and Dommasnes (1975). Numbers were converted into biomass using the length weight relationships derived from the fish measured on board. Biomass estimation was carried out on each strata (polygon) using the arithmetic mean of the backscattering energy (NASC, s_A) attributed to each fish species and the surface expressed in square nautical miles. For purposes of comparison, results are given by ICES Sub-Divisions (IXaN, VIIIcW, VIIIcEw , VIIIcEe and VIIIb)

Otoliths are taken from anchovy, sardine, horse mackerel, blue whiting, mackerel and hake (*Merluccius merluccius*) in order to determine age and to obtain the age-length key (ALK) for each species and area.

CUFES counts

Samples from CUFES are collected every three nmi while acoustically prospecting the transects. Once the sample is taken it is fixed in a buffered 4% formaldehyde solution. Anchovy and sardine eggs are sorted out and counted before being preserved in the same solution. The remaining ichthyoplankton (other eggs and larvae) are also preserved in the same way.

Plankton and hydrological characterisation

Continuous records of SSS, SST and flourometry are taken using a SeaBird Thermosalinograph coupled with a Turner Flourometer. Plankton and CTD and bottle rosette for water samples casts are performed at night. Five stations are placed over the transects, which are those of the acoustic prospection but that are extended onto open waters until the 1000-2000 m isobaths. The stations are evenly distributed over the surveyed area at a distance of 16-24 nmi.

Plankton was sampled using several nets (Bongo, WP2 and CalVet). Fractionated dried biomass at 53-200, 200-500, 500-1000 and >2000 µm fractions was calculated together with species composition and groups at fixed strata from samples collected at the CTD+bottle rosette carousel (pico and nanoplankton, microplankton and mesozooplankton). For this purpose, FlowCAM, LOPC and ZooImage techniques were used.

Water samples were stored at -20°C for further dissolved nutrients analysis (NO_3, NO_2, P, NH_4^+, SiO_4).

Top predator observations

Three observers placed above the bridge of the vessel at a height of 16 m above sea level work in turns of two prospecting an area of 180° (each observer cover a field of 90°). Observations are carried out with the naked eye although binoculars are used (7x50) to confirm species identification and determine predator behaviour. Observations are carried out during daylight while the vessel prospects the transects and while it covers the distance between transects at an average speed of 10 knots. Observers record species, number of individuals, behaviour, distance to the vessel and angle to the trackline and observation conditions (wind speed and direction, sea state, visibility, etc.). Observers also record presence, number and type of boats and type, size and number of floating litter. The same methodology is used on the PELGAS surveys and both observer teams shared a common database.

Centre of gravity

For each main specie, a centre of gravity (Woillez et al. 2007) was calculated as a weighted average of each sample location (allocated NASC value as weighting factor). Due to the particular topography of the NW Spanish area, instead longitude and latitude, we have used depth and a new variable called “distance from the origin” calculated as follows:

- Locations below 43º10 N: distance is calculated as (Lat-41.5)*60, being *Lat* the latitude of the middle point of any particular EDSU within this region.

- Location between 43º10’ N and 8ºW (i.e. NW corner): distance is calculated as ((I.Lat-43.18333)^2+ (*I.Lon**(cos(I.Lat*pi()/180))-6.714441)^2)$^{0.5}$)*60+(43.1833-41.5)*60, being *I.Lat* and *I.Lon* the coordinates at which a normal straight line from middle point of any particular EDSU within this region intercepts a line defined by the following geographical coordinates: 43º11N-9º12.50’W and 43º39.50’N-8º06’W.

- Location between 8ºW and the Spanish-French border: distance is calculated as 158.329+ (Lon+5.8755324052)*60, being *Lon* the corrected longitude (longitude multiplied by the cosine of latitude) of the middle point of any particular EDSU within this region.

Besides each fish was measured and weighed to obtain a length-weight relationship. Otoliths were also extracted from anchovy, sardine, horse mackerel, blue whiting and mackerel in order to estimate age and to obtain the age-length key (ALK) for each species for each area.

Results

The survey started on 9th March and ended on 6th April. A total of 3260 nautical miles were steamed, 1075 of them corresponding to the survey track. Contrary to the previous year, weather conditions were in general good, although three tracks were interrupted due to the presence on air bubble. Besides, some pings were also removed due to the presence of bubbles sweep down. Also most of the tracks located in the NW corner (i.e. VIIIc-west), were sternway steamed in order to avoid bubbles sweep down. The last track, located in the French waters was not surveyed.

Calibration

All frequencies were calibrated on 9th March, with the following results:

Table 2: Acoustic equipment calibration. Main in and outputs for each frequency.

		200 kHz	120 kHz	38 kHz	18 kHz
Main	TS	-39.10 dB	-39.50 dB	-42.30 dB	-42.70 dB
	Gain	27.00 dB	27.00 dB	26.50 dB	22.40 dB
	Two way Beam Angle	-20.70 dB	-21.00 dB	-20.60 dB	-17.00 dB
	Angles (deg)	7.0 x 7.0	7.0 x 7.0	7.1 x 7.1	11.0 x 11.0
	Pulse Duration	1.024 ms	1.024 ms	1.024 ms	1.024 ms
	Power	90 W	200 W	2000 W	2000 W
	Sample Interval	0.193 m	0.193 m	0.193 m	0.193 m
	Rec. Bandwidth	3.09 kHz	3.03 kHz	2.43 kHz	1.57 kHz
Beam Model Results	Transducer Gain	26.03 dB	26.73 dB	24.73 dB	22.94 dB
	Sa Corr	-0.27 dB	-0.37 dB	-0.58 dB	-0.80 dB
	Athw Beam Angle	6.57 deg	6.38 deg	6.95 deg	10.97 deg
	Along. Beam Angle	6.53 deg	6.51 deg	7.12 deg	10.63 deg
	Athw Offset Angle	-0.29 deg	-0.05 deg	0.05 deg	0.19 deg
	Along. Offset Angle	-0.09 deg	-0.01 deg	-0.17 deg	0.31 deg
Data dev from beam model	RMS	0.60 dB	0.52 dB	0.20 dB	0.55 dB
Data dev polynomial model	RMS	0.56 dB	0.44 dB	0.18 dB	0.51 dB

Main oceanographic conditions

Figure 2a-c shows the sea surface temperature, salinity and flourometry from the continuous records. In the western areas (i.e. IXa-N) temperatures ranged from 13.18º to 22.27ºC, with a mean value of 14.13º (median, 14.07º). In the same way salinity ranged from 28.28 to 36.31 ppm (mean 33.70 and median 33.91 ppm), with a strong correlation with longitude, being waters less salted and warmer close to the coast due to the river flows. Fluorescence ranged from 0.84 to 2.75 (mean 1.20, median , 1.12). In the northern areas (VIIIc) temperature ranged from 12.58º to 14.92ºC (mean, 13.26º, median 13.18º) being 0.75º colder than that of the western area. In addition, salinity ranged from 31.64 to 36.04 ppm (mean 35.23, median 35.34 ppm), thus more salted than those from the western area. Fluorescence ranged from 0.94 to 3.63 (mean 1,64, median 1.52); complementary, all variables were correlated with latitude. Thus, interpolation was made using this two areas . The surveyed area can be divided in several areas according to the surface continuous records. IXaN area with low salinity, warmer waters and weak flourometry (i.e. chlorophyll); NW corner (VIIIc-W) with high flourometry values, salty waters from the coast to the self-beak, and temperatures in transition from warmer waters in the south to colder waters in the north ; from Cape Ortegal to Llanes Canyon, with lesser salty waters in coastal areas than in open waters, colder temperature through all the area and a weak chlorophyll density ; from Llanes Canyon to Suances , with warmer waters than that of the surrounded areas, but with almost same salinity as found in the surrounded areas, with a clear influence from the river flows and the chlorophyll increasing eastwards; from Suances to Laredo, characterised by an intrusion of colder waters, low salinity in coastal waters, and a moderate concentration of chlorophyll; and the inner part where both sea surface temperature and flourometry showed a clear west-eastward cline, and, as in the rest of the surveyed area except in VIIIc-west, an influence of the river flows in the coastal areas.

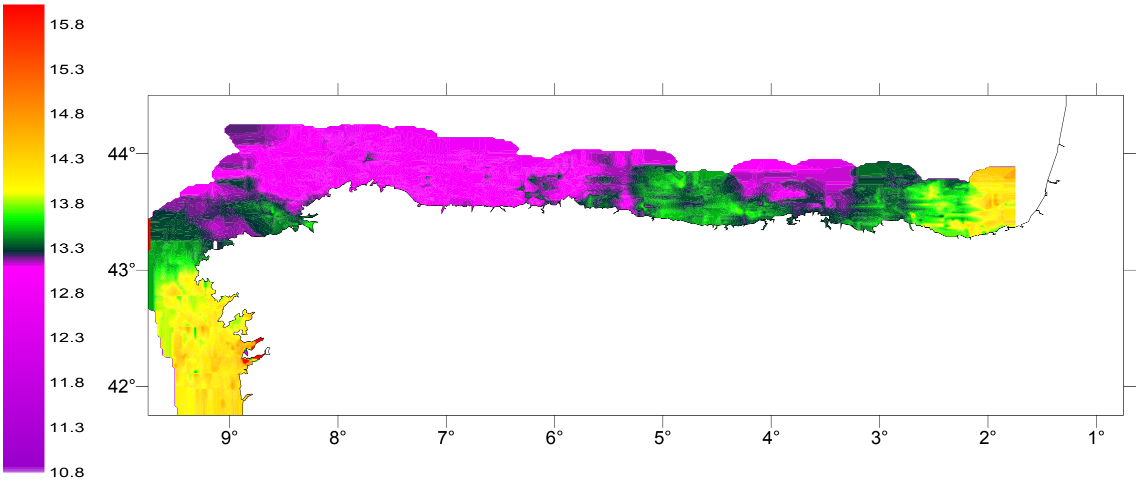


Figure 2a: Sea Surface Temperature during PELACUS 0314 survey

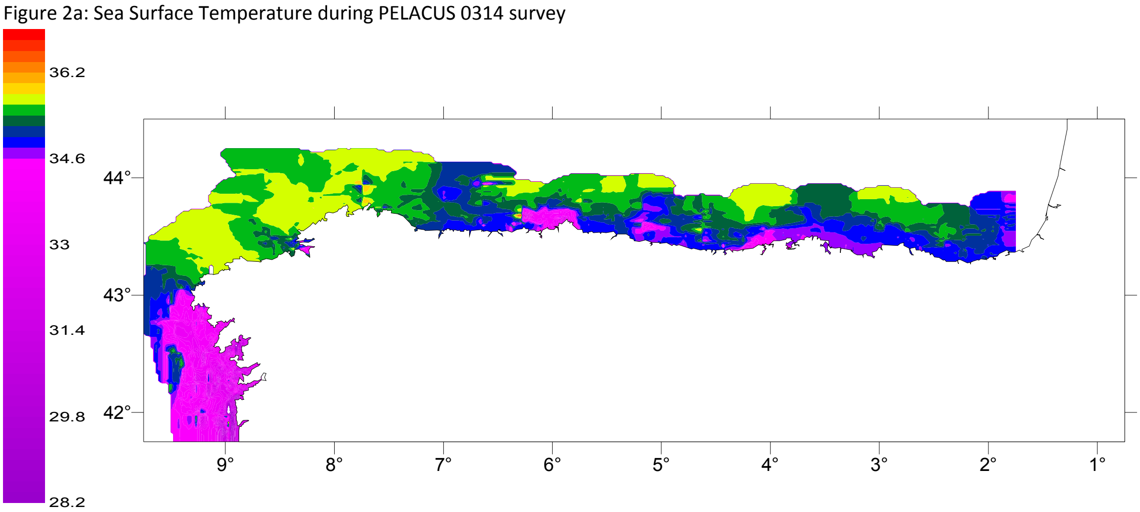


Figure 2b: Sea Surface Salinity during PELACUS 0314 survey

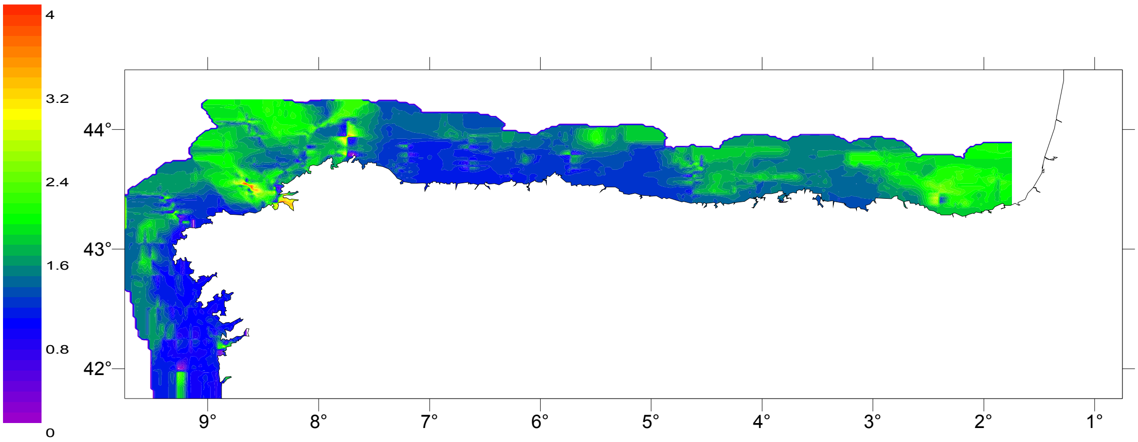


Figure 2c: Sea Surface Fluorescence during PELACUS 0314 survey

Fishing stations

Without including the trawl hauls done at the beginning of the survey for checking and setting up purposes, 52 fishing station were performed, one of them was removed. Figure 3 shows the location and the value for each ground-truth criteria (from 0 to 3).

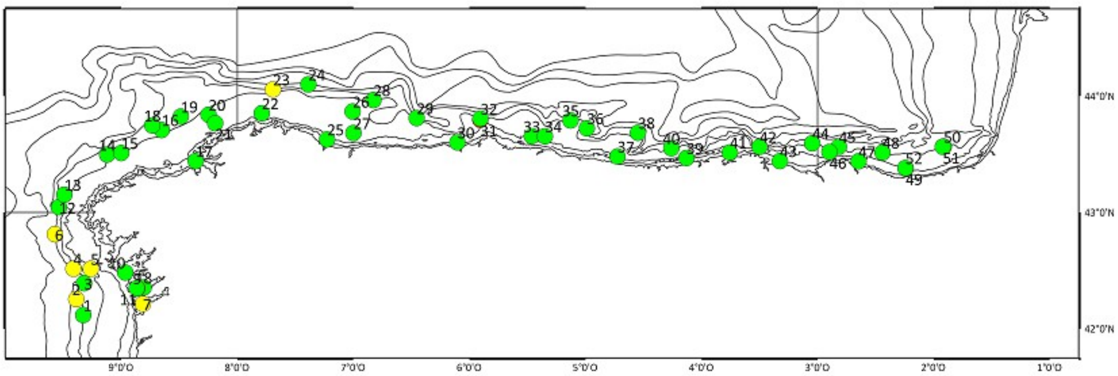


Figure 3: Fishing station and colour system according to ground-truth criteria (red bad; yellow, acceptable; and green good)

As it can be seen most of the fishing stations were performed under good conditions. Mackerel was the most abundant fish species (34% of the total catch in number) and was also present in the 88% of the fishing hauls. Horse mackerel was also abundant (29% of the total catch in number) and a 67% of haul presence. Finally, blue whiting accounted the 21% of the total catch in number and was present in the 61% of the trawl hauls. Mackerel mainly occurred in the Cantabrian Sea although some adults together with juveniles has been caught in IXa-N and VIIIc-west; in these areas mean length was around 24 cm, without significant differences in length distribution (Kolmogorov Smirnov test) whilst in the Cantabrian Sea mean length increased up to 35cm, thus spawners, with a slight differences, but significant, in both mean length and length distribution between those hauls performed in shallower waters (<140 m depth) and those located close to the shelf edge. Horse mackerel showed a great variety in both mean lengths and length distributions along the surveyed area. On the contrary, the mean length of blue whiting samples was around of 22.5 cm in almost all the hauls and only in two samples obtained near the Llanes Canyon (4º30'W) mean length was lower (21.3 cm).

Figure 4 shows the fish proportion in number obtained in each trawl haul. Boarfish, sardine and bogue, although less representative, were also important. Boarfish mainly occurred in the Cantabrian Sea with a small patch located in the northern coastal waters of VIIIc-west (i.e. close to the Estaca de Bares Cape -8º W-). In the former area was found round Estaca de Bares Cape and in the inner part of the Bay of Biscay. Mean length was similar in almost the whole area (14.09 cm), and only small fish (8.76 cm) were found in the shelf-edge close to the Galicia Asturias border. Juvenile bogue, as shown in mackerel, were mainly located in IXaN whilst adults occurred in the Cantabrian Sea. For Sardine as well mean length in IXaN was 17.03 and in the Cantabrian Sea, except one single haul performed close to the Bilbao harbour the mean length was around 20 cm.

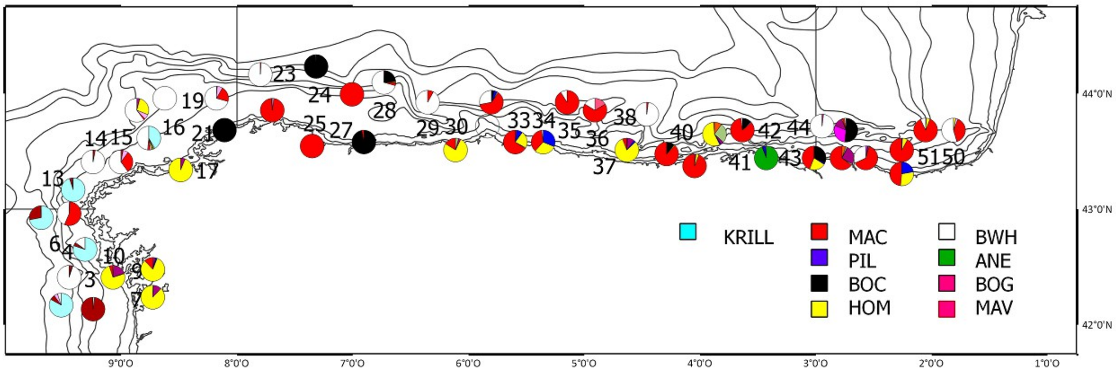


Figure 4: Fish proportion (% in number) at each fishing station. (KRILL -M. norvegica; MAC-mackerel; PIL-sardine; BOC-boarfish; HOM- horse mackerel; WHB-blue whiting; ANE- anchovy; BOG-bogue; and MAV-M. muelleri)

Finally it should be noted the presence of lantern fish, *Maurulicus muelleri*, over the shelf of IXaN. This fish species occurred in small schools during day time as shown in figure 5.

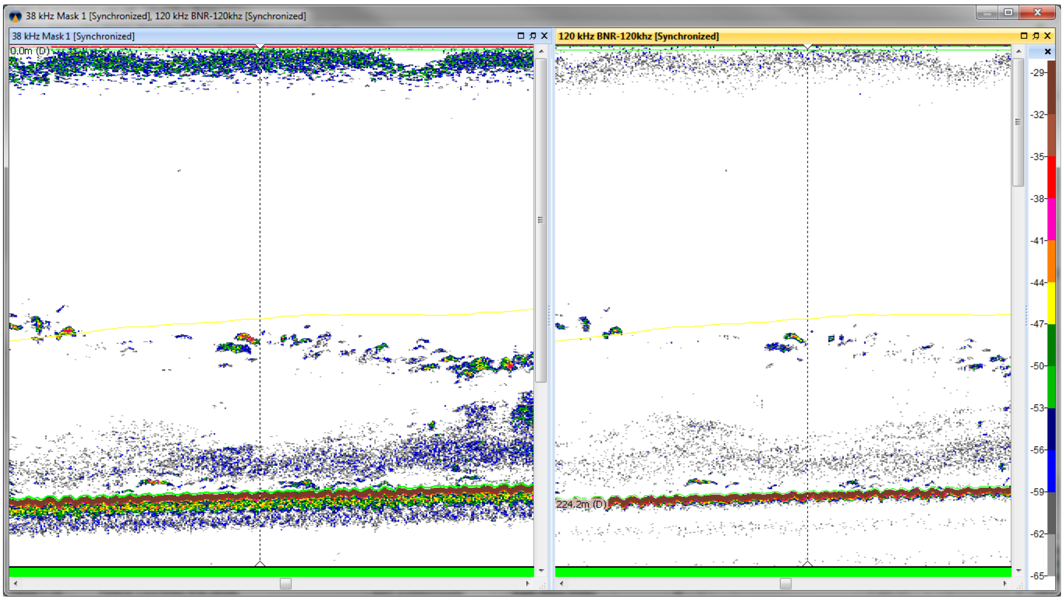


Figure 5: M. muelleri schools located at 140 m depth (total depth is 200). The yellow line is the depth sensor of the trawl door. M. muelleri represented 98% of the catch and 2% was krill (Meganyctiphanes norvegica).The fishing station was performed on 12th March at 13:30 GMT.

CUFES sardine egg counts

658 CUFES stations were done and 4214 were collected in 117 samples (33% positive stations). Last year the total egg number collected was 5936 but the number of positive stations was 105 (28% positive stations). Figure 6 shows the sardine egg counts

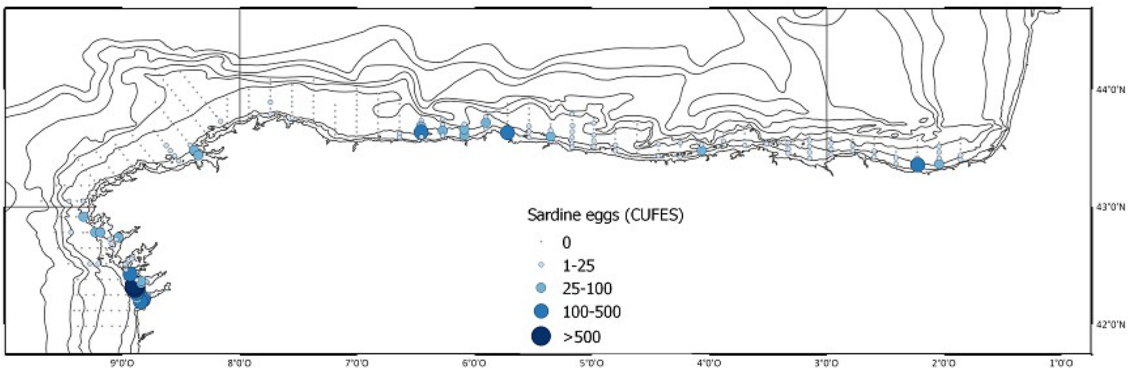


Figure 6. Number of sardine egg collected at the CUFES stations

Acoustic

A total of 251.893,2 s_A were attributed to fish species which is is 2.4 times higher than that of the previous year when only 105.384,67 s_A were attributed to fish species. Table 3 shows the fishing station used to allocate backscattering energy when echotraces were similar to those found around these fishing station.

Table 3: Fishing station used for backscattering energy allocation and transects

Fishing station	Transects
PE01	RA02
PE02	RA01, RA02
PE03	RA03, RA04
PE04	RA05, RA06, RA07, RA08
PE05	RA04, RA05, RA06, RA07
PE06	RA06, RA07, RA08, RA09, RA11, RA13
PE10	RA06, RA07, RIAS
PE11	RIAS
PE12	RA09, RA10, RA11
PE13	RA10
PE15-16	RA15, RA16
PE15-18	RA15, RA16
PE15	RA12, RA13, RA14
PE19-18	RA17
PE17	RA12, RA16, RA17
PE19	RA18
PE20	RA17, RA18, RA19
PE22	RA21, RA22
PE23	RA20, RA21, RA22, RA23
PE24	RA23
PE26	RA25, RA27
PE27	RA23, RA24, RA25, RA26, RA27
PE28	RA23, RA24, RA25, RA26, RA27
PE29	RA28, RA29, RA30, RA31, RA32
PE30	RA27, RA28, RA29, RA30, RA31, RA32, RA33
PE32	RA28, RA29, RA30, RA31, RA32, RA33
PE33	RA31, RA32, RA33, RA36
P33-P30	RA34, RA35
PE34	RA33, RA34, RA35, RA36, RA37, RA38
PE35	RA32, RA33, RA34, RA35, RA36,
PE36	RA34, RA36
PE37	RA35, RA36, RA37, RA38, RA39,
PE38	RA37, RA38, RA39, RA43
PE39	RA40, RA42
PE40	RA40, RA43, RA45, RA46
PE41	RA37, RA40, RA41, RA43, RA44,
PE42	RA41, RA42, RA44, RA45, RA46
PE43	RA45, RA46
PE44	RA46, RA47, RA48
PE45	RA48, RA49
PE46	RA47, RA48, RA49
PE47	RA48, RA49, RA50, RA51
PE48	RA50, RA51
PE49	RA49, RA50, RA51
P49-P52	RA52, RA53
P50-P51	RA50, RA51, RA52, RA53

Table 4 shows the backscattering energy distributed by species and ICES subdivision, either by direct allocation (DA) or through the proportion found at the fishing stations (Fst). Direct assignation was feasible accounting for its special acoustic properties, morphology and geographical characteristics for some board fish, horse mackerel and especially, mackerel. On the other hand, only a 1.19% of the total energy attributed to fish remained unallocated.

Table 4: Backscattering energy (s_A) allocated by species, both by direct allocation (DA) and by the fish proportion found at the ground-truth fishing stations, and by ICES Sub-Division (WHB-blue whiting; MAC-mackerel; HOM- horse mackerel; PIL-sardine; JAA-blue jack mackerel; BOG-bogue; MAS-chub mackerel; BOC-boarfish; SBR-sea breams and similar specie; HMM-mediterranean horse mackerel; Other species and- unallocated NASC)

		WHB	MAC	HAK	HOM	PIL	JAA	BOG	MAS	BOC	SBR	HMM	Other	total
IXa	**DA**	0	16	0	4543	0	0	0	0	0	0	0	174	4733
	Fst	5540	94	2213	56324	340	407	18209	14	0	1612	0	1087	85841
VIIIc-W	**DA**	0	5	0	84	0	0	0	0	3420	0	0	168	3677
	Fst	12278	77	1086	4456	1	4	775	1	0	54	0	124	18858
VIIIc-Ew	**DA**	0	7967	0	0	0	0	0	0	3096	0	0	2689	11063
	Fst	32385	6395	1286	29357	4989	400	4058	323	18048	3963	669	1	101874
VIIIc-Ee	**DA**	0	1400	0	0	0	0	0	0	0	0	0	0	1400
	Fst	5127	1749	294	2914	711	4	1917	962	6955	242	229	655	21758
Total	**DA**	0	9388	0	4627	0	0	0	0	6515	0	0	3030	23561
	Fst	55330	8315	4879	93052	6042	815	24959	1300	25003	5872	899	1867	228332
Total		55330	17703	4879	97679	6042	815	24959	1300	31518	5872	899	4897	251893

Spatial patterns

Table 5 and figure 7 summarizes the spatial indices of the main fish species.

Table 5: Center of gravity according to the weighting average calculated using Distance to the Origin (Dist.Org.; expressed in nautical miles), distance to 200 m isobath (Dist 200) and depth (DEPTH, expressed in meters) together with its standard deviation and confidence interval. (WHB-blue whiting; MAC-mackerel; HAK -hake; HOM- horse mackerel; PIL-sardine; JAA-blue jack mackerel; BOG-bogue; MAS-chub mackerel; BOC-boarfish; ANE-anchovy ; HMM-mediterranean horse mackerel.

	BWH	MAC	HAK	HOM	PIL	JAA	BOG	MAS	BOC	ANE	HMM
Depth	246.79	163.18	182.37	67.16	136.98	100.06	57.50	197.11	165.79	54.60	94.30
s.d.	312.95	189.00	99.77	236.16	52.46	29.59	113.57	52.97	192.52	3.29	18.61
c. i.	37.36	22.56	11.91	28.20	6.26	3.53	13.56	6.32	22.99	0.39	2.22
Dist 200	3.90	4.84	5.53	8.38	5.38	6.10	7.81	3.11	5.61	8.70	4.27
s.d.	10.02	7.47	3.21	22.89	4.55	1.94	11.06	1.50	15.43	0.44	1.21
c. i.	1.20	0.89	0.38	2.73	0.54	0.23	1.32	0.18	1.84	0.05	0.14
Dist. Or	226.42	284.62	149.87	144.04	295.46	176.95	127.71	373.37	250.86	373.78	354.52
s.d.	353.30	147.04	114.13	570.87	86.91	50.76	285.73	29.69	219.17	0.70	14.13
c. i.	42.16	17.55	13.62	68.13	10.37	6.06	34.10	3.54	26.16	0.08	1.69

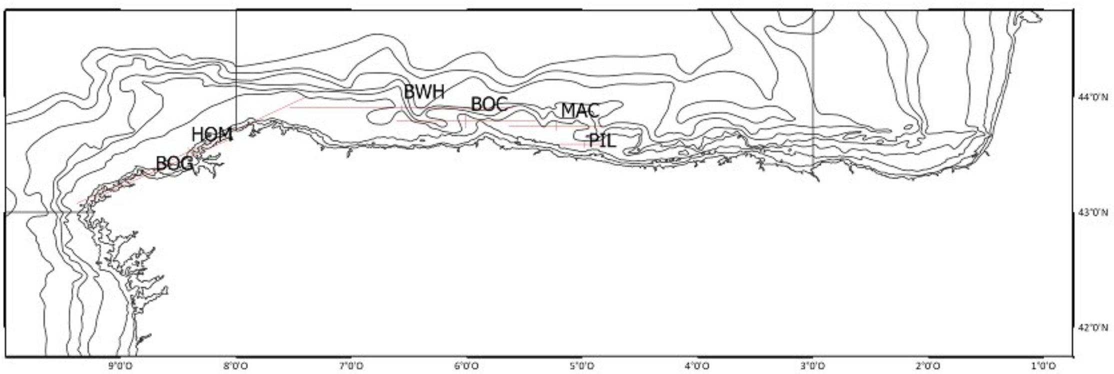


Figure 7 Centre of gravity of NASC distribution for the main fish species. Lines are proportional to the confidence intervals for both variables, Distance to the Origin (D.O.) and Depth

That of horse mackerel reflects the high abundance found within the Rías in IXaN and, in general in shallower waters. The center of gravity of mackerel remains more or less in the position as in the previous year. For blue whiting, although some fish have been detected over the continental shelf, the bulk of the distribution is still located on the self-edge, but this year the center has been estimated eastward than the previous year. On the other hand, sardine distribution, although the schools detected in the Rias, remains as well in more or less the same position as in the previous year.

Mackerel distribution and assessment

Mackerel was the most important fish species, both in number and spatial distribution. Figure 8 shows the spatial distribution.

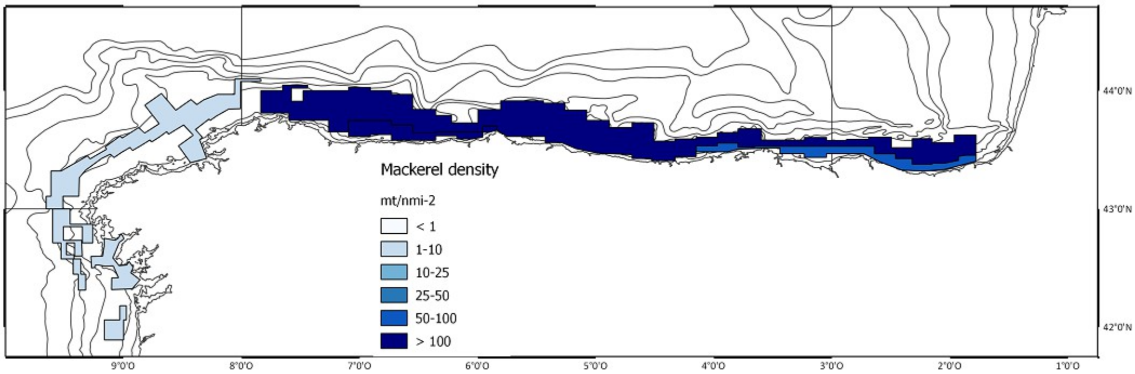


Figure 8. Mackerel: spatial distribution PELACUS0314 cruise. Polygons are drawn to encompass the observed echoes, and polygon colour indicates the mean density expressed as tonnes per squared nautical mile (<1,; 1-10; 10-25; 25-50; 50-100; and >500)

Table 6 shows the mackerel assessment. 808 422 mt has been estimated, corresponding to 2.802 million fish. The bulk of the distribution occurred in the central part of the Cantabrian Sea. In western areas (IXaN and VIIIc-west), where the juvenile mackerel fraction was distributed, density was scarce and, in some cases, very difficult to observe at 38 kHz and probably both abundance and distribution area would be greater; in these areas age group 1 was predominant (84% in number and 63% in weight). On the contrary, in the Cantabrian Sea (VIIIc-East), where the bulk of the biomass occurs, age groups 5, 6 and 7 where predominant and accounted for the 65% of the biomass (64% in weight)

Table 6 Mackerel acoustic assessment

		SURVEY:	PELACUS 0314 MACKEREL					
Zone	**Area**	**No**	**Mean**	**Surface**	**Fishing st.**	**PDF**	**No (million fish)**	**Biomass (tonnes)**
Ixa-N	Ixa-N-South	9	0.84	92.24	P03-P05-P08-P10-P12-P13-P15-P20	ST01	3	326
	Ixa-N-Rias Baixas	55	1.36	189.90	P03-P05-P08-P10-P12-P13-P15-P20	ST01	11	1081
	Ixa-N-North	25	1.07	229.58	P03-P05-P08-P10-P12-P13-P15-P20	ST01	10	1026
	Total	***89***	***1***	***512***			***24***	***2433***
VIIIc-w	Artabro	100	0.81	899.84	P03-P05-P08-P10-P12-P13-P15-P20	ST01	30	3040
	Total	***100***	***1***	***900***			***30***	***3040***
VIIIc-E	VIIIc-Ew-Coast	37	19.10	277.93	P18-P20-P22	ST02	108	29735
	VIIIc-Ee-Coast	48	14.64	382.41		ST02	114	31366
	VIIIc-offshore	365	44.11	2926.46	P32-P33-P34-P35-P36-P37-P38-P39-P40-P42-P44	ST03	2525	741848
	Total	***450***	***39***	***3587***			***2748***	***802949***
	Total VIIIc	***550***	***32***	***4998***			***2778***	***805989***
	Total Spain	***639***	***28***	***4998***			***2802***	***808422***

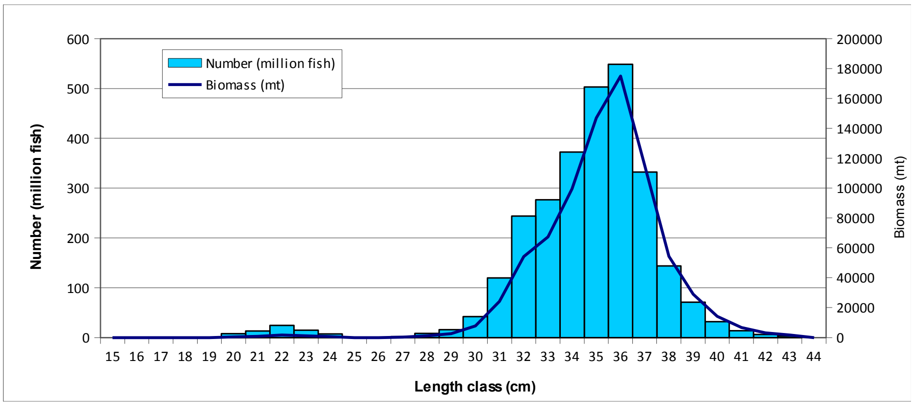
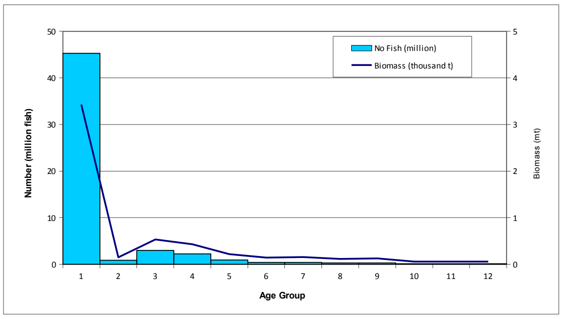
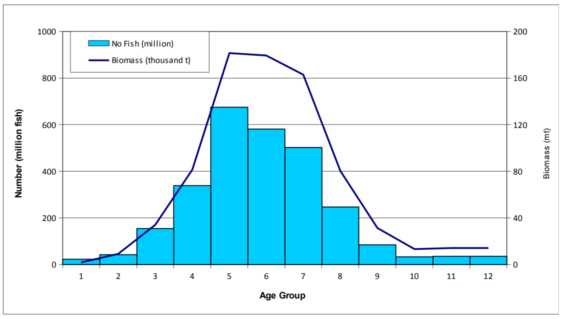


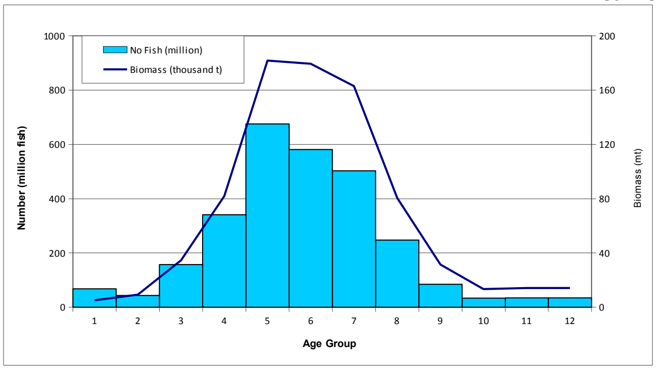
Figure 9. Mackerel length distribution in both number and biomass during PELACUS0314 survey.



Biomass: 5.47 thousand mt
Mean weight: 87.65 g
Number: 54 million fish
Mean length: 24.03 cm (s.d. 3.96)



Biomass: 802.95 thousand mt
Mean weight: 296.75 g
Number: 2748 million fish
Mean length: 35.31 cm (s.d. 2.51)



Biomass: 808.42 thousand mt
Mean weight: 290.99 g
Number: 2802 million fish
Mean length: 35.09 cm (s.d. 2.98)

Figure 10. Mackerel abundance and biomass by age group during PELACUS0314 survey.

Comparing with the previous year, the total mackerel biomass assessed is 47 % higher (379 149 t corresponding to 1,725 million fish). As in previous year juveniles were mainly located in the west part (VIIIc-w and IXaN), where age group 1 accounted for the 83% of total fish number and the 63% of the total biomass. In Cantabrian Sea (VIIIc-East), were the bulk of the population was located (97% of the fish number and 99% of the total biomass), age groups 4, 5 and 6 accounted for the 65% of the total biomass. On the other hand, age group 2 only represents the 1% of the total abundance. This result is consistent with that obtained the previous year when the strength of age class 1 was weak.

Table 7. Mackerel abundance in number (thousand fish) and biomass (tons) by age group and ICES sub-area in PELACUS0314.

SURVEY: PELACUS 0314. MACKEREL

BIOMASS (thousand tonnes). ZONE: VIIIc+IXaN

	AGE GROUPS													
Length	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**	**No fish (milli**
10														
11														
12														
13														
14														
15														
16														
17														
18														
19	0.01												0.01	0
20	0.43												0.43	8
21	0.84												0.84	13
22	1.80												1.80	24
23	1.27												1.27	15
24	0.66												0.66	7
25	0.03												0.03	0
26														
27	0.05	0.14	0.05										0.23	2
28		0.32	0.95										1.27	9
29		0.23	0.70	1.64									2.58	16
30		0.64	3.53	2.25	1.28								7.70	42
31		1.34	10.72	8.04	4.02								24.11	120
32		3.87	3.87	23.19	23.19								54.11	244
33		2.59	5.18	20.74	36.29	2.59							67.40	276
34			7.11	10.67	35.57	24.90	17.78	3.56					99.59	372
35			2.49	4.98	42.36	52.33	24.92	19.94					147.03	503
36				7.00	24.50	56.01	52.51	28.00	7.00				175.03	549
37				3.39	10.17	33.91	37.30	13.57	6.78	3.39	3.39	3.39	115.30	332
38					4.34	6.51	21.70	8.68	6.51	2.17	2.17	2.17	54.26	144
39						3.23	6.45	3.23	6.45	3.23	3.23	3.23	29.03	71
40							2.36	2.36	2.36	2.36	2.36	2.36	14.15	32
41								1.11	2.22	1.11	1.11	1.11	6.65	14
42										1.06	1.06	1.06	3.18	6
43											0.88	0.88	1.75	3
44														
Biomass (thousand t)	5	9	35	82	182	179	163	80	31	13	14	14	808.42	2802
%	0.63	1.13	4.28	10.13	22.48	22.20	20.17	9.95	3.87	1.65	1.76	1.76		
M. weight	71.47	217.42	223.71	245.54	275.29	318.01	333.93	335.23	381.81	414.30	420.87	420.87	290.99	
No Fish (million)	68	43	157	340	676	581	502	247	85	33	35	35	2802	
%	2.43	1.53	5.62	12.15	24.12	20.74	17.93	8.81	3.02	1.18	1.24	1.24		
M. length	22.53	32.01	32.30	33.26	34.48	36.09	36.65	36.69	38.23	39.22	39.42	39.42	35.09	
s.d.	1.21	1.48	1.74	1.69	1.61	1.16	1.34	1.36	1.46	1.51	1.72	1.72	2.98	

On the other hand given that in some cases NASC direct allocation was not feasible and, therefore, this was done using the Nakken and Dommasnes method, the change in the TS length relationship for boarfish, would result in a small decrease of a 1.29 % in the total abundance (i.e. from 808 to 798 thousand tonnes)

Behaviour:

This year, most of the mackerel occurs in a pelagic layer, at around 30-50 m depth. In some cases schools were also seen in the surface and, in general, they showed strong diving reaction from the upper layers to the bottom, especially when marine mammals were present, but also raising reaction from the bottom to the upper layers, as shown in figures 10 and 11. Yet, the relationship between this raising behaviour and explanatory variables was not studied. On the other hand the main difference between this year and the previous is both the thickness and the continuity of the subsurface layer. Until now, rather than a subsurface layer, mackerel occurred in scarce patches while the bulk of the distribution was located near the sea bottom. Over the subsurface patches, the spring artisanal hand-line fleet is concentrated (figure 12).

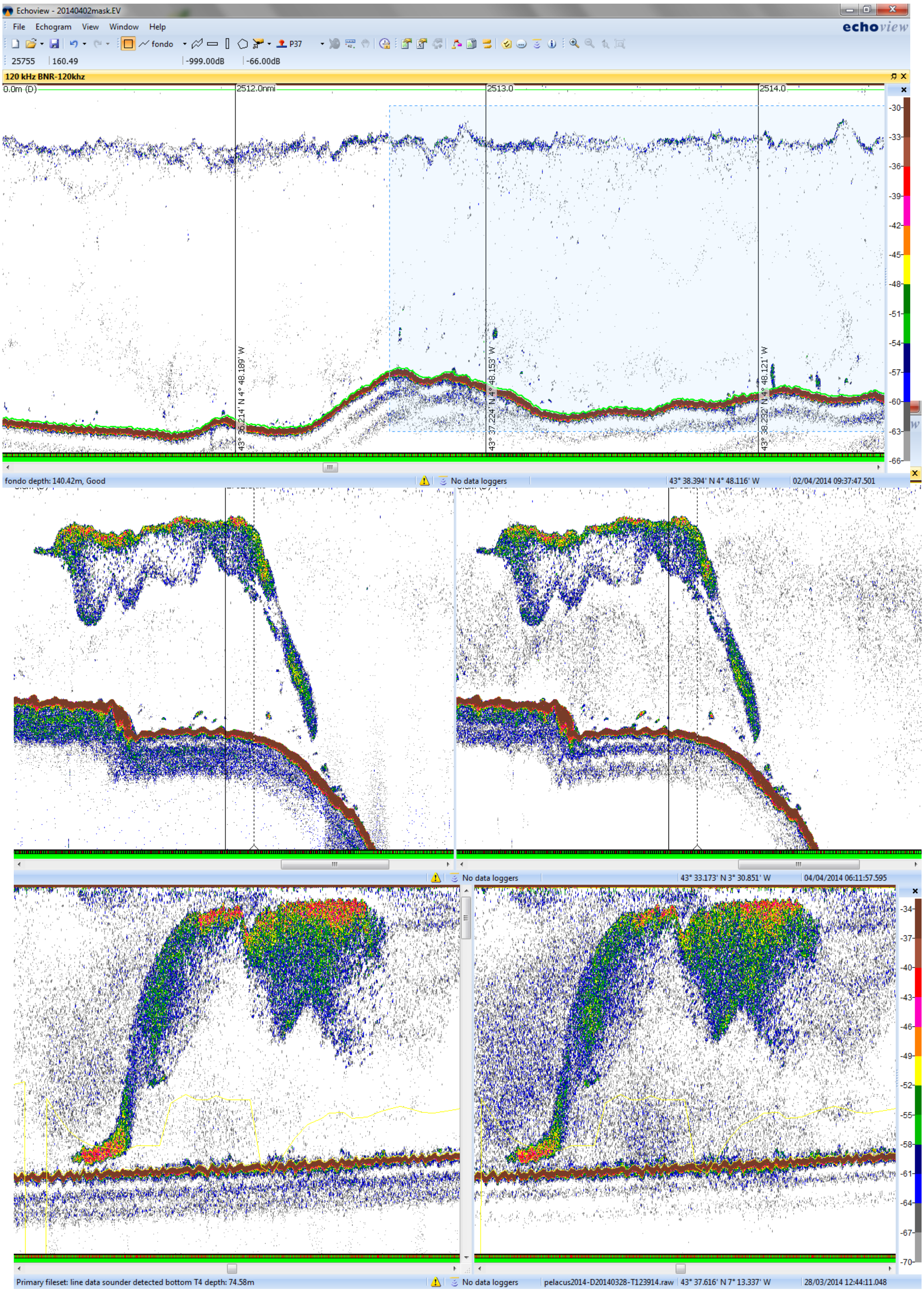


Figure 10. Mackerel occurrence during PELACUS 0314. Top panel subsurface layer (120 kHz echogram; threshold set at -70dB); Mid panel, diving reactions close to the self-edge(200 kHz left and, 120 kHz, right). Bottom panel, raising reaction.


Figure 11: Mackerel schools at the surface

Figure 12: Hand-line working over a mackerel schools.

Mackerel diet

The times series of mackerel stomach contents (1999-2014) has been presented this year. Data came from the biological samples obtained in different trawls hauls during PELACUS (i.e. only day time data). Figure 13 shows the percentage of non empty stomachs. 75% of stomachs analysed, ranging from to 56 to 92%, were full or partial full. Main prey has varied along time series, but copepods and mackerel eggs were the most important preys in number along the time series. In volume, three periods can be distinguished; from 2001 to 2004 salps accounted for around 54% of the stomach volume; 2006 to 2011 when copepods accounted for the 40% of the total stomach volume, reaching the maximum in 2009 and then showing a continuous declining trend; and since 2011 when crustacean became more important (Euphausiacea, Mysidacea, Decapoda, both adult and larvae) (figure 14). Since no long-term trends or cycles were detected in any zooplankton species (Bode et al, 2012) and only an increase in the zooplankton diversity related with inter-seasonal variability, the variability observed in the mackerel diet would be rather related to a variability in the zooplankton diversity which ultimately depends on the seasonal temperature.

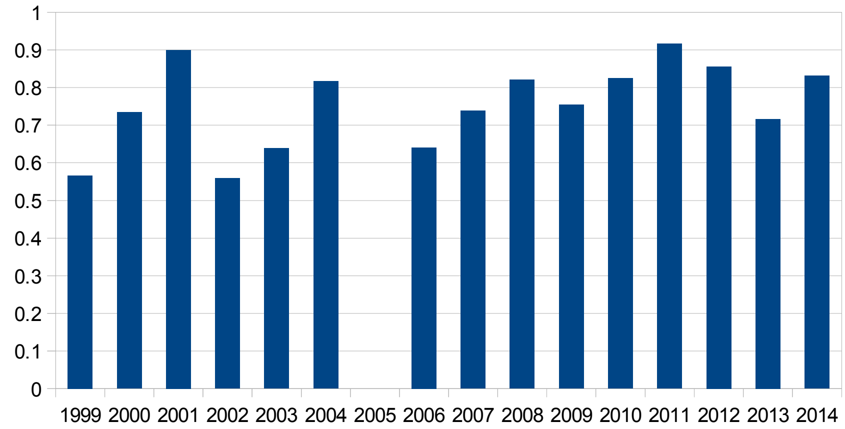
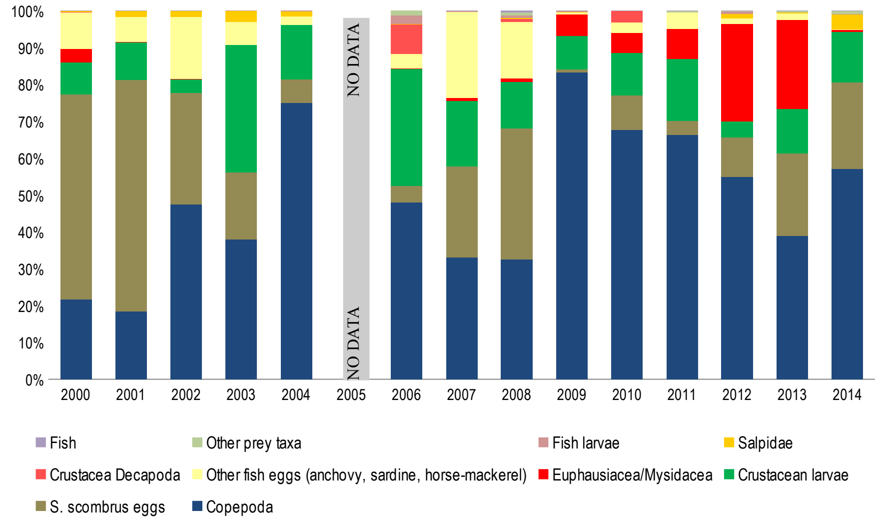


Figure 13:Percentage of non-empty mackerel stomachs taken during PELACUS time series (1999-2014)



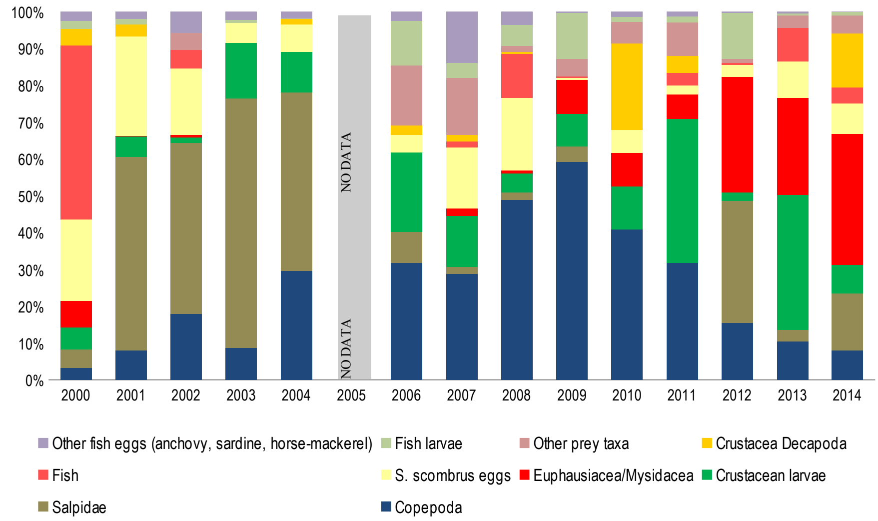


Figure 14: Mackerel diet in number (top panel) and in volume (bottom panel). All figures are in percentage.

Blue whiting distribution and assessment

As stated previously, main blue whiting distribution area is located around the self-edge at 247 m depth. Besides is the closest fish species to the 200 m isobath, occurring with lantern fish (*Maurolicus muelleri*) and krill (*Meganyctiphanes norvegica)*.Besides, the density was in general low and no extension of the distribution area into open waters in pelagic layers has been detected. Instead, comparing to the previous year, it seems that the distribution is spreading through the continental shelf (figure 15). Mean length was rather homogeneous along the surveyed area at around 22.5 cm and only smaller fish were found, close to Santander.

