Working Document presented to the ICES WKPELA 2018 Benchmark Assessment Workshop. ICES HQ. Copenhagen, 12-16 February 2018.

Ane.27.9a stock (Anchovy in ICES Division 9a). Southern component (Anchovy in ICES Subdivision 9a South): Fishery and Surveys data. Data availability and trends.

Fernando Ramos(1), Alexandra Silva(2), Andrés Uriarte(3), Margarita Rincón(4), Susana Garrido(2)

(1) Instituto Español de Oceanografía (IEO), Centro Oceanográfico de Cádiz. Spain.
(2)Instituto Português do Mar e da Atmosfera (IPMA). Portugal.
(3) AZTI Tecnalia. Pasajes (Gipúzcoa). Spain.
(4) Instituto de Ciencias Marinas de Andalucía (ICMAN). Consejo Superior de Investigaciones Científicas. España.

1. Landings in subdivision 9a South.

1.1. Total landings and landings by country.

Anchovy in subdivision 9a South (also termed as Gulf of Cadiz – GoC- anchovy) is harvested by an international fishery operated by Portuguese and Spanish fleets (at present composed by 63 Portuguese vessels and 86 Spanish ones). The Portuguese annual landings statistics date back to 1943 (Pestana, 1996; ICES, 1997). Spanish annual landings started to be available since 1989 because of the mixing of catches coming from the Spanish and Moroccan fishing grounds in the official fishery statistics until that year. Therefore, a complete coverage of catch statistics for the entire subdivision is only available for the post-1989 fishery. This period will be the one which will be assessed with the Gadget model.

For this recent fishery, the official landings statistics are the result of the cross-checking of first sale notes and log-books (which are mandatory for vessels larger than 10 m in the Spanish fishery since 2004). In both countries landings are not considered to be significantly under reported. Some irrelevant landings misallocations to some unlikely artisanal gears may be detected in the Spanish official statistics. National statistics are provided to the ICES WGHANSA by subdivision/quarter/métier. Since 1998, both Spanish IEO and Portuguese IPMA (former IPIMAR) have used a common Excel Workbook (the Data Submission Work Book) to provide all necessary annual landings and sampling data (on a quarterly basis), which was originally developed for the former ICES Working Group on the Assessment of Mackerel, Horse-mackerel, Sardine and Anchovy (WGMHSA). In more recent years, commercial catch and sampling data are uploaded in the InterCatch software by the respective national submitters and then processed by the stock coordinator using this same software.

Since 1943 on, Portuguese annual landings have oscillated between 12,501 t (1957) and less than 1 t (1992-1995), (historical average: 1,678 t). This historical series reveals alternating periods of high and very low catches (Pestana, 1996; ICES, 1997; ICES, 2017a; **Figure 1.1.1**). The greatest contribution to the Portuguese annual landings came from 9a South during the period 1943-1967 (mean value 4,526 t). After this period, the landings from this subdivision decreased to 386 t (mean value) from 1968 to 1983 and abruptly to 32 t (mean value) from 1984 to 1997. Landings increased again to 366 t (mean value) from 1999 to 2004, but they decreased up to 43 t (mean value) from 2005 to 2016.

Spanish annual landings from the subdivision 9a South for the period with available and contrasted data (since 1989) have ranged between 571 t (1995) and 8,977 t (1998), (historical average: 4,848 t), (ICES, 2017a; **Figure 1.1**). Although the environmental forcing has been suggested as the main cause (Ruiz *et al.*, 2006), the historical minimum record in 1995 was mainly the result from a severe reduction in the fishing effort caused by the interruption of fishing (from May to December) by the most powerful fleet segment in the Gulf, the Barbate's single-purpose purse-seine fleet, to pressure to the National Fisheries Administration because of problems with the renewal of the EU-Morocco fisheries agreement in that year (Moroccan North-Atlantic fishing grounds are also traditionally exploited by these vessels targeting anchovy under these fisheries agreements). The Spanish fishery also experienced periods of high and low catches. Historical peaks were recorded in 1998 (8,977 t) and 2014 (8,933 t). Decreased catches were recorded in the periods 1992-1996 (2,068 t on average, including the abovementioned historical minimum in 1995), 2000 (2,182 t) and 2008-2010 (2,997 t on average), (**Figure 1.1.1**).

Since 1989 on, total landings from the international fishery in the subdivision 9a South have oscillated between 1,984 t (1993) and 13,740 t (2013), (historical average: 4,960 t), (ICES, 2017a; **Figure 1.1.2**). The Spanish fishery in the Gulf of Cadiