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Acoustic assessment and distribution of anchovy and sardine juveniles in the ICES Subdivision IXa South during the *ECOCÁDIZ-RECLUTAS 1009* Spanish survey (October-November 2009).

By

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ABSTRACT

ECOCÁDIZ-RECLUTAS 1009 survey is the first attempt by the IEO of acoustically assessing the abundance of anchovy and sardine juveniles in their main recruitment areas off the Gulf of Cádiz. The survey was conducted between 26th October and 5th November 2009 onboard the Spanish R/V *Emma Bardán.* In order to achieve a better sampling coverage of juveniles, the acoustic sampling grid was more intensive (4 nm-spaced transects) than the adopted one in conventional surveys. Unfortunately, the initially planned survey area limits and the ship-time available (17 transects over waters shallower than 50 m depth between Tavira and Chipiona, and 11 days) showed both insufficient due to a deeper bathymetric distribution of anchovy juveniles than expected and the sucession of a series of unforeseen problems which led to drastically reduce the actual sampled area to only 6 transects from the easternmost zone. Acoustic estimates from this last area are available for anchovy (2 771 t, 524 million fish), sardine (25 167 t, 500 millions), chub mackerel (17 627 t, 152 millions) and Mediterranean horse-mackerel (17 005 t, 159 millions). The abundance and biomass of age 0 anchovies in the surveyed area were estimated at 2 588 t and 510 million fish, respectively, *i.e.* 93% and 97% of the total estimated anchovy biomass and abundance. Sardine estimates were not age-structured but the abundance and biomass of juveniles smaller than 17 cm were estimated at 3 382 t and 130 millions, 13% and 26% of the total estimated species' biomass and abundance. An approximate evaluation of the impact of the incomplete coverage of the anchovy juvenile distribution during the survey was carried out by comparison of our data with the resulting yields and location of positive fishing stations from a groundfish survey carried out just after the present survey.

INTRODUCTION

During the 2007 and 2008 meetings of ICES *Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES areas VIII and IX* (WGACEGG) was advanced the possibility of carrying out, since 2009 on, internationally coordinated yearly surveys aimed at the direct estimation of the anchovy and sardine recruitment in the Division IXa (ICES, 2007, 2008). Conduction of such surveys would require, at least in the Gulf of Cadiz, of an appropiate acoustic sampling of the shallowest waters of its central part, an area which the conventional surveys (either Spanish or Portuguese) did not sample but, however, used to conform a great part of the recruitment areas of these species.

The general objective of these surveys should initially be focused in the acoustic assessment by vertical echo-integration and mapping of the abundance and biomass of recruits of small pelagic species (especially anchovy and secondarily sardine), as well as the mapping of both the oceanographic and biological

conditions featuring the recruitment areas of these species in the Division IXa. The long term objective of the surveys would be to be able to assess the strength of the incoming recruitment to the fishery the next year.

ECOCÁDIZ-RECLUTAS 1009 survey is the first attempt by the IEO of acoustically assessing the abundance of anchovy and sardine juveniles in their main recruitment areas off the Gulf of Cádiz. The continuation of this survey is still not guaranteed for next years and in fact no survey of these characteristics has been carried out in 2010.

The present Working Document summarises the main results from this survey. Unfortunately, the surveyed area was practically restricted to a third of the previously planned acoustic transects because of a series of biological, technical, logistic and unexpected reasons which will be commented below.

MATERIAL AND METHODS

The *ECOCÁDIZ-RECLUTAS 1009* survey was carried out between 26th October and 5th November 2009 onboard the Spanish R/V *Emma Bardán*. Previous studies and knowledge on the Gulf of Cádiz anchovy nursery grounds and recruitment areas led to initially plan the conduction of the survey over those Spanish and Portuguese coastal waters located between Tavira (east of Cape Santa María, Portugal) and Chipiona (west of Bay of Cádiz, Spain) landmarks and from less than 50 m depth inshore.

In order to increase the acoustic sampling coverage, an intensive systematic parallel grid of 4 nm equally spaced transects normal to the shoreline was designed, resulting a grid composed by a total of 17 transects (**Figure 1**). An alternative option of increasing the transect length up to the 100 m isobath was also considered, but only as a possibility, hence no extra ship-time was considered necessary when initially planning the survey (**Figure 1**).

Echo-integration was carried out with a *Simrad™ EK60* echo sounder working in the multi-frequency fashion (38, 120, 200 kHz). Average survey speed was initially planned to be at 10 knots although such speed was not reached for the reasons given below. The acoustic signals were integrated over 1-nm intervals (ESDU). Raw acoustic data were stored for further post-processing using *Myriax Software Echoview™* software package (by *Myriax Software Pty. Ltd.,* ex *SonarData Pty. Ltd.*). Acoustic equipment was previously calibrated during the *JUVENA 2009* acoustic survey, a survey conducted in the Bay of Biscay waters just before the present survey, following the standard procedures (Foote *et al*., 1987).

Survey execution and abundance estimation followed the methodologies adopted by the ICES *Planning Group for Acoustic Surveys in ICES Sub-Areas VIII and IX* (Anon., 1998) and the recommendations given by the *Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES areas VIII and IX* (WGACEGG; ICES, 2006b,c).

Fishing stations were opportunistic, according to the echogram information, and they were carried out using the 10-12 m-vertical opening pelagic trawl *Gloria HOD 352* at an average speed of 4 knots. Gear performance and geometry during the effective fishing was monitored with a set of *SCANMAR™ Trawl Eye-Vertical Opening-Depth* sensors which were operated by a combination of *SCANMAR™* portable hydrophone and *ScanBas* desk unit.

Trawl samples provided biological data on species and they were also used to identify fish species and to allocate the back-scattering values into fish species according to the proportions found at the fishing stations (Nakken and Dommasnes, 1975). The *PESMA 2010* software (J. Miquel, unpublished) has got implemented the needed procedures and routines for the acoustic assessment following the above approach.

Length frequency distributions (LFD) by 0.5-cm class were obtained for all the fish species in trawl samples (either from the total catch or from a representative random sample of 100-200 fish). For the purpose of the acoustic assessment it was only considered those size distributions based on a minimum of 30 individuals.

Individual biological sampling (length, weight, sex, maturity stage, stomach fullness, mesenteric fat content) was performed in each haul for anchovy, sardine (in both species with otolith extraction), mackerel and horse-mackerel species, and bogue.

No egg sampling by CUFES was carried out during the survey.

The following TS/length relationship table was used for acoustic estimation of assessed species (recent IEO standards after Anon., 1998; and recommendations by ICES, 2006b,c):

Species	b_{20}
Sardine (*Sardina pilchardus*)	-72.6
Round sardinella (*Sardinella aurita*)	-72.6
Anchovy (*Engraulis encrasicolus*)	-72.6
Chub mackerel (*Scomber japonicus*)	-68.7
Mackerel (*S. scombrus*)	-84.9
Horse mackerel (*Trachurus trachurus*)	-68.7
Mediterranean horse-mackerel (*T. mediterraneus*)	-68.7
Blue jack mackerel (*T. picturatus*)	-68.7
Bogue (*Boops boops*)	-67.0

Vertical profiles of hydrographical variables were recorded by day from quasi-opportunistic CTD stations carried out in both extremes of alternate acoustic transects and after finishing each of the fishing stations by using a *Sea-bird Electronics® SBE 25 SEALOGGER* profiler.

RESULTS

Acoustic sampling

The initial plan of restricting the acoustic survey to waters shallower than 50 m depth only was necessarily rejected since anchovy recruits were found since the first moment beyond than this isobath. Instead, the alternative scheme of extending the acoustic transects to the 100 m isobath had to be adopted as the best compromise, which involved to invest more time per transect than the foreseen. On the other hand, the research vessel's auto-noise was assessed by different tests during the survey's first day and they indicated that the best speed for acoustic sampling was that of 8.5 knots, somewhat slower than the conventional or standard one of 10 knots. Further, a worsening of the sea conditions was recorded during the second half of the survey which affected to the transductors' performance (numerous signal losses), mainly that of the 38 kHz. In order to reduce such losses the engine revolutions were reduced from 1250 rpm (yielding at about 8.5 knots) to 1150 rpm (7.5 knots in average). All of these facts, joined to other logistic-based factors such as the (relatively low) R/V autonomy, very distant home-ports, an interruption of one day long for replacing the crew, and even the coincidence with Spanish Navy military manoeuvres just in the middle of the survey, prevented from achieving the foreseen sampling coverage. Thus, our acoustic sampling area had to be restricted only to the one comprising the six easternmost planned transects (transects 01 to 06) plus one additional transect (00) placed 4 miles eastward to the first transect, in front of Rota, because of the occurrence of anchovy recruits in these waters.

Fishing stations

Seventeen (17) fishing operations, 14 of them valid ones according to a correct gear performance and resulting catches, were carried out (**Table 1**, **Figure 2**).

Fishing hauls were usually attempted by fishing over an isobath crossing the acoustic transect as close as possible to the depths where the fishing situation of interest was detected over that transect. In this way the mixing of different size compositions (*i.e*., bi-, multi-modality of length frequency distributions) was avoided as well as a direct interaction with fixed gears. The mixing of sizes is more probable close to nursery-recruitment areas and in regions with a very narrow continental shelf. Given that all of these situations were not very uncommon in the sampled area, all but one valid haul (13 hauls) were conducted over isobath.

Because of the echo-traces usually occurred close to the bottom, all the pelagic hauls but fishing station 12, were carried out like a bottom-trawl haul, with the ground rope working very close to the bottom. According to the above, the sampled depth range in the valid hauls oscillated between 24-84 m.

The percentage of occurrence of the more frequent species in the valid hauls is shown in the enclosed text table below (see also **Figure 3**). From the set of small and mid-sized pelagic fish species stood especially out anchovy, sardine, chub mackerel and Mediterranean horse-mackerel (present in 11 hauls each, 79% of occurrence), followed quite far by bogue (6 hauls, 43%). Mackerel and horse-mackerel showed an even lower occurrence and abundance in hauls whereas round sardinella and blue jack-mackerel were absent.

Species	# of fishing stations	Occurrence (%)
Engraulis encrasicolus	11	78,57
Scomber colias	11	78,57
Sardina pilchardus	11	78,57
Trachurus mediterraneus	11	78,57
Loligo vulgaris	10	71,43
Alloteuthis media	9	57,14
Alloteuthis subulata	9	57,14
Merluccius merluccius	8	57,14
Diplodus bellotti	7	50,00
Boops boops	6	42,86
Pomadasys incisus	6	42,86
Liza ramada	6	42,86

For the purposes of the acoustic assessment, anchovy, sardine, round sardinelle, mackerels, horse & jack mackerels, and bogue were initially considered as the survey target species. All of the invertebrates, and both bentho-pelagic (*e.g*., manta rays) and benthic fish species (*e.g*., flatfish, gurnards, etc.) were excluded from the computation of the total catches in weight and in number from those fishing stations where they occurred. Catches of the remaining non-target species were included in an operational category termed as "*Others*".

According to these premises, during the survey was captured a total of 4 795 kg and 89 thousand fish. 53**%** of the total fished biomass corresponded to chub mackerel, 29**%** to sardine, 7**%** to Mediterranean horse-mackerel, and only 5% to anchovy (**Table 2**). The most abundant species were sardine and anchovy (35% and 34% of the total number, respectively), followed by chub mackerel (28%) and then, at a far distance by Mediterranean horse-mackerel (4%). Mackerel and horse mackerel were accidental in the pelagic trawls, whereas blue jack mackerel and round sardinella were absent.