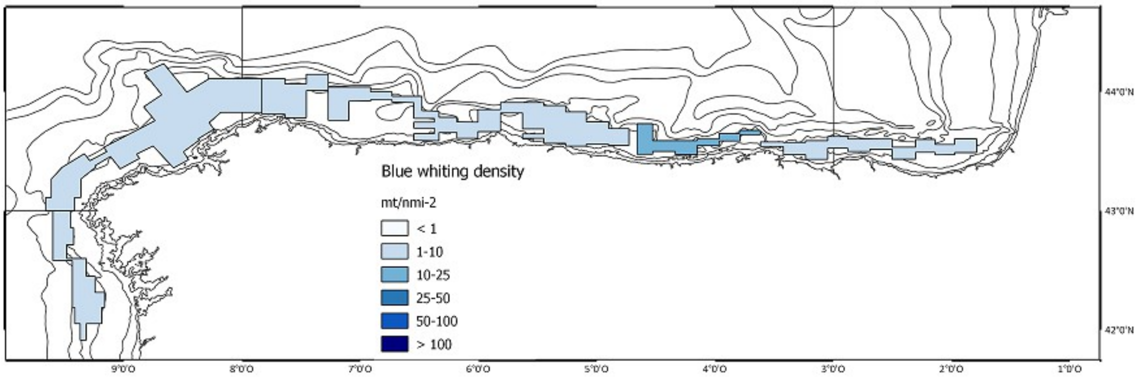


Figure 15. Blue whiting spatial distribution PELACUS0314 cruise. Polygons are drawn to encompass the observed echoes, and polygon colour indicates the mean density expressed as tonnes per squared nautical mile (<1,; 1-10; 10-25; 25-50; 50-100; and >100)

Table 8 shows the blue whiting assessment. A total of 24.117 tonnes corresponding to 414 million fish has been estimated. Comparing to previous years, blue whiting is increasing its biomass from 7146 mt (123 million fish) assessed in 2012, and 13.488 mt (corresponding to 299 million fish) in 2013. Beside length structured, as show in figure 16 was significant different from that found in the previous year. According to the information got at the fishing station which as it has been stayed was similar along the surveyed area (up to 20 fishing stations with more than 31 sampled specimens), no signal of younger fish (length < 18cm) has been found.

Table 8: Blue whiting assessment

SURVEY: PELACUS 0314 BLUE WHITING

Zone	Area	No	Mean	ó^2	Area	Fishing st.	PDF	No (million fish)	Biomass (tonnes)
IXa	Ixa_N	58	95.52	235	479	P02-P03-P04-P06	S01	40	2407
	Total	**58**	**95.52**		**479**			**40**	**2407**
VIIIc-W	VIIIc_W	182	67.46	104	1643	P12-P14-P15-P16-P18-P19-P20	S02	94.37	5891.61
	Total	***182***	***67***		***1643***			***94***	***5892***
VIIIc-E	Estaca	43	84.00	215	351	P23-P24	S03	26	1548
	Asturias	136	150.80	457	1177	P24-P28-P29-P32-P34-P35-P36	S04	159	9201
	Cantabria	37	223.28	409	263	P38-P40	S05	58	2919
	Euskadi	59	86.89	158	477	P42-P44-P48	S06	38	2150
	Total	***275***	***136.39***		***2268***			***280***	***15818***
Total IXa		***58***	***96***		***479***			***40***	***2407***
Total VIIIc		***457***	***109***		***3910***			***374***	***21710***
Total Spain		***515***	***107.43***		***4389***			***414***	***24117***

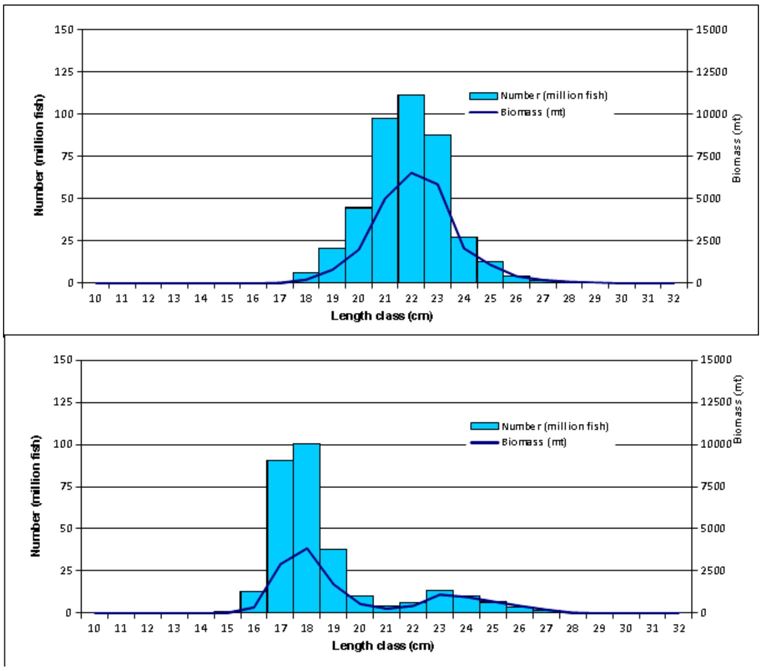


Figure 16. Blue whiting length distribution in both number and biomass during the PELACUS0314 (above) and PELACUS 0313 (below) surveys.

As in the case of mackerel, when the new TS length relationship is applied in multispecific areas, the total biomass decreases up to 22870 mt (5.5%).

Horse mackerel distribution and assessment

Horse mackerel density was higher than that found the previous year. In IXaN, the bulk of the distribution occurred within the Rías Baixas in a very dense and near bottom schools (figure 17).

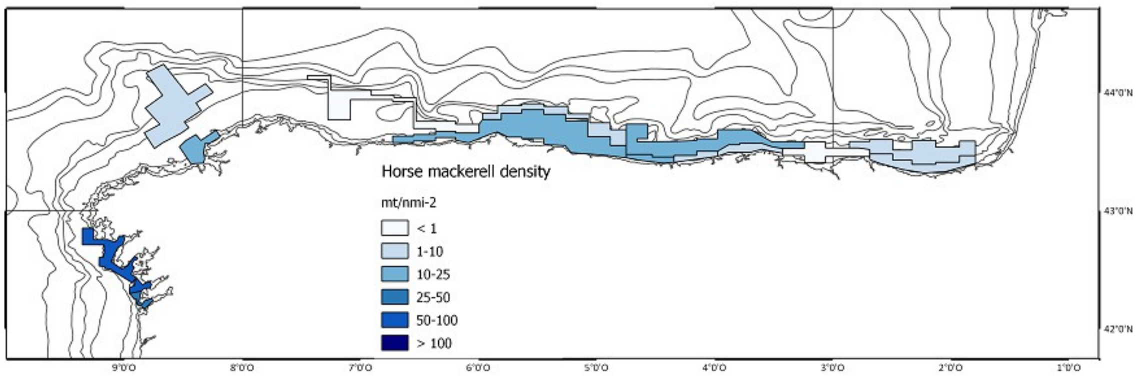


Figure 17. Horse mackerel spatial distribution PELACUS0314 cruise. Polygons are drawn to encompass the observed echoes, and polygon colour indicates the mean density expressed as tonnes per squared nautical mile (<1,; 1-10; 10-25; 25-50; 50-100; and >100

Total biomass was estimated to be 44.356 mt (556 million fish), 13024 of those located in IXaN (217 millions fish) and the remaining 31.332 in VIIIc (340 million fish). (table 9, figure 18)

Table 9: Horse mackerel assessment

		SURVEY:	PELACUS 0314 HORSE MACKEREL						
Zone	**Area**	**No**	**Mean**	**õ^2**	**Area**	**Fishing st.**	**PDF**	**No (million fish)**	**Biomass (tonnes)**
IXa	R Vigo	22	556.67	674.99	27.20	P07	S01	22	1307
	R Pontevedra	16	773.98	1259.80	31.13	P08-P11	S02	41	1907
	R Arousa	57	635.74	1446.86	173.65	P10	S03	154	9810
	Total	***95***	***641***		***232***			***217***	***13024***
VIIIc-W	Artabro_ Coast	15	262.10	451.09	116.91	P17	S04	43.39	2704.57
	Artabro_Shelf	59	7.79	9.56	494.24	P18-P19	S05	2.50	610.23
	Total	***74***	***59***		***611***			***46***	***3315***
VIIIc-E	VIIIcE_west_Coast	98	171.52	288.11	748.83	P30-P33-P34	S06	164	12046
	VIIIcE_west_Shelf	33	9.37	20.36	336.88	P30-P33-P34	S06	4	296
	VIIIcE_mid_Coast	32	25.35	75.07	244.75	P32-P36-P45	S07	3	978
	Llanes	6	182.38	179.84	50.03	P37	S08	16	718
	San Vicente	6	114.14	132.90	48.48	P39	S09	8	480
	Santander	11	85.72	104.78	81.59	P41	S10	16	499
	Abra Bilbao	22	1.42	3.71	180.29	P46	S11	0	22
	Donostia_Shelf	25	51.39	114.14	177.57	P49-P52	S12	16	715
	Donostia_Coast	44	33.32	46.14	343.45	P50-P51	S13	8	1542
	Cantabria_Shelf	52	169.91	732.69	471.35	P40	S14	57	10722
	Total	***329***	***98.08***		***2683***			***294***	***28017***
	Total IXa	***95***	***641***		***232***			***217***	***13024***
	Total VIIIc	***403***	***91***		***3294***			***340***	***31332***
	Total Spain	***498***	***195.84***		***3526***			***556***	***44356***

As in the previous years, length distribution showed a great heterogeneity along the surveyed although a clear mode around 20 cm has been found in almost all the fishing stations.

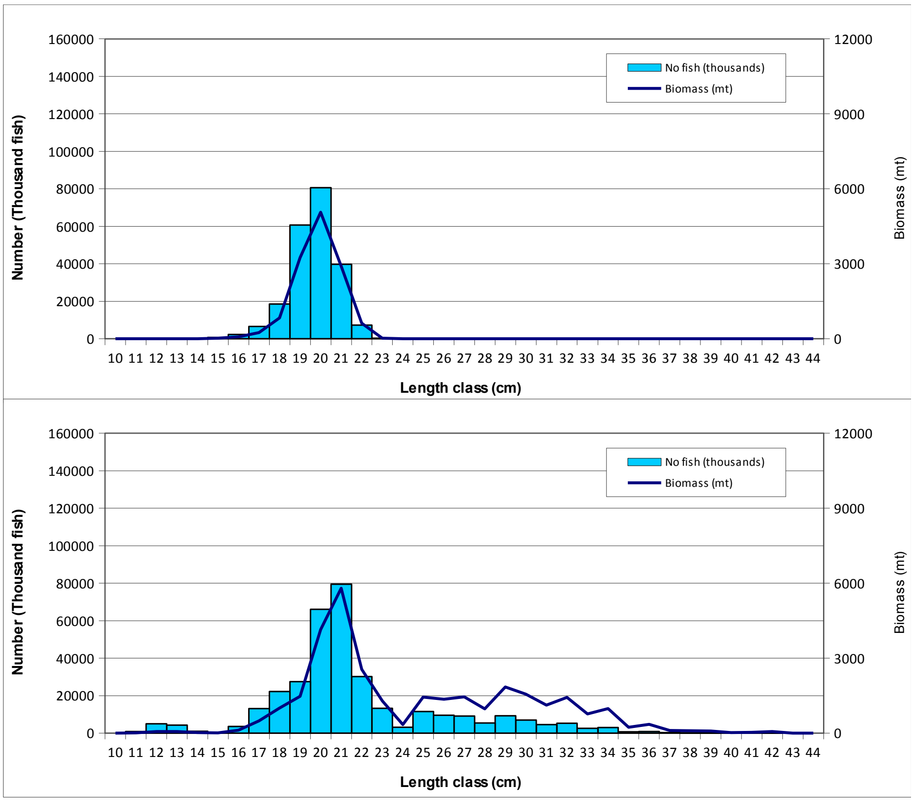


Figure 18. Horse mackerel length distribution in both number and biomass during the PELACUS0314 in IXaN (above) and VIIIc (below).

The total biomass assessed in Pelacus 0314 was significantly higher than that estimated last year (6.362 mt corresponding to 44 million fish). A total of 6.372 mt has been estimated, corresponding to 44million fish, which was smaller than that assessed the last year (18264 mt corresponding to 110 million fish). The bad weather conditions found last year as well as the behaviour observed of near-coast schools, mainly concentrated in shallower waters in a very hard and rough sea bed, thus no accessible to the pelagic year, which represented the 33% of the total backscattering energy and left as unallocated, would be a plausible explanation for such increase. On the other hand, as shown in figure 19, the main difference between both surveys is the lack of a 20 cm mode (mainly age group 1) during the previous survey as compared with 2014 survey. Given the presence of this length mode through the whole surveyed area, it seems that the strength of the 2013 recruitment would be higher than that of the previous ones.

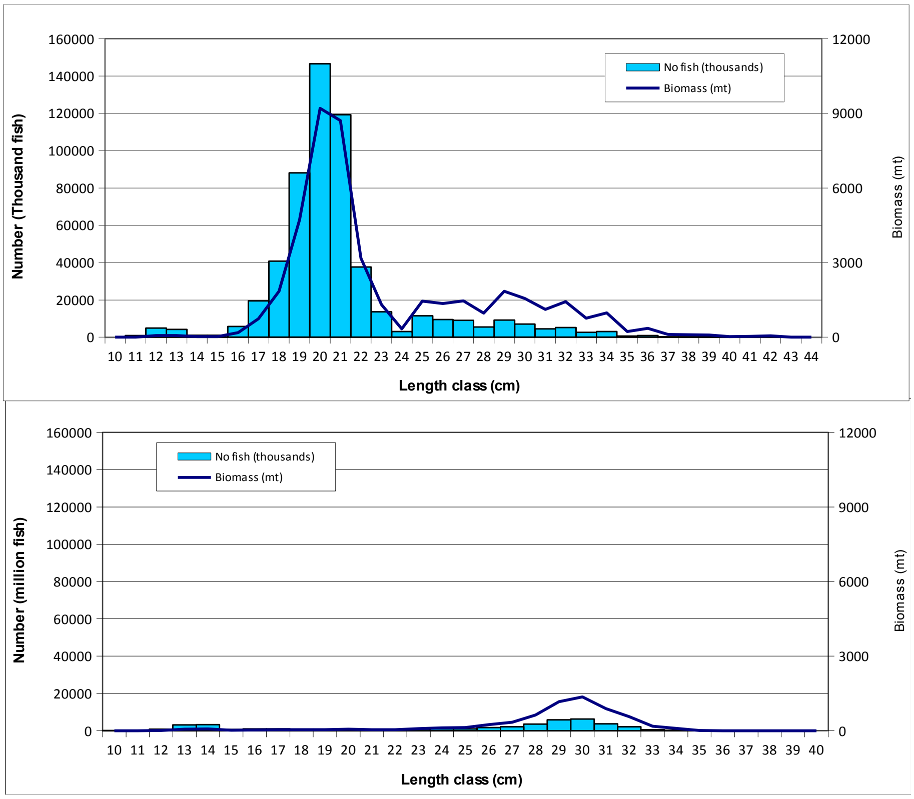


Figure 19: Horse mackerel length distribution in both number and biomass during the PELACUS0314 (above) and PELACUS 0313 (below) surveys.

On the other hand the differences between this assessment and that derived from the application of the new boarfish TS length relationship is almost negligible (0.25%)

Boarfish distribution and assessment

Boarfish spatial distribution and length structure remained very similar to those observed last year (figure 20). Smaller size was detected in the eastern part of Cape Ortegal (7ºW) with a principal mode located at 8 cm, while for the rest of the areas the main mode was estimated at 14 cm. Besides, as in previous years, boarfish occurred either in isolate, thick schools, mainly located in the western part and in near bottom layer, sometimes mixed with other fish species.

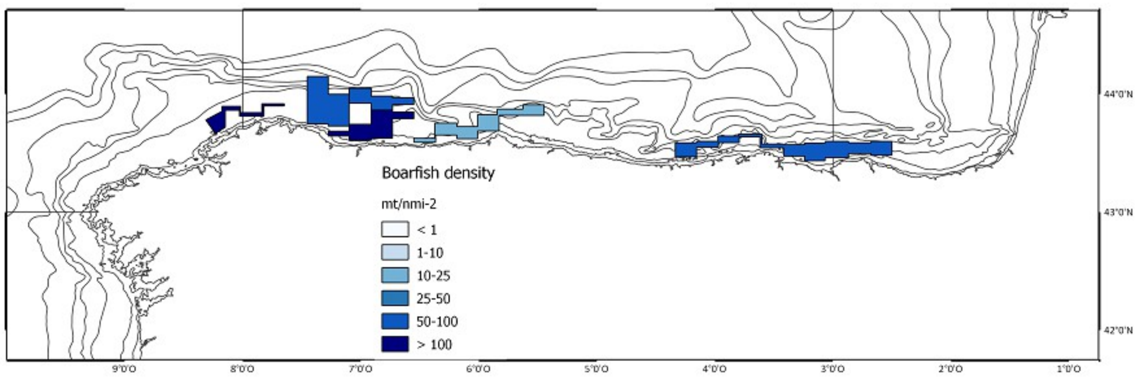


Figure 20. Board fish spatial distribution PELACUS0314 cruise. Polygons are drawn to encompass the observed echoes, and polygon colour indicates the mean density expressed as tonnes per squared nautical mile (<1,; 1-10; 10-25; 25-50; 50-100; and >100)

For the assessment we have kept the old TS/length relation ship for comparison purposes, but, together with this, we have used the new one estimation.

Accordingly, using the new TS estimation, a total of 25344 has been estimated corresponding to 581 million fish. (table 10). In the same way, using the old TS estimation which was so much lower than the new one (6.4 dB), the total biomass reached 98220 mt (2167 million fish), which was 6 times higher than that of the previous year (16067 tonnes, corresponding to 437 million fish), but still far from the maximum assessed in 2011 when more than 220 thousand tonnes were estimated. In 2012 the total biomass assessed were 33.238 corresponding to 518 million fish.

Table 12: Boarfish acoustic assessment

		SURVEY:	PELACUS 0314 BOAR FISH					
Zone	**Area**	**No**	**Mean**	**Area**	**Fishing st.**	**PDF**	**No (million fish)**	**Biomass (tonnes)**
VIIIc-W	Capelada	13	264.57	93.92	P21	S01	39.10	2321.75
	Total	***13***	***265***	***94***			***39***	***2322***
VIIIc-E	Estaca	34	136.59	310.86	P24	S02	74	3790
	Masma Coast	28	315.74	225.18	P27	S03	107	6763
	Masma Off-shore	17	301.03	144.32	P28	S04	184	2643
	Asturias_Occ	30	112.63	251.50	P32-P40-P42-P44-P45-P46	S05	47	2590
	Cantabria	55	186.94	423.37	P32-P40-P42-P44-P45-P46	S05	131	7235
	Total	***164***	***196.73***	***1355***			***542***	***23022***
Total VIIIc		***177***	***202***	***1449***			***581***	***25344***
Total Spain		***177***	***202***	***1449***			***581***	***25344***

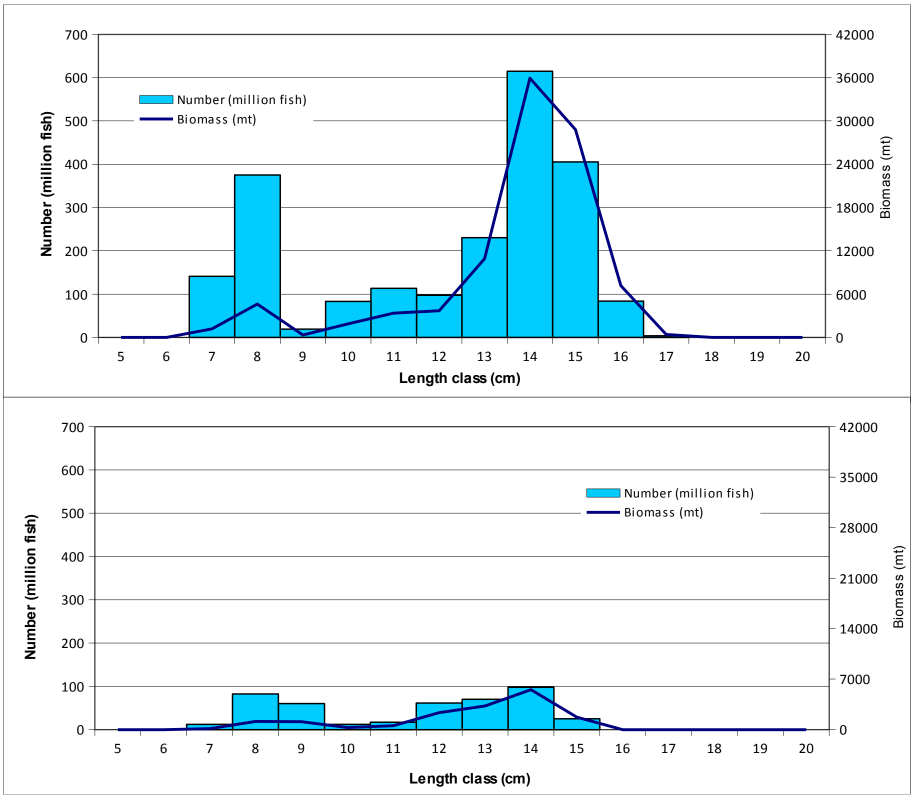


Figure 21. Boarfish length distribution in both number and biomass during the PELACUS0314 (above) and PELACUS 0313 (below) surveys.

When possible boarfish schools were directly allocated. Nevertheless, relative frequency response seems to be highly variable, and, although there is a clear pattern with a weak response at high frequencies, specially at 200 kHz, in some cases responses at 18 kHz or at 120 kHz were higher than those reported by Fässler et al (2013), as shown in figure 22a-b. Whether this changes are related to the fish size (i.e. different frequency resonant in relation total size) or to physiological condition or behaviour (i.e. spawning) should be further investigated.