Back-scattering energy attributed to the "pelagic assemblage" and individual species

A total of 113 nmi (ESDU) from 6 transects has been acoustically sampled by echo-integration for assessment purposes. The enclosed text table below provides the nautical area-scattering coefficients attributed to each of the selected target species and for the whole "pelagic fish assemblage".

S_A (m^2 nmi^{-2})	Total spp.	Sardine	Round sardinella	Anchovy	Mackerel	Chub mack.	Horse-mack.	Medit. h-mack.	Blue jack-mack.	Bogue
Total Area (%)	126896 (100.0)	30931 (24.4)	0 (0.0)	8977 (7.1)	0 (0.0)	44412 (35.0)	13 (0.01)	41707 (32.9)	0 (0.0)	855 (0.7)

For this "pelagic fish assemblage" has been estimated a total of 126 896 m^2 nmi^{-2}. The highest NASC values have been recorded in the inner shelf, mainly in front the Guadalquivir river mouth. The mapping of the total back-scattering energy is shown in **Figure 3**. By species, chub mackerel accounted for 35% of this total back-scattered energy, followed by Mediterranean horse-mackerel (33%), sardine (24%) and anchovy (only 7%). These especies have been those ones finally assessed. Bogue and horse-mackerel recorded negligible energetic contributions.

Spatial distribution and abundance/biomass estimates

Anchovy

Parameters of the survey's length-weight relationship for anchovy are given in **Figure 4**. The positive valid fishing stations with anchovy and the coherent strata considered for the acoustic estimation are shown in **Figure 5**. The estimated abundance and biomass by size and age class are given in **Tables 3** and **4** and **Figures 6** and **7**.

Anchovy surprisingly avoided the coastal and inner shelf waters in front of the Guadalquivir river mouth, showing their highest densities just in a relatively small area located at the east of the above zone, also all over the inner shelf (**Figure 5**). Curiously, the void left by anchovy is occupied, as it will commented below, by the other 3 assessed species.

Three coherent post-strata have been differentiated according to the S_A values distribution and the size composition in the fishing stations. The acoustic estimates by each post-stratum and total area are shown in **Tables 3** and **4**, and **Figure 6** and **7**. Anchovy was the most abundant species but, conversely, the species which yielded the lowest biomass of the set of the assessed species. Thus, a total of 2 771 t and 524 millions of fish have been estimated for this species for the whole surveyed area. The polygon 1 concentrated the bulk of the assessed (sampled) population. The size class range of the assessed population varied between 4.5 and 17 cm, with three modal classes at 5.5, 10 (the main one) and 12 cm. Age structured estimates yielded the following results:

- The abundance and biomass of age 0 anchovies in the surveyed area were estimated at 2 588 t and 510 million fish, respectively, *i.e.* 93% and 97% of the total estimated anchovy biomass and abundance.
- The size of age 0 anchovies ranged between 4.5 and 13 cm size classes, showing two modes at 5.5 cm (secondary) and 10 cm (the main one).
- Age 0 anchovies were more abundant in the abovementioned zone where also showed the highest values of acoustic energy (polygon 1). Here, age 0 anchovies showed a smaller size as well: the size ranged between 4.5 and 12 cm, wth modes at 5.5 cm (secondary) and 10 cm (the main one).
- In the remaining post-strata the age 0 anchovies were somewhat larger and showing one only mode at 10 cm.

Sardine

Parameters of the survey's size-weight relationship for sardine are shown in **Figure 4**. The positive valid fishing stations with sardine and the coherent strata considered for the acoustic estimation are shown in **Figure 8**. Estimated abundance and biomass by size class are given in **Table 5** and **Figure 9**.

Sardine showed a more widespread distribution than anchovy, occurring all over the inner-middle shelf and showing the highest densities in deeper waters than the former species (**Figure 8**).

Four coherent post-strata were delimited for the acoustic assessment. The acoustic estimates by stratum and total area are shown in **Table 5** and **Figure 9**. Sardine was the most important species in terms of biomass and the second in abundance: 25 167 t and 500 millions of fish have been estimated for this species for the whole surveyed area.

The size range of the assessed population ranged between 10.5 and 23 cm size classes, with three modal classes at 12 (the less abundant mode), 15 (the secondary mode) and 18.5 cm (the main one). The size composition of the surveyed population evidences that the central coastal area might correspond with both a recruitment and spawning area for the species (**Table 5**, **Figure 9**). The estimates are not age structured, although may be assumed that the two first cohorts should correspond to juvenile sardines. According to this, and establishing a size limit for this fraction at the 16.5 cm size class, the abundance and biomass of these juveniles (i.e., smaller than 17 cm) would be estimated at 3 382 t and 130 millions,13% and 26% of the total estimated biomass and abundance.

Chub mackerel

Parameters of the survey's length-weight relationship are shown in **Figure 4**. The positive valid fishing stations with chub mackerel and the coherent strata considered for the acoustic estimation are shown in **Figure 10**. Estimated abundance and biomass by size class are given in **Table 6** and **Figure 11**.

Chub mackerel showed a low density in coastal waters, the species being mainly distributed in the easternmost area, in the deeper waters of the inner shelf and over the middle shelf (**Figure 10**).

Three sectors were differentiated for the purposes of acoustic assessment. The acoustic estimates by homogeneous stratum and total area are shown in **Table 6** and **Figure 11**. Chub mackerel in the sampled area rendered estimates of 17 627 t (the second most important species after sardine) and 152 million fish.

The size class range for the assessed population oscillated between 20 and 33 cm size classes, although fish larger than 28 cm were very scarce. At least one modal class at 23.5 cm may be differentiated in the sampled population, corresponding to sub-adult fish (**Table 6** and **Figure 11**). Smaller fish seem to be more frequent in the western area.

Mediterranean horse-mackerel

The survey's length-weight relationship for this species is shown in **Figure 4**. Positive fishing stations and coherent strata are represented in **Figure 12**. Estimated abundance and biomass by size class are given in **Table 7** and **Figure 13**.

Mediterranean horse-mackerel was only present over the Spanish inner shelf waters, with the densest concentrations being recorded in the central area, in front of the Guadalquivir river mouth **(Figure 12**). Size range of the sampled population oscillated between 20 and 36 cm size classes, although the bulk of the sampled specimens occurred between 21 and 26 cm, with fish larger than 31.5 cm being accidental. One modal class may be observed at 23 cm (**Table 7**, **Figure 13**).

The acoustic estimates, given in **Table 7** and **Figure 13**, were: 17 007 t and 159 millions of fish.

(SHORT) DISCUSSION

Figure 14 shows an attempt of assessing the magnitude of our under-sampling of the extension of the distribution area of anchovy juveniles by comparison of our results with the ones obtained during the ARSA 1109 groundfish survey, a survey conducted just after the acoustic one (9^{th} – 23^{rd} November). This is the only ancillary information available, since the fishery in those dates (the other source of information possible) either showed a very low intensity or even stopped.

Although the bottom-trawl gear used in the groundfish survey (2 m vertical opening) not showed as the most suitable gear to sample anchovy, the distribution of the occurrence of the species in this last survey might give us an approximate picture of the probable general distribution of the species in the area. The size and age composition from bottom trawl hauls indicate that smaller (age 0) anchovies are mainly concentrated in the same waters previously sampled by us. Taking into account that our results are under-estimated, these data seem to suggest that such estimates might well include the bulk of the juvenile fraction of the anchovy population.

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Table 1. *ECOCÁDIZ-RECLUTAS 1009* survey. Descriptive characteristics of the fishing stations. Null hauls are shadowed.

Fishing station	Date	Start		End		GMT Time		Depth (m)		Duration (min.)		Acoustic track	Zone
		Latitude	Longitude	Latitude	Longitude	Start	End	Start	End	Effective trawling	Total maneuver		
01	27/10/09	36º 34.815' N	6º 44.073' W	36º 37.239' N	6º 46.593' W	11:46	12:44	105	108	60	108	R01	Sanlúcar
02	27/10/09	36º 37.541' N	6º 47.174' W	36º 36.392' N	6º 45.420' W	14:52.	15:29	110	105	37	66	R01	Sanlúcar
03	28/10/09	36º 37.684' N	6º 45.656' W	36º 40.077' N	6º 46.765' W	12:08	12:50	100	100	42	69	R02	Sanlúcar
04	28/10/09	36º 44.625' N	6º 36.741' W	36º 41.903' N	6º 34.417' W	14:56	15:50	26	26	54	72	R02	Sanlúcar
05	29/10/09	36º 46.267' N	6º 37.019' W	36º 49.503' N	6º 38.083' W	11:43	12:33	25	24	50	75	R03-R04	Te. Salabar-Te. Carbonero
06	29/10/09	36º 42.876' N	6º 41.976' W	36º 40.935' N	6º 40.089' W	15:27	16:11	52	51	44	72	R03-R02	Te. Salabar-Sanlúcar
07	30/10/09	36º 58.021' N	6º 35.175' W	36º 53.858' N	6º 38.001' W	11:51	12:34	20	19	43	87	R04-R05	Te. Carbonero-Charco del Toro
08	30/10/09	36º 44.332' N	6º 46.949' W	36º 42.179' N	6º 45.010' W	15:29	16:14	76	76	45	74	R04-R03	Te. Carbonero-Te. Salabar
09	30/10/09	36º 41.288' N	6º 36.163' W	36º 43.753' N	6º 31.882' W	9:40	10:19	22	20	39	63	R01-R02	Chipiona
10	31/10/09	36º 36.007' N	6º 33.712' W	36º 35.852' N	6º 32.246' W	11:45	12:25	42	48	40	65	R01-R00	Chipiona-Rota
11	31/10/09	36º 37.167' N	6º 39.743' W	36º 40.179' N	6º 42.205' W	13:42	14:41	71	69	59	89	R02	Sanlúcar
12	02/11/09	36º 50.152' N	6º 40.740' W	36º 52.304' N	6º 42.648' W	11:44	12:27	25	27	43	75	R05	Te. Carbonero
13	02/11/09	36º 52.908' N	6º 43.208' W	36º 50.222' N	6º 40.824' W	14:06	14:52	28	25	46	73	R05	Charco del Toro
14	03/11/09	36º 45.985' N	6º 49.425' W	36º 48.270' N	6º 51.289' W	11:52	12:41	84	84	49	78	R05	Te. Carbonero
15	03/11/09	36º 48.570' N	6º 48.744' W	36º 50.323' N	6º 50.698' W	14:06	14:46	65	67	40	67	R05	Charco del Toro
16	04/11/09	36º 33.737' N	6º 38.346' W	36º 31.168' N	6º 35.590' W	11:25	12:21	79	78	56	80	R00	Rota
17	04/11/09	36º 31.716' N	6º 30.648' W	36º 33.906' N	6º 31.847' W	13:40	14:24	56	55	44	69	R00	Rota

Table 2. *ECOCÁDIZ-RECLUTAS 1009* survey. Catches by species in number (upper panel) and weight (in kg, lower panel) from valid fishing stations.

Fishing station	ABUNDANCE (nº)									
	Anchovy	*Sardine*	*Chub Mack*	*Mackerel*	*Horse Mack*	*Blue Jack-Mackerel*	*Medit. Horse-Mackerel*	*Bogue*	Others spp.	TOTAL
04		17677	6832				585	8	133	**25235**
05	451	11752	28				1297		750	**14278**
06	219	98	3				5		52	**377**
07		336	3445				516	42	679	**5018**
08	479	64	1	1			30	2	468	**728**
09	1923	316	7				174		244	**2664**
10	554	37		1			22	20	28	**662**
11	920	9	1				18		62	**1010**
12	12		14679				15	4	11	**14721**
13			138		1		464	14	457	**1074**
14	6568	2	1						13	**6584**
15	11336	109		1	3				9	**11458**
16	3681	116					7		7	**3811**
17	692		2				157		17	**868**
TOTAL	**26835**	**30516**	**25137**	**3**	**4**		**11498**	**90**	**2930**	**88805**

Fishing station	BIOMASS (kg)									
	Anchovy	*Sardine*	*Chub Mack*	*Mackerel*	*Horse Mack*	*Blue Jack-Mackerel*	*Medit. Horse-Mackerel*	*Bogue*	Others spp.	TOTAL
04		903.87	649.92				51.12	1.85	23.90	**1630.65**
05	1.78	453.51	4.27				112.61		79.92	**652.08**
06	1.39	4.32	0.30				0.48		5.92	**12.41**
07		7.06	426.48				52.64	2.70	58.29	**547.16**
08	3.96	3.75	0.07	0.18			2.70	0.18	0.74	**11.57**
09	6.80	12.10	1.19				26.00		28.75	**74.84**
10	2.55	2.14		0.22			2.62	2.09	3.94	**13.57**
11	7.00	0.38	0.11				1.50		4.54	**13.53**
12	0.11		1439.83				1.45	0.70	2.18	**1444.27**
13			13.50		0.02		41.10	1.57	92.06	**148.25**
14	74.79	0.05	0.09						1.98	**76.91**
15	99.40	2.69		0.15	0.16				1.08	**103.47**
16	37.65	3.60					0.38		0.65	**42.28**
17	4.65		0.22				18.35		0.71	**23.93**
TOTAL	**240.09**	**1393.45**	**2535.97**	**0.55**	**0.18**		**310.95**	**9.08**	**304.65**	**4794.91**

Table 3. *ECOCÁDIZ-RECLUTAS 1009* survey. Anchovy (*E. encrasicolus*). Estimated abundance and biomass by size class.

***ECOCÁDIZ-RECLUTAS 1009* . *Engraulis encrasicolus* . ABUNDANCE (in number of fish)**					
Size class	**POL01**	**POL02**	**POL03**	**TOTAL n**	**Millions**
4	0	0	0	0	**0**
4.5	1315544	0	0	1315544	**1**
5	6577719	0	0	6577719	**7**
5.5	17103669	0	0	17103669	**17**
6	7893263	0	0	7893263	**8**
6.5	7324207	82417	0	7406624	**7**
7	4482120	123670	0	4605790	**5**
7.5	27939723	183068	0	28122791	**28**
8	40102510	141815	0	40244325	**40**
8.5	55689227	295454	0	55984681	**56**
9	63649626	1424374	0	65074000	**65**
9.5	85978706	4073443	306826	90358975	**90**
10	90654242	8338079	935993	99928314	**100**
10.5	41998299	7427884	1207049	50633232	**51**
11	17500091	4517934	949101	22967126	**23**
11.5	2782943	2598789	975153	6356885	**6**
12	4277516	1811272	1165684	7254472	**7**
12.5	3259288	2050488	1170543	6480319	**6**
13	1018228	1373010	798547	3189785	**3**
13.5	0	869122	254762	1123884	**1**
14	0	355574	223034	578608	**1**
14.5	0	322355	101758	424113	**0**
15	0	89368	19519	108887	**0**
15.5	0	29970	19519	49489	**0**
16	0	0	19519	19519	**0**
16.5	0	0	0	0	**0**
17	0	0	19519	19519	**0**
17.5	0	0	0	0	**0**
18	0	0	0	0	**0**
TOTAL n	**479546921**	**36108086**	**8166526**	**523821533**	**524**
Millions	**480**	**36**	**8**	**524**	

Table 3 (cont'd)**.**

ECOCÁDIZ-RECLUTAS 1009 . *Engraulis encrasicolus* . BIOMASS (t)				
Size class	**POL01**	**POL02**	**POL03**	**TOTAL**
4	0	0	0	0
4.5	0.760	0	0	0.760
5	5.185	0	0	5.185
5.5	17.896	0	0	17.896
6	10.706	0	0	10.706
6.5	12.623	0.142	0	12.765
7	9.648	0.266	0	9.914
7.5	74.017	0.485	0	74.502
8	129.058	0.456	0	129.514
8.5	215.236	1.142	0	216.378
9	292.447	6.544	0	298.991
9.5	465.368	22.048	1.661	489.077
10	573.309	52.731	5.919	631.959
10.5	308.04	54.48	8.853	371.373
11	147.864	38.174	8.019	194.057
11.5	26.922	25.140	9.433	61.495
12	47.110	19.948	12.838	79.896
12.5	40.655	25.577	14.601	80.833
13	14.316	19.305	11.228	44.849
13.5	0	13.713	4.020	17.733
14	0	6.270	3.933	10.203
14.5	0	6.328	1.998	8.326
15	0	1.946	0.425	2.371
15.5	0	0.722	0.470	1.192
16	0	0	0.518	0.518
16.5	0	0	0	0
17	0	0	0.624	0.624
17.5	0	0	0	0
18	0	0	0	0
TOTAL	**2391.160**	**295.417**	**84.540**	**2771.117**

Table 4. *ECOCÁDIZ-RECLUTAS 1009* survey. Anchovy (*E. encrasicolus*). Estimated abundance (thousands of individuals) and biomass (tonnes) by age group and homogeneous stratum (Polygons, POL03 to POL01, ordered from west to east).

Age class	POL03	POL02	POL01	TOTAL
	Number	Number	Number	Number
0	5514	30552	472418	**510077**
I	2598	5556	7129	**13655**
II	54	0	0	**89**
III	0	0	0	**0**
IV	0	0	0	**0**
TOTAL	**8167**	**36108**	**479547**	**523822**

Age class	POL03	POL02	POL01	TOTAL
	Weight	Weight	Weight	Weight
0	47.314	217.041	2304.542	**2587.779**
I	35.737	78.346	86.369	**180.777**
II	1,480	0	0	**0**
III	0	0	0	**0**
IV	0	0	0	**0**
TOTAL	**84.531**	**295.387**	**2390.911**	**2768.556**

Table 5. *ECOCÁDIZ-RECLUTAS 1009* survey. Sardine (*S. pilchardus*). Estimated abundance and biomass by size class.

***ECOCÁDIZ-RECLUTAS 1009* . *Sardina pilchardus* . ABUNDANCE (in number of fish)**						
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**TOTAL n**	**Millions**
10	0	0	0	0	0	**0**
10,5	0	0	155082	0	155082	**0**
11	0	0	776393	0	776393	**1**
11,5	0	2795680	1087049	0	3882729	**4**
12	0	2795680	1863442	0	4659122	**5**
12,5	0	0	1708360	217811	1926171	**2**
13	0	1954804	3882458	0	5837262	**6**
13,5	0	2853600	1863442	653800	5370842	**5**
14	20529	6977307	4193113	2288667	13479616	**13**
14,5	50182	11180653	931967	5885668	18048470	**18**
15	29652	15152319	1242622	8174335	24598928	**25**
15,5	41056	15243336	931967	6103479	22319838	**22**
16	34214	11550928	1087049	4577701	17249892	**17**
16,5	25091	7445839	1087049	2724656	11282635	**11**
17	27372	7445839	1242622	1853045	10568878	**11**
17,5	15965	32875877	3882458	2724656	39498956	**39**
18	11404	47913390	6057046	653800	54635640	**55**
18,5	6842	53527505	6367702	435989	60338038	**60**
19	2281	53230664	6057046	0	59289991	**59**
19,5	0	43401826	2019015	435989	45856830	**46**
20	0	38119717	1863442	0	39983159	**40**
20,5	0	26381583	155082	0	26536665	**27**
21	0	18018331	465738	0	18484069	**18**
21,5	0	11078258	155082	0	11233340	**11**
22	0	0	0	0	0	**0**
22,5	0	975334	0	0	975334	**1**
23	0	2795680	0	0	2795680	**3**
23,5	0	0	0	0	0	**0**
24	0	0	0	0	0	**0**
TOTAL n	**264588**	**413714150**	**49075226**	**36729596**	**499783560**	**500**
Millions	**0,3**	**414**	**49**	**37**	**500**	

Table 5 (cont'd)**.**

ECOCÁDIZ-RECLUTAS 1009 . *Sardina pilchardus* . BIOMASS (t)					
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**TOTAL**
10	0	0	0	0	**0**
10,5	0	0	1,329	0	**1,329**
11	0	0	7,720	0	**7,72**
11,5	0	32,046	12,460	0	**44,506**
12	0	36,724	24,478	0	**61,202**
12,5	0	0	25,577	3,261	**28,838**
13	0	33,189	65,916	0	**99,105**
13,5	0	54,686	35,711	12,529	**102,926**
14	0,442	150,277	90,311	49,293	**290,323**
14,5	1,210	269,551	22,469	141,896	**435,126**
15	0,797	407,372	33,408	219,768	**661,345**
15,5	1,227	455,409	27,843	182,347	**666,826**
16	1,132	382,223	35,971	151,477	**570,803**
16,5	0,917	272,049	39,718	99,551	**412,235**
17	1,101	299,512	49,985	74,540	**425,138**
17,5	0,705	1451,953	171,468	120,334	**1744,46**
18	0,552	2317,283	292,943	31,620	**2642,398**
18,5	0,361	2828,002	336,423	23,034	**3187,82**
19	0,131	3065,032	348,766	0	**3413,929**
19,5	0	2717,648	126,423	27,300	**2871,371**
20	0	2590,22	126,620	0	**2716,84**
20,5	0	1941,438	11,413	0	**1952,851**
21	0	1433,337	37,049	0	**1470,386**
21,5	0	950,889	13,311	0	**964,2**
22	0	0	0	0	**0**
22,5	0	96,971	0	0	**96,971**
23	0	298,433	0	0	**298,433**
23,5	0	0	0	0	**0**
24	0	0	0	0	**0**
TOTAL	**8,575**	**22084,244**	**1937,312**	**1136,950**	**25167,081**

Table 6. *ECOCÁDIZ-RECLUTAS 1009* survey. Chub mackerel (*S. colias*). Estimated abundance and biomass by size class.