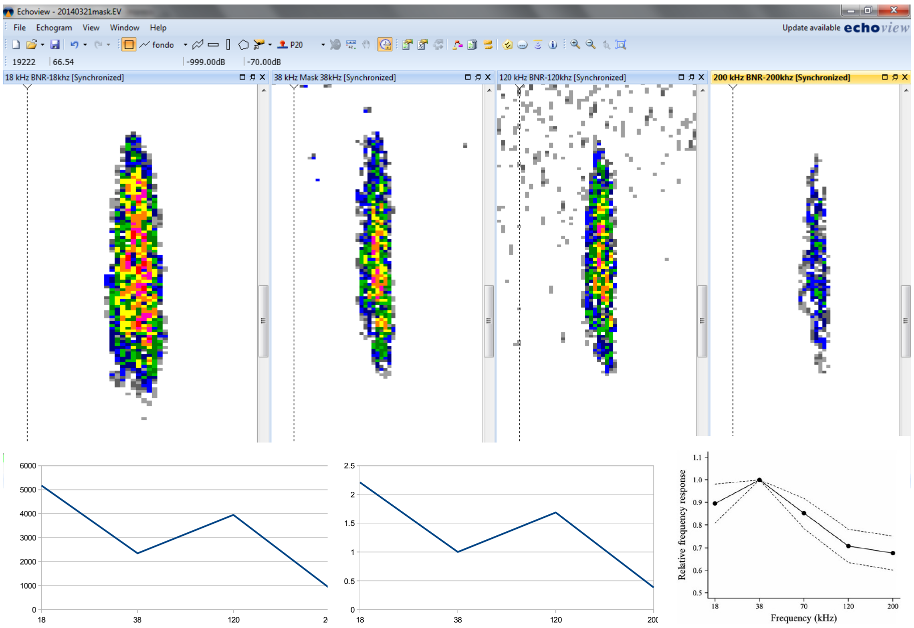


Figure 22a. Boarfish school as observed at 18, 38, 120 and 200 kHz and its absolute frequency response (left plot), relative one (middle plot) and the observed relative frequency response as found in Fässler et al (2003) (right plot).

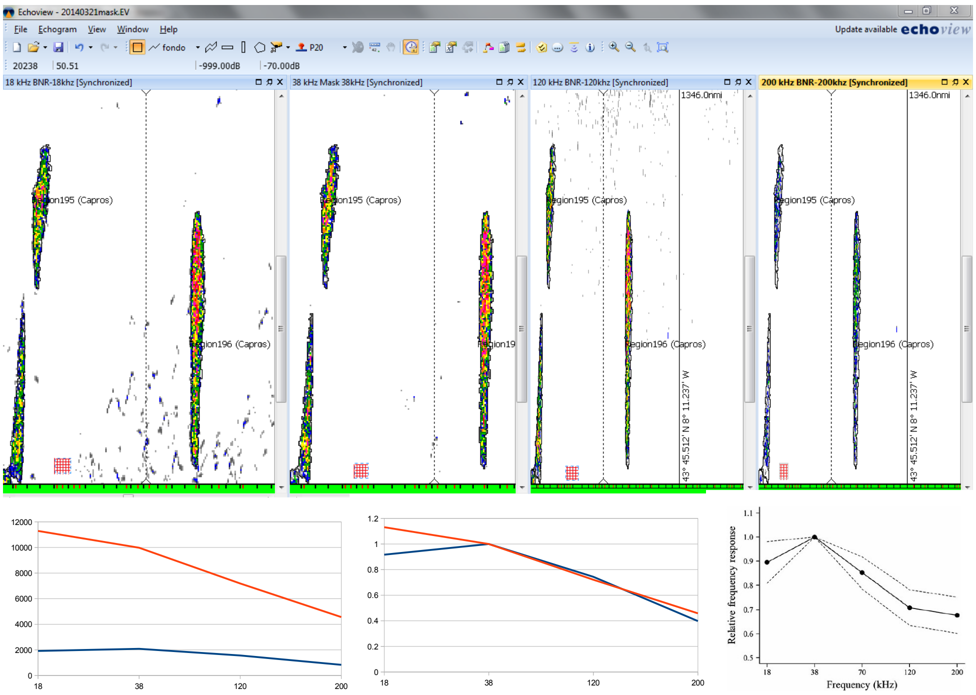


Figure 22b. Ib. Boarfish schools as observed at 18, 38, 120 and 200 kHz and its absolute frequency response (left plot), relative one (middle plot) and the observed relative frequency response as found in Fässler et al (2003) (right plot).

Sardine distribution and assessment

A total of 9,669 tons of sardine (157 million fish) was estimated to be present in the surveyed area. That represents an important increase in relation to 2013 abundance and biomass, but still at the lower levels of the time series. Fish were mainly found in Cantabrian area (mainly in VIIIc East-West subdivision) and inside Rias Baixas (South Galicia, ICES sub-areas IXa-N) and was almost absent from the rest of the surveyed area (figure 23). Most fish in the entire surveyed area were assigned as belonging to the age 2 (38% of the abundance and 43% of the biomass) and age 3 (24.5% of the abundance and 25.5 % of the biomass) years classes. By subdivisions, the IXaN (South of Galicia) population was dominated by age 1 fish whilst the Cantabrian area was mainly composed by a population of age 2 and age 3 individuals.

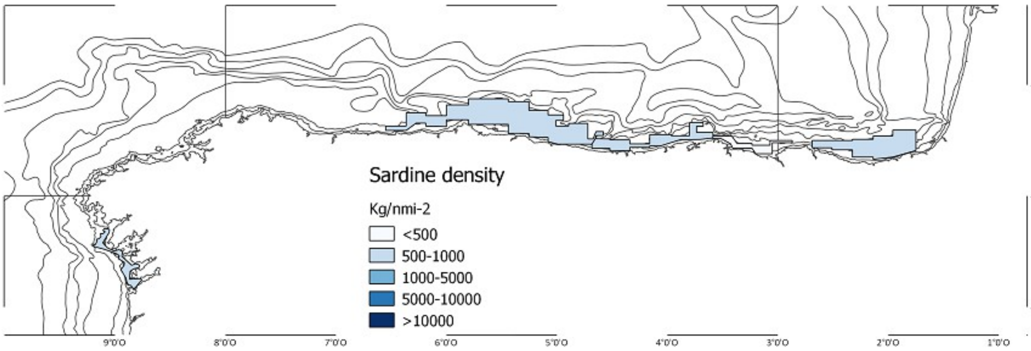


Figure 23. Sardine spatial distribution in PELACUS0314 cruise. Polygons are drawn to encompass the observed echoes, and polygon colour indicates the mean density expressed as kilograms per squared nautical mile (<500,; 500-1000; 1000-5000; 5000-10000; and >10000)

The distribution of sardine eggs (obtained from the analysis of 358 CUFES stations) indicates a very coastal distribution, agreeing with that observed in previous years The percentage of positive stations was very similar in both surveys, but total number of sardine eggs detected in Spanish waters was 4214, which represents an important decrease from the 2013 value.

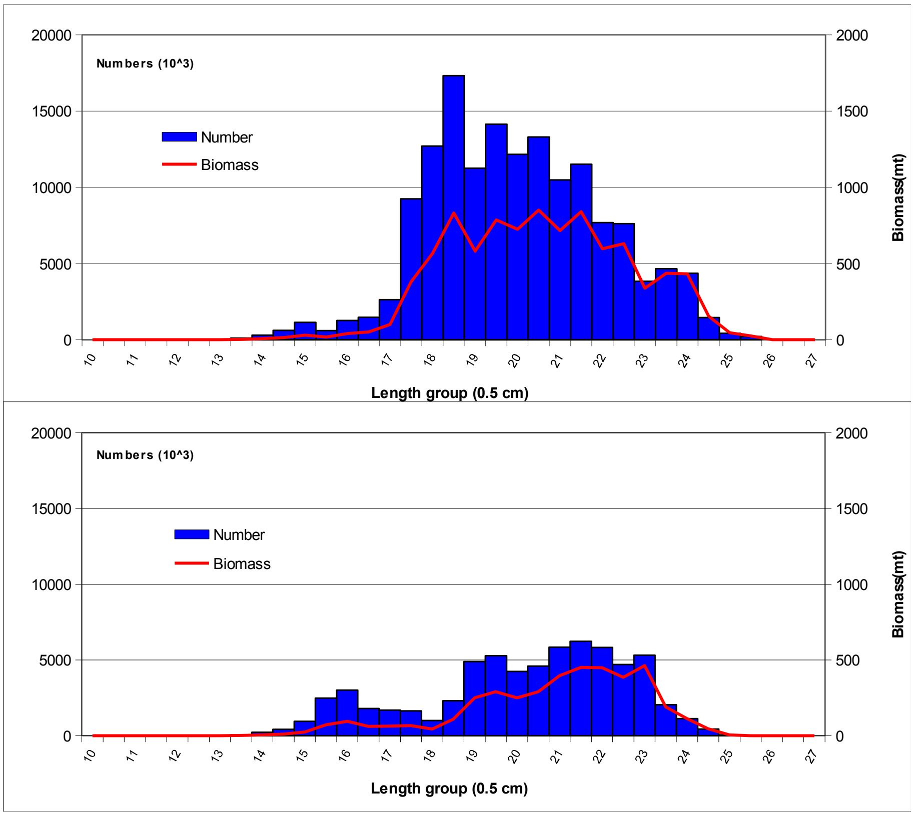


Figure 24. Sardine length distribution in both number and biomass during the PELACUS0314 (above) and PELACUS 0313 (below) surveys.

Other fish species

Only bogue (Boops boops) has an important contribution to the pelagic community; on the contrary, anchovy or Mediterranean horse mackerel had a lesser contribution, with only few tonnes.

Discussion and conclusions

PELACUS 0314 was characterised by relative stable weather conditions along the surveyed area. Besides, there was an important increase in backscattering energy as compared with the previous year. This resulted in an increase of the biomass estimated in the majority of the fish species, but still sardine is at lowest productivity ever recorded. Good recruitment would be observed in horse mackerel, but for the rest of the fish species, no strong signals for age group 1 have been detected.

The reasons for this increase would be related to the weather stability which could have increased the fish availability either for a change in the behaviour (i.e. spatial pattern distribution) or for an increase in the food availability. This is relevant accounting the increase of the occurrence of mackerel subsurface layers observed this year. As PELACUS is a multidisciplinary survey series (we collect environmental and biological ancillary information, stomach contents, including CTD cats, plankton tows or continuous records of plankton, eggs, S, T and flourometry), we will try to explain this change of behaviour. Our main hypothesis is that these species could follow mackerel when is undertaking vertical migration, probably related with the spawning activity, just for feeding eggs and, therefore, changing the expected schooling behaviour by the dispersed one, used during the feeding activity.

The challenges for the next years are to increase the number of school directly allocated accounting the relative frequency response and to investigate and also to update the list of TS/length relationship for the most important fish species.

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