***ECOCÁDIZ-RECLUTAS 1009* . *Scomber colias* . ABUNDANCE (in number of fish)**					
Size class	**POL01**	**POL02**	**POL03**	**TOTAL n**	**Millions**
19	0	0	0	0	**0**
19,5	0	0	0	0	**0**
20	0	0	169917	169917	**0**
20,5	0	0	246912	246912	**0**
21	3396812	0	1390167	4786979	**5**
21,5	0	0	2876492	2876492	**3**
22	3396812	0	2181323	5578135	**6**
22,5	13588583	19857	2722757	16331197	**16**
23	16986730	19857	1949742	18956329	**19**
23,5	24913515	218351	1874792	27006658	**27**
24	14721744	168731	1546967	16437442	**16**
24,5	24913515	347383	850862	26111760	**26**
25	10191771	287828	588789	11068388	**11**
25,5	9059946	148874	154841	9363661	**9**
26	4529973	129032	93092	4752097	**5**
26,5	2264986	49620	154841	2469447	**2**
27	4529973	39699	93092	4662764	**5**
27,5	0	9921	0	9921	**0**
28	0	0	0	0	**0**
28,5	0	9921	0	9921	**0**
29	1131825	0	0	1131825	**1**
29,5	0	0	139596	139596	**0**
30	0	0	0	0	**0**
30,5	0	0	0	0	**0**
31	0	0	0	0	**0**
31,5	0	0	0	0	**0**
32	0	0	0	0	**0**
32,5	0	0	0	0	**0**
33	0	9921	0	9921	**0**
33,5	0	0	0	0	**0**
34	0	0	0	0	**0**
TOTAL n	**133626185**	**1458995**	**17034182**	**152119362**	**152**
Millions	**134**	**1**	**17**	**152**	

Table 6 (cont'd)**.**

ECOCÁDIZ-RECLUTAS 1009 . *Scomber colias* . BIOMASS (t)				
Size class	**POL01**	**POL02**	**POL03**	**TOTAL**
19	0	0	0	**0**
19,5	0	0	0	**0**
20	0	0	11,182	**11,182**
20,5	0	0	17,548	**17,548**
21	260,244	0	106,507	**366,751**
21,5	0	0	237,157	**237,157**
22	300,873	0	193,211	**494,084**
22,5	1291,018	1,887	258,683	**1551,588**
23	1728,434	2,020	198,39	**1928,844**
23,5	2710,996	23,760	204,008	**2938,764**
24	1710,790	19,608	179,771	**1910,169**
24,5	3087,689	43,053	105,453	**3236,195**
25	1345,395	37,996	77,725	**1461,116**
25,5	1272,302	20,907	21,745	**1314,954**
26	675,940	19,254	13,891	**709,085**
26,5	358,698	7,858	24,522	**391,078**
27	760,555	6,665	15,630	**782,850**
27,5	0	1,764	0	**1,764**
28	0	0	0	**0**
28,5	0	1,972	0	**1,972**
29	237,602	0	0	**237,602**
29,5	0	0	30,915	**30,915**
30	0	0	0	**0**
30,5	0	0	0	**0**
31	0	0	0	**0**
31,5	0	0	0	**0**
32	0	0	0	**0**
32,5	0	0	0	**0**
33	0	3,121	0	**3,121**
33,5	0	0	0	**0**
34	0	0	0	**0**
TOTAL	**15740,536**	**189,865**	**1696,338**	**17626,739**

Table 7. *ECOCÁDIZ-RECLUTAS 1009* survey. Mediterranean horse-mackerel (*T. mediterraneus*). Estimated abundance and biomass by size class.

***ECOCÁDIZ-RECLUTAS 1009* . *Trachurus mediterraneus* . ABUNDANCE (in number of fish)**					
Size class	**POL01**	**POL02**	**POL03**	**TOTAL n**	**Millions**
19	0	0	0	0	**0**
19,5	0	0	0	0	**0**
20	289103	0	0	289103	**0**
20,5	1879777	574992	0	2454769	**2**
21	6507551	2233264	0	8740815	**9**
21,5	5784490	3872275	0	9656765	**10**
22	13882715	5223993	0	19106708	**19**
22,5	9833451	7240926	0	17074377	**17**
23	10122554	10355128	0	20477682	**20**
23,5	3615003	11828291	98515	15541809	**16**
24	4772022	11042847	98515	15913384	**16**
24,5	1735226	7521731	196859	9453816	**9**
25	867613	7099205	689264	8656082	**9**
25,5	433958	5887789	1181669	7503416	**8**
26	433958	3038983	2560198	6033139	**6**
26,5	289103	1316237	2166308	3771648	**4**
27	0	952508	2658542	3611050	**4**
27,5	144552	679407	2264652	3088611	**3**
28	144552	427392	1772418	2344362	**2**
28,5	0	0	1083154	1083154	**1**
29	0	427392	492405	919797	**1**
29,5	0	0	295374	295374	**0**
30	0	129150	393890	523040	**1**
30,5	0	252015	295374	547389	**1**
31	0	0	393890	393890	**0**
31,5	0	400224	295374	695598	**1**
32	0	0	0	0	**0**
32,5	0	0	0	0	**0**
33	0	0	0	0	**0**
33,5	0	596281	98515	694796	**1**
34	0	0	0	0	**0**
34,5	0	0	0	0	**0**
35	0	0	0	0	**0**
35,5	0	0	0	0	**0**
36	0	0	98515	98515	**0**
36,5	0	0	0	0	**0**
37	0	0	0	0	**0**
TOTAL n	**60735628**	**81100030**	**17133431**	**158969089**	**159**
Millions	**61**	**81**	**17**	**159**	

Table 7 (cont'd)**.**

ECOCÁDIZ-RECLUTAS 1009 . *Trachurus mediterraneus* .BIOMASS (t)				
Size class	**POL01**	**POL02**	**POL03**	**TOTAL**
19	0	0	0	**0**
19,5	0	0	0	**0**
20	19,444	0	0	**19,444**
20,5	134,829	41,242	0	**176,071**
21	497,009	170,564	0	**667,573**
21,5	469,728	314,447	0	**784,175**
22	1196,978	450,417	0	**1647,395**
22,5	899,020	661,999	0	**1561,019**
23	980,057	1002,575	0	**1982,632**
23,5	370,202	1211,300	10,089	**1591,591**
24	516,289	1194,735	10,658	**1721,682**
24,5	198,116	858,780	22,476	**1079,372**
25	104,423	854,437	82,958	**1041,818**
25,5	55,002	746,241	149,769	**951,012**
26	57,863	405,21	341,370	**804,443**
26,5	40,515	184,457	303,586	**528,558**
27	0	140,165	391,214	**531,379**
27,5	22,316	104,888	349,620	**476,824**
28	23,392	69,163	286,822	**379,377**
28,5	0	0	183,582	**183,582**
29	0	75,808	87,339	**163,147**
29,5	0	0	54,786	**54,786**
30	0	25,031	76,342	**101,373**
30,5	0	51,002	59,777	**110,779**
31	0	0	83,178	**83,178**
31,5	0	88,128	65,041	**153,169**
32	0	0	0	**0**
32,5	0	0	0	**0**
33	0	0	0	**0**
33,5	0	154,25	25,485	**179,735**
34	0	0	0	**0**
34,5	0	0	0	**0**
35	0	0	0	**0**
35,5	0	0	0	**0**
36	0	0	30,769	**30,769**
36,5	0	0	0	**0**
37	0	0	0	**0**
TOTAL	**5585,183**	**8804,839**	**2614,861**	**17004,883**

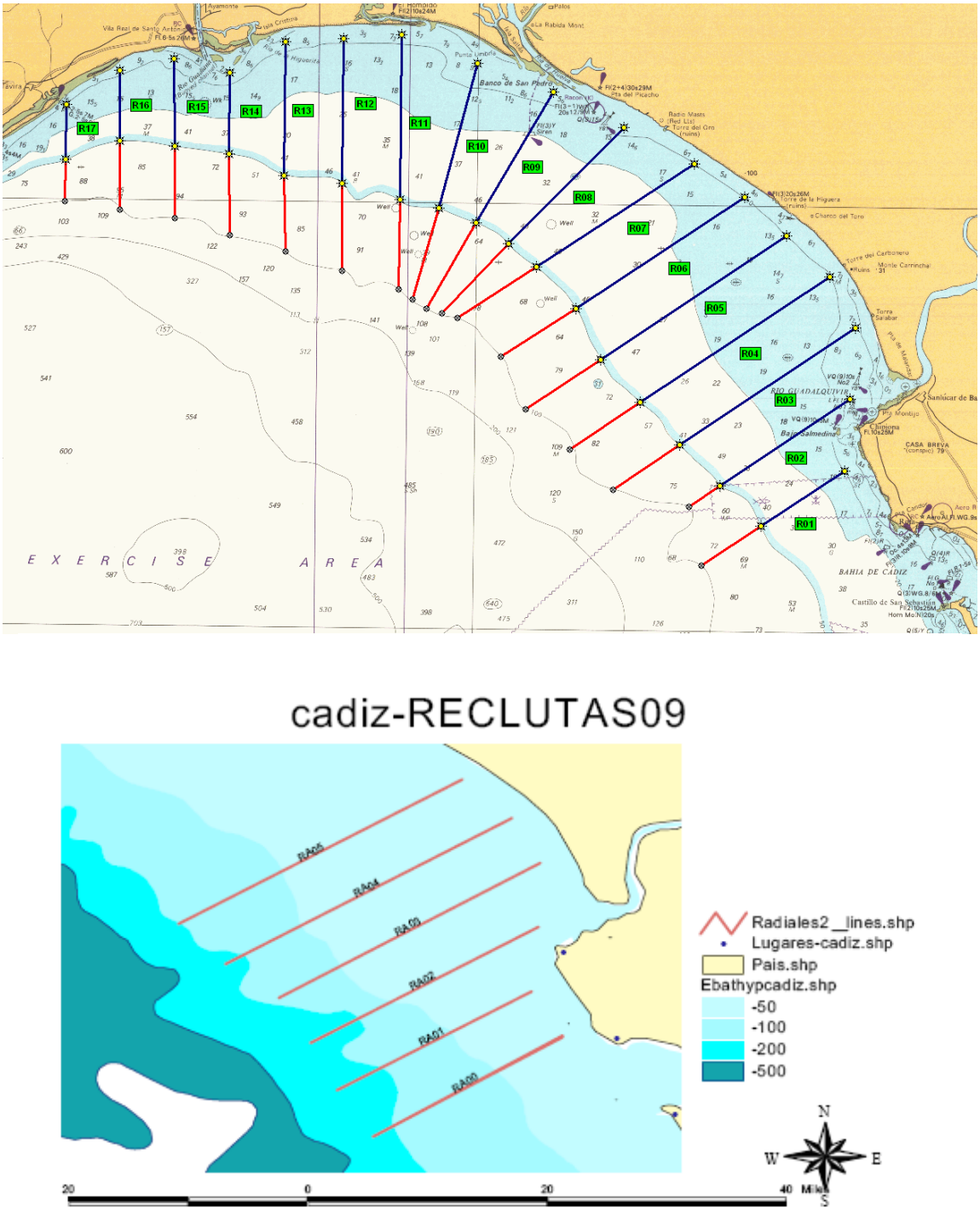


Figure 1. *ECOCÁDIZ-RECLUTAS 1009* survey. Top: the foreseen grid of 17 transects for acoustic sampling. Transects' segments shallower than 50 m depth in blue. Optional extension of transects up to the 100 m isobath (finally the adopted scheme) in red. Bottom: the acoustically sampled transects including the extra- one RA00 (see text for comments).

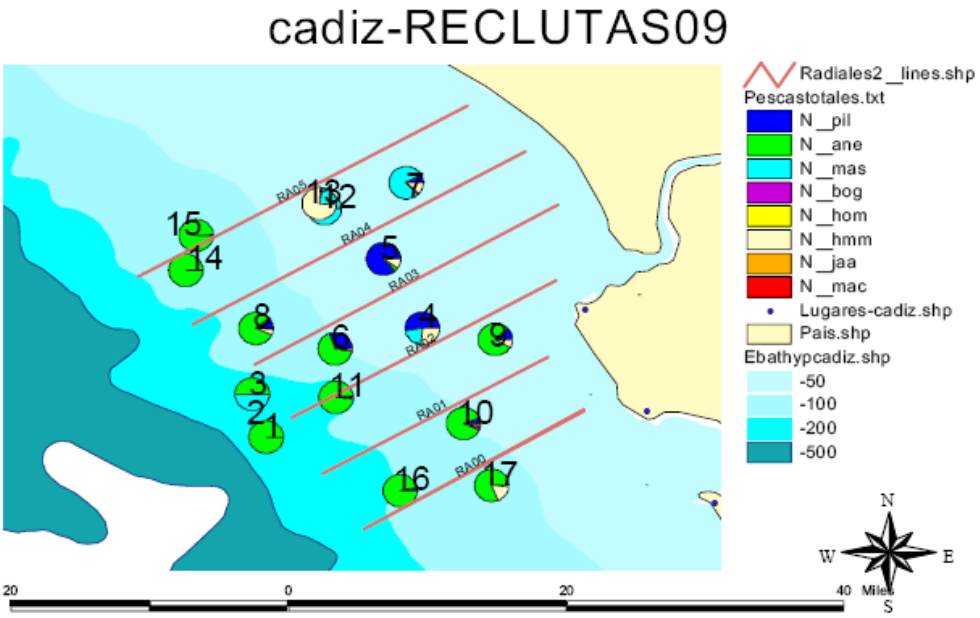


Figure 2. *ECOCÁDIZ-RECLUTAS 1009* survey. Location of valid fishing stations with indication of their species composition (percentages in number).

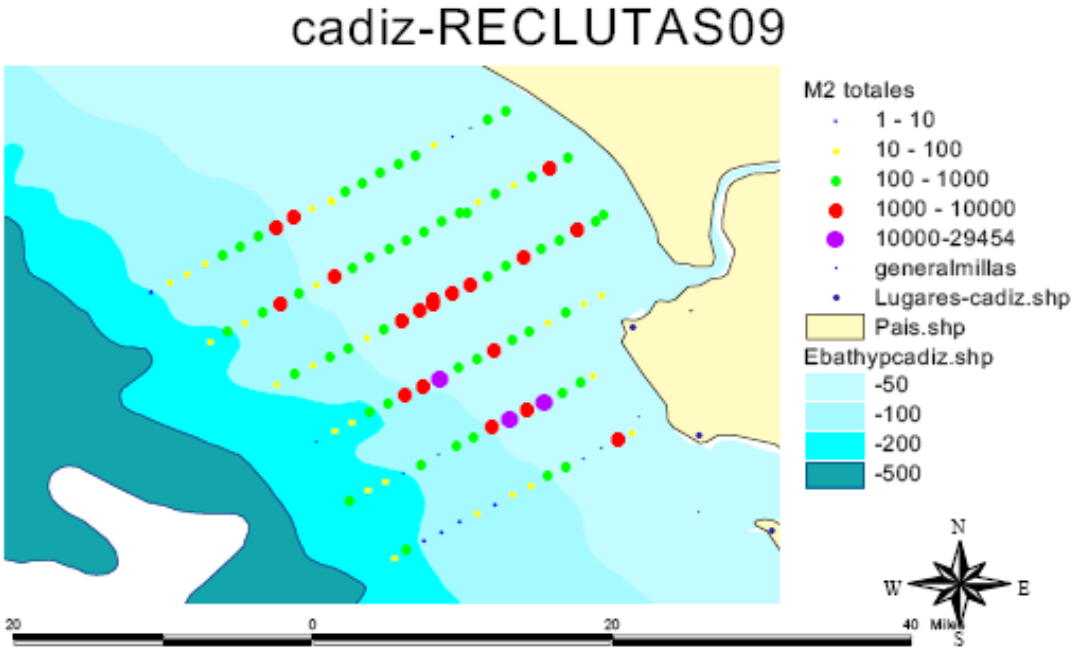
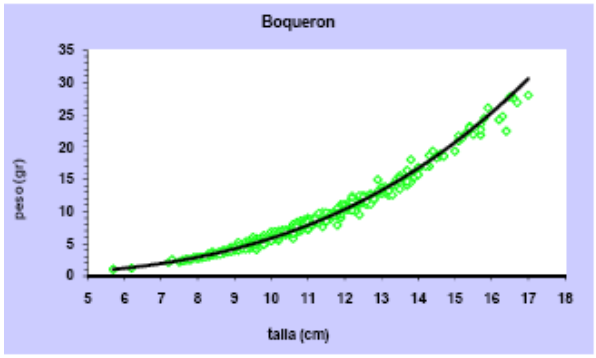
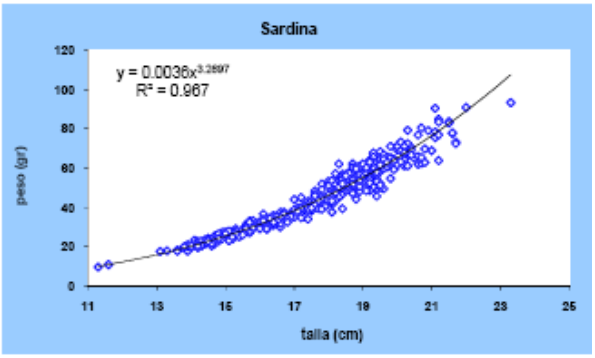


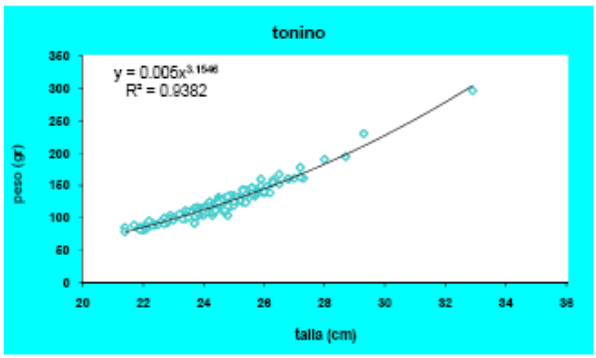
Figure 3. *ECOCÁDIZ-RECLUTAS 1009* survey. Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the pelagic fish species assemblage.



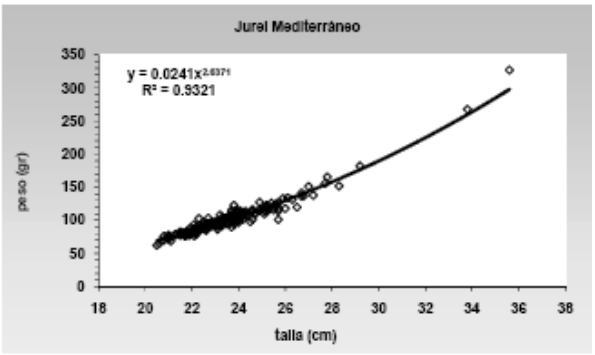
a	0.004523
b	3.112199
n	506
r^2	0.985



a	0.003636
b	3.269658
n	470
r^2	0.96698

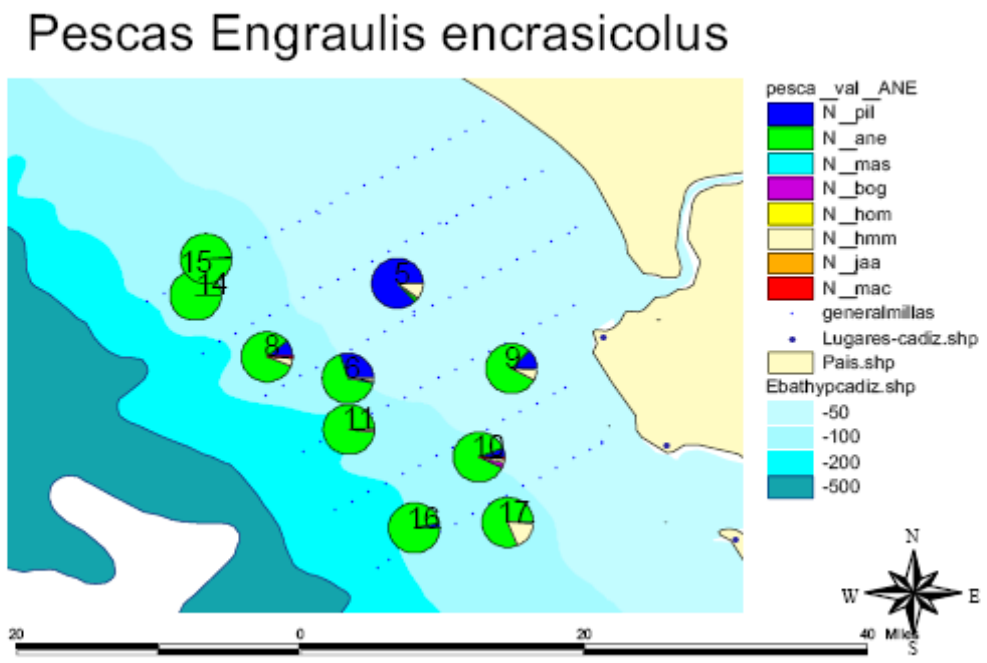


a	0.004977
b	3.154642
n	188
r^2	0.9382



a	0.024132
b	2.637081
n	197
r^2	0.9321

Figure 4. *ECOCÁDIZ-RECLUTAS 1009* survey. Size-weight relationships of the assessed species.



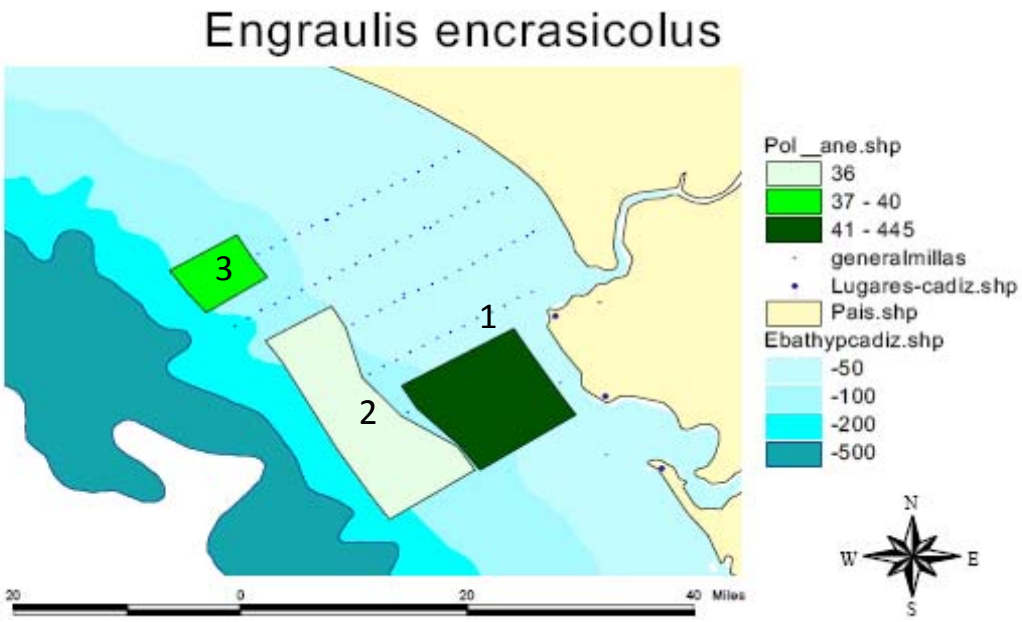


Figure 5. *ECOCÁDIZ-RECLUTAS 1009* survey. Anchovy (*Engraulis encrasicolus*). Top: valid fishing hauls for the species (more than 30 individuals showing a normal distribution). Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

***ECOCÁDIZ-RECLUTAS 1009*: Anchovy (*E. encrasicolus*)**

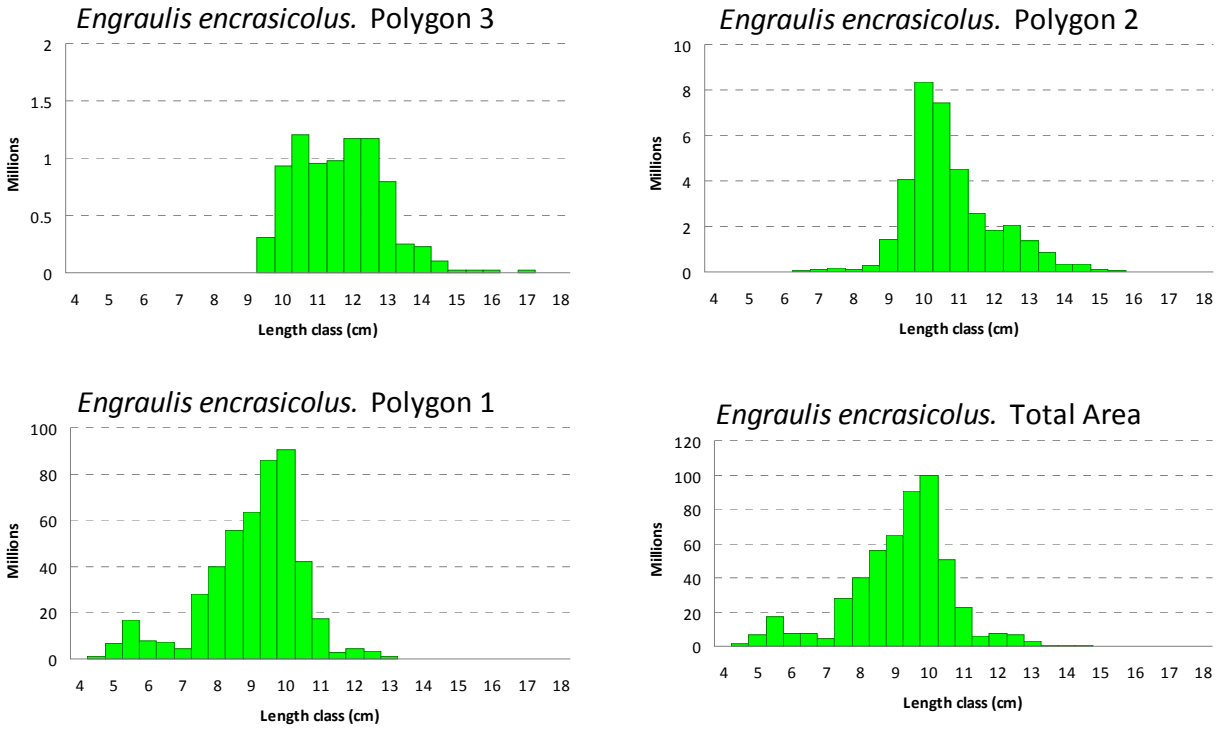


Figure 6. *ECOCÁDIZ-RECLUTAS 1009* survey. Anchovy (*E. encrasicolus*). Estimated abundances by length class by homogeneous stratum (numeration as in Figure 6) and total sampled area. Note the different scales in the y axis.

***ECOCÁDIZ-RECLUTAS 1009*: Anchovy (*E. encrasicolus*)**

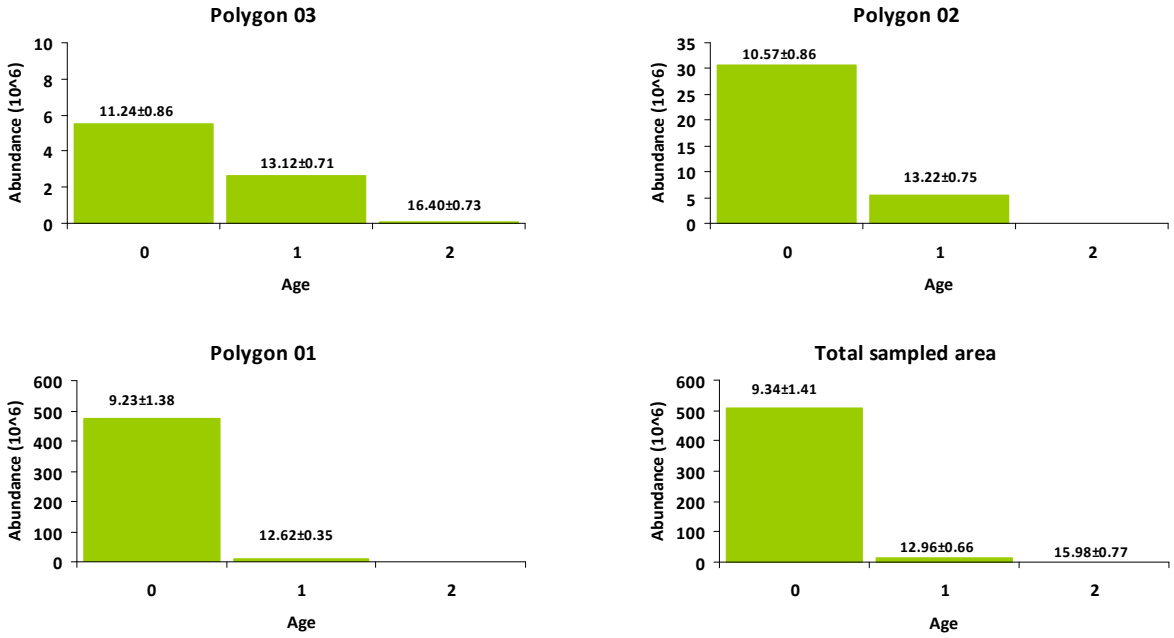
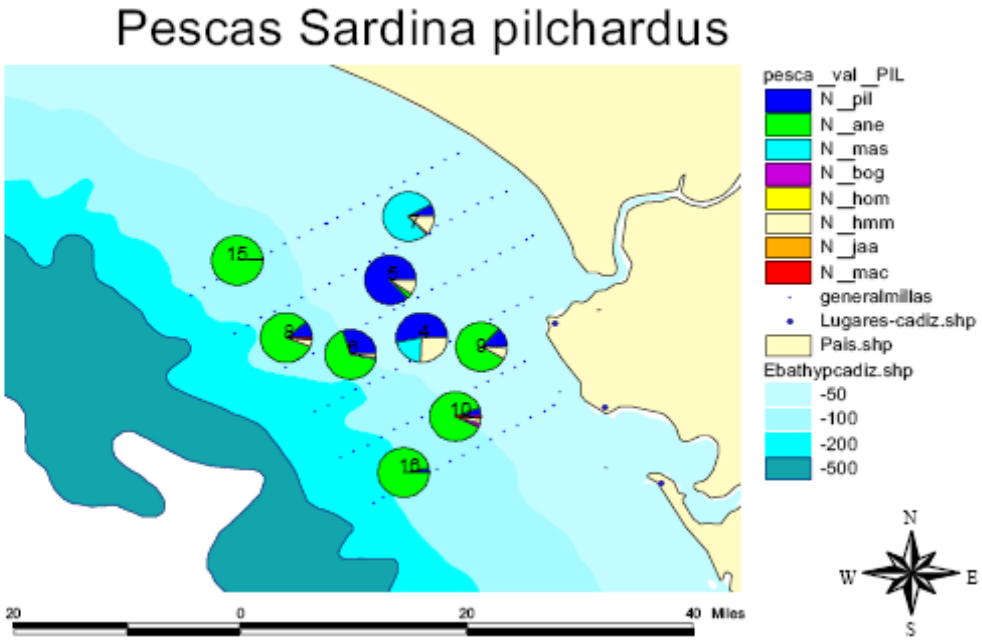


Figure 7. *ECOCÁDIZ-RECLUTAS 1009* survey. Anchovy (*E. encrasicolus*). Estimated abundance (millions fish) by age group, homogeneous stratum (numeration as in Figure 6) and total area. Note the different scales in the y axis.



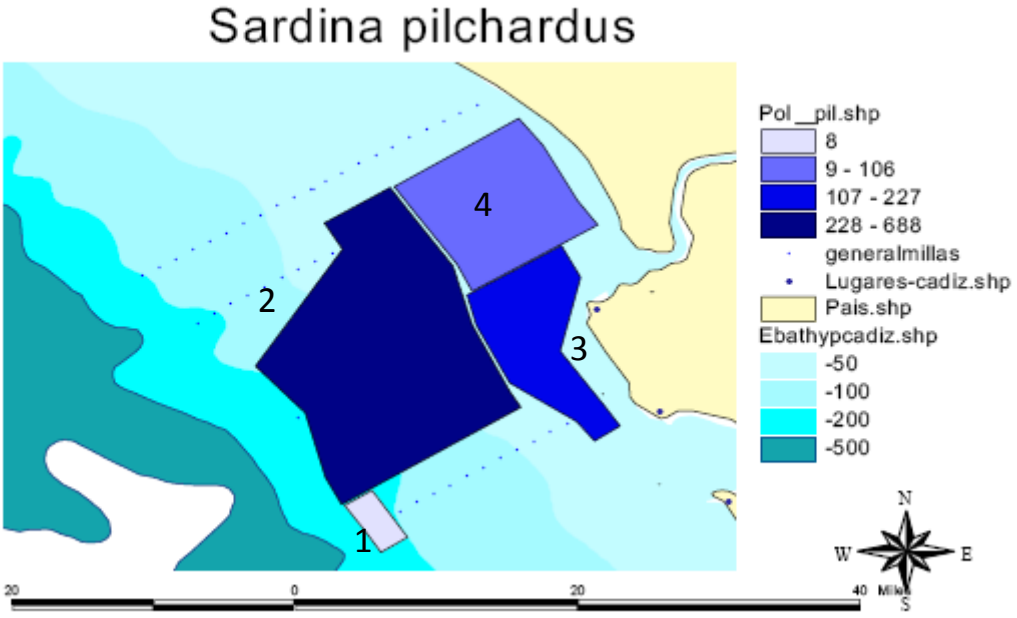


Figure 8. *ECOCÁDIZ-RECLUTAS 1009* survey. Sardine (*Sardina pilchardus*). Top: valid fishing hauls for the species (more than 30 individuals showing a normal distribution). Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

***ECOCÁDIZ-RECLUTAS 1009*: Sardine (*S. pilchardus*)**

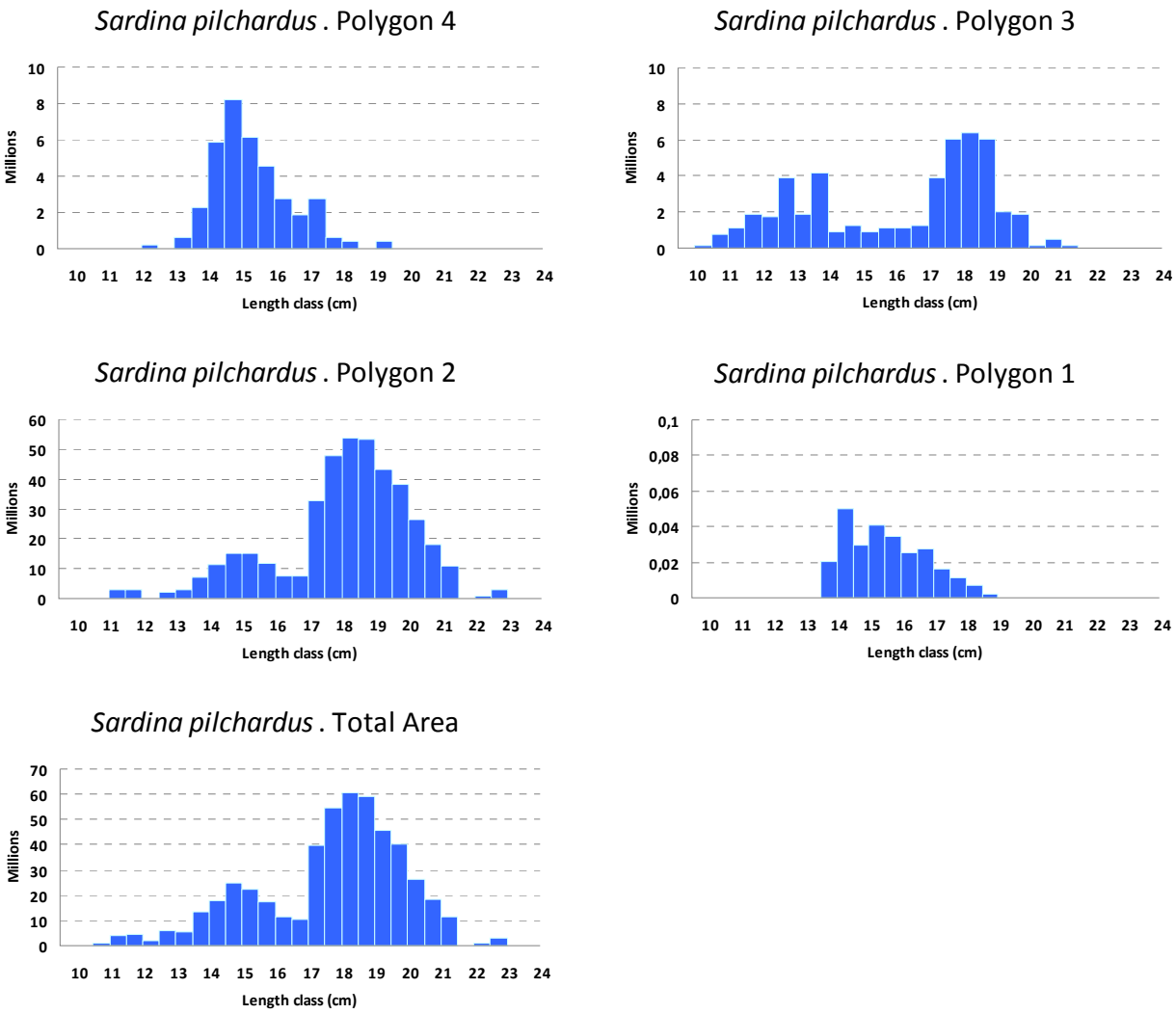
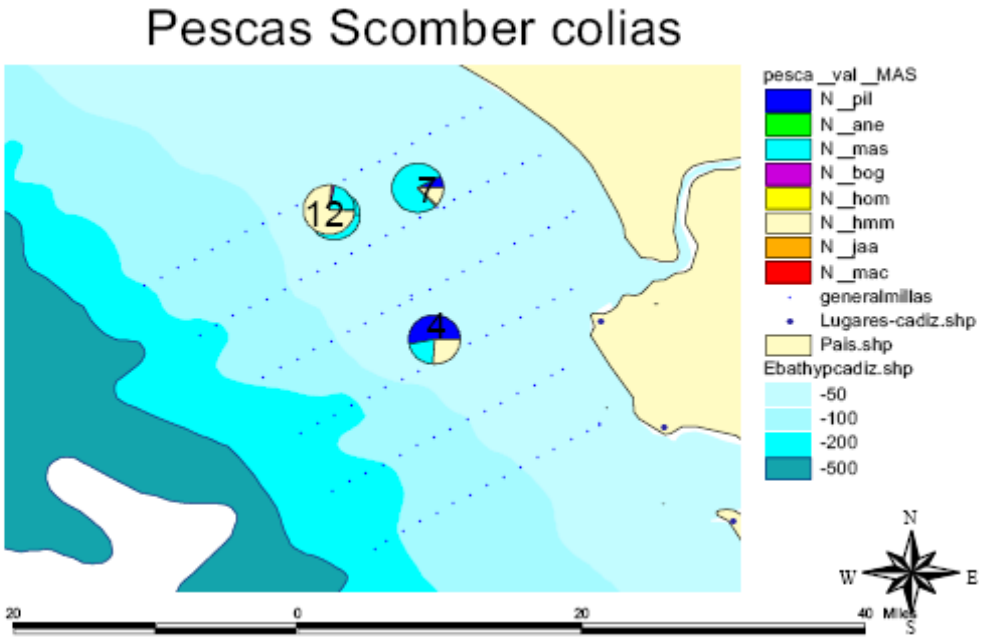


Figure 9. *ECOCÁDIZ-RECLUTAS 1009* survey. Sardine (*S. pilchardus*). Estimated abundances by length class by homogeneous stratum (numeration as in Figure 8) and total area. Note the different scales in the *y* axis.



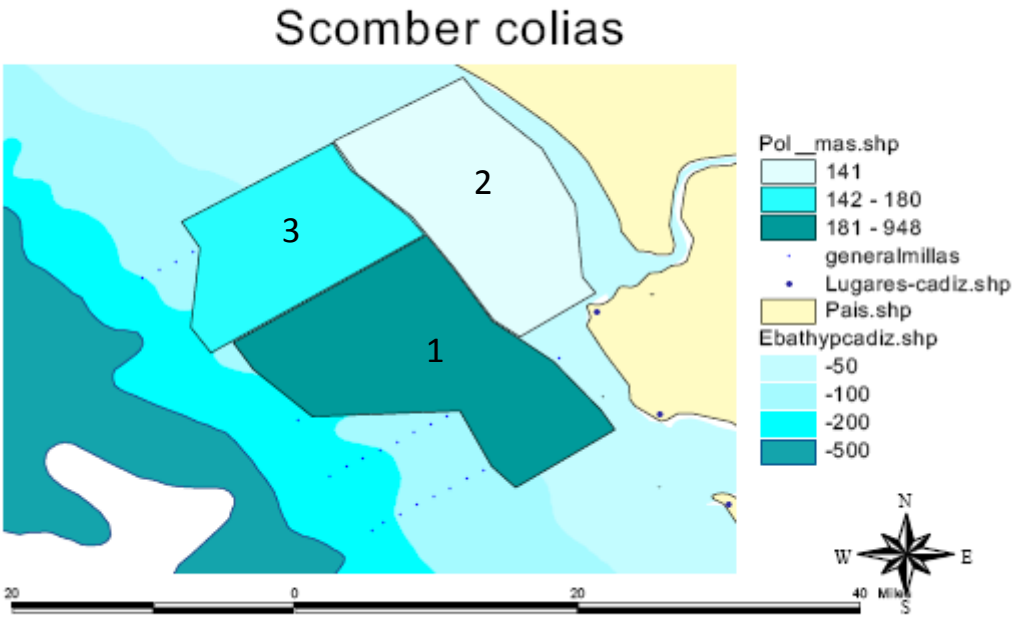


Figure 10. *ECOCÁDIZ-RECLUTAS 1009* survey. Chub mackerel (*Scomber colias*). Top: valid fishing hauls for the species (more than 30 individuals showing a normal distribution). Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

***ECOCÁDIZ-RECLUTAS 1009*: Chub mackerel (*S. colias*)**

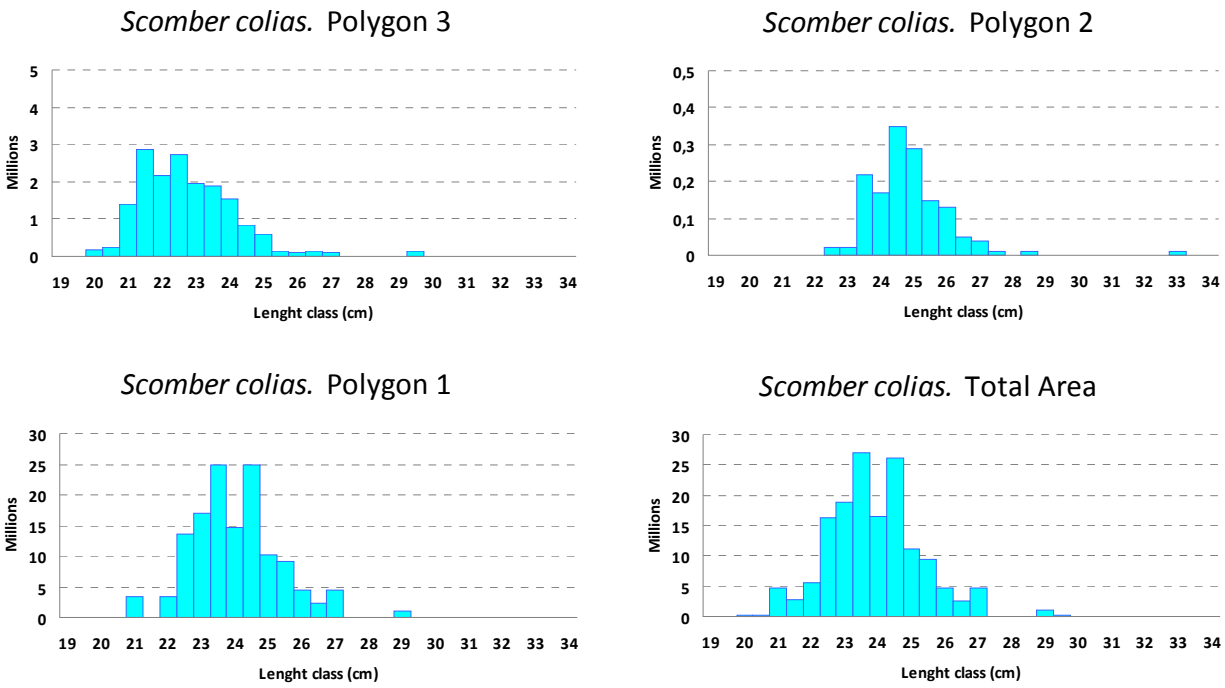
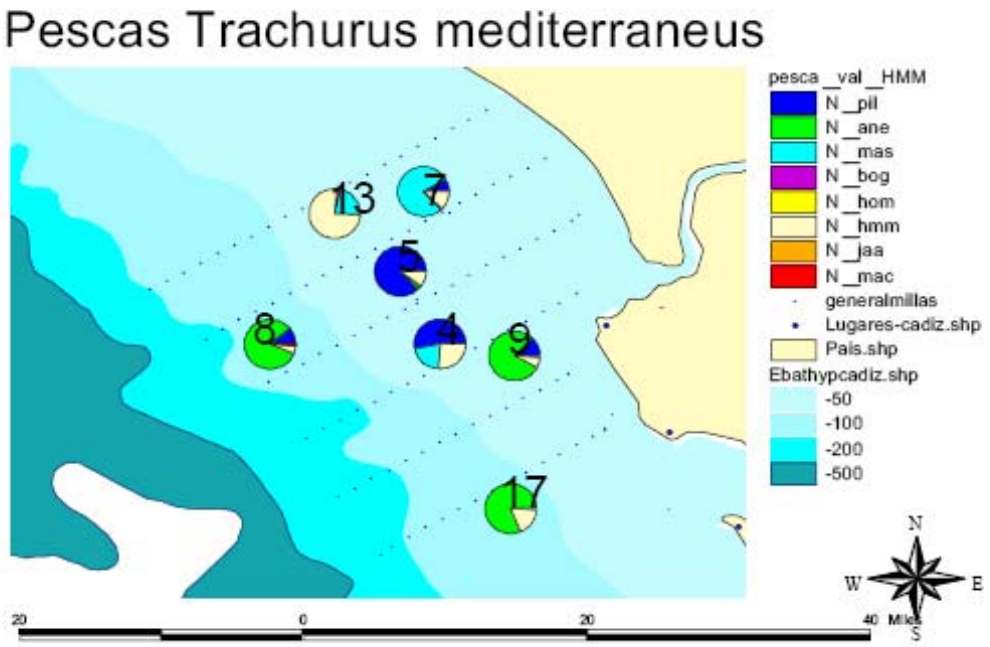


Figure 11. *ECOCÁDIZ-RECLUTAS 1009* survey. Chub mackerel (*S. colias*). Estimated abundances by length class by homogeneous stratum (numeration as in Figure 10) and total area. Note the different scales in the *y* axis.



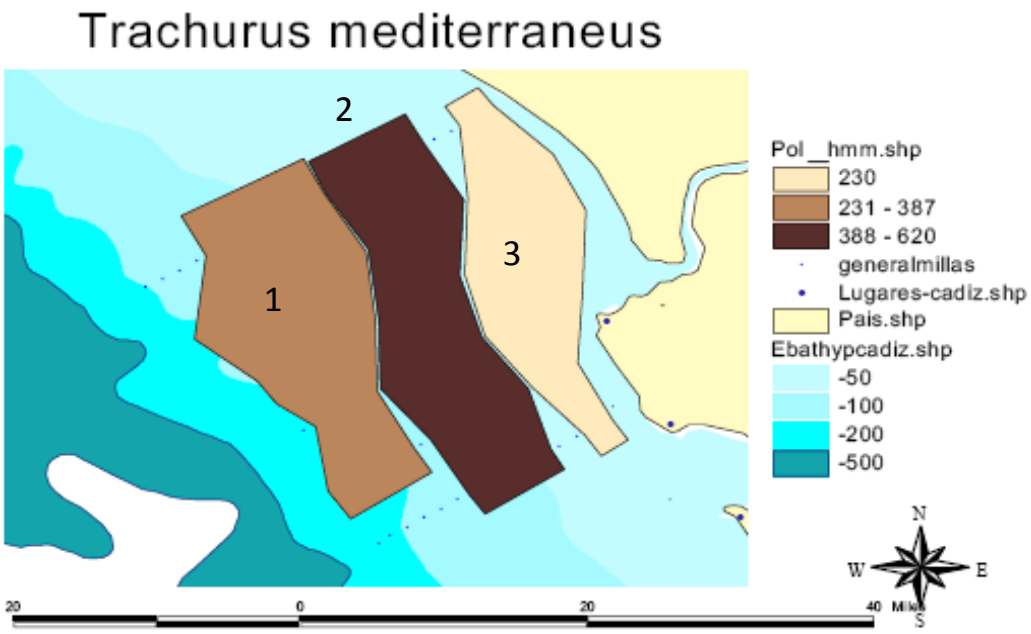


Figure 12. *ECOCÁDIZ 0710* survey. Mediterranean horse-mackerel (*Trachurus mediterraneus*). Top: valid fishing hauls for the species (more than 30 individuals showing a normal distribution). Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

***ECOCÁDIZ-RECLUTAS 1009*: Mediterranean horse-mackerel (*Trachurus mediterraneus*)**

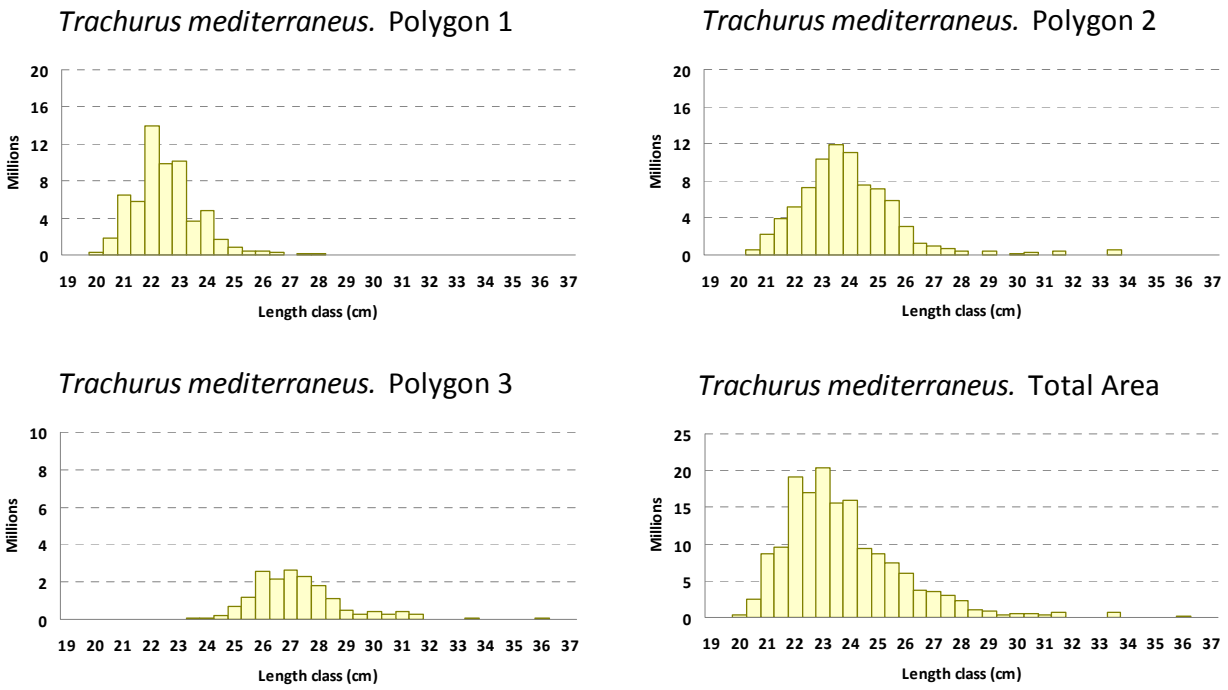


Figure 13. *ECOCÁDIZ-RECLUTAS 1009* survey. Mediterranean horse-mackerel (*Trachurus mediterraneus*). Estimated abundances by length class by homogeneous stratum (numeration as in Figure 12) and total area. Note the different scales in the *y* axis.

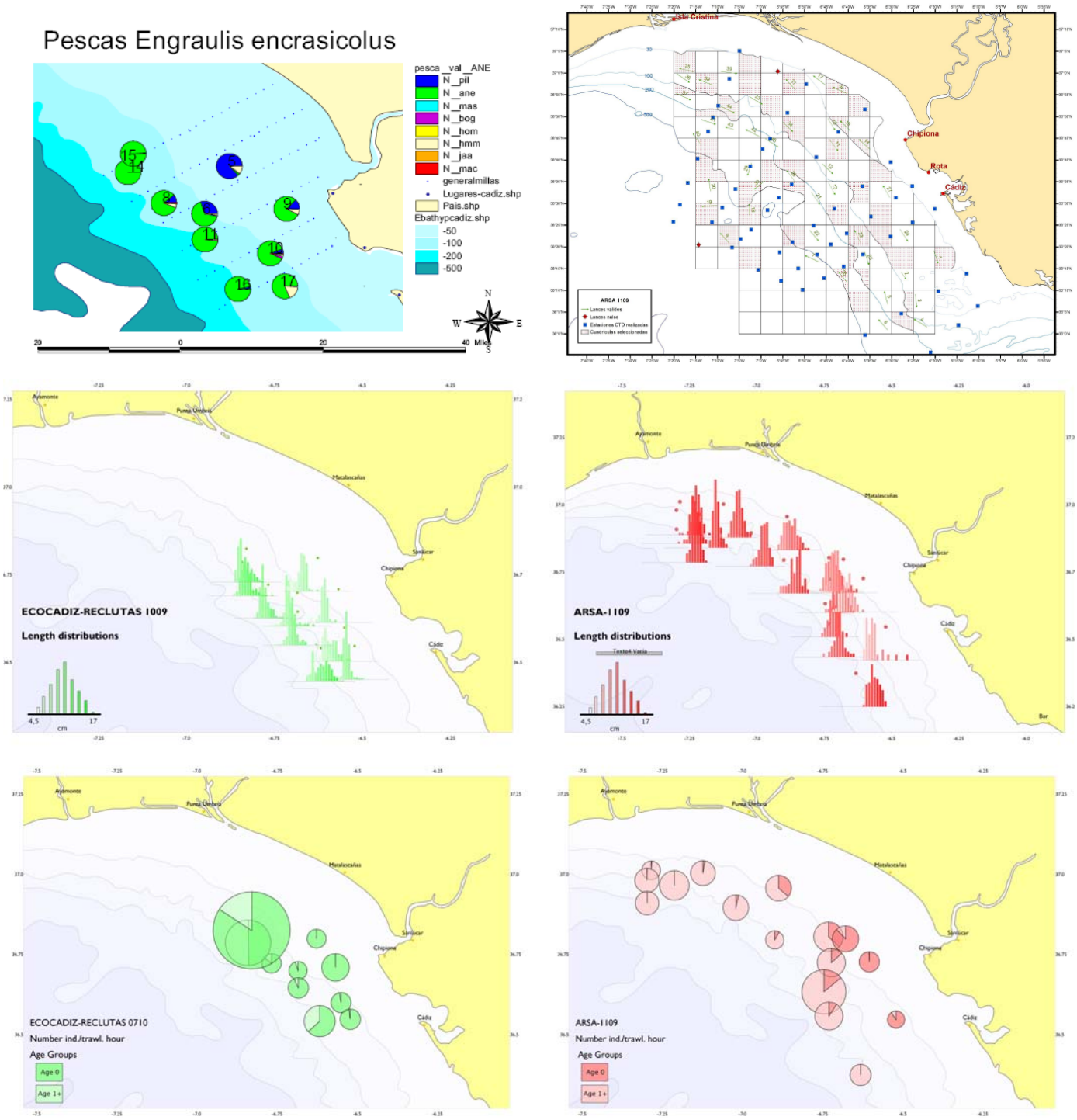


Figure 14. *ECOCÁDIZ-RECLUTAS 1009* survey. Comparison of results obtained from fishing stations carried out during the present survey (26th October- 05th November, left column) with those ones carried out during the *ARSA 1109* groundfish survey (09 th – 23 th November 2009, right column). Top row: Sampling grids with indication of the location of the trawl hauls. Middle row: anchovy length frequency distributions by fishing station. Bottom row: anchovy age composition (% in numbers of age 0 fish vs age 1+ fish by trawling hour) by fishing station. Circle size proportional to the yield in numbers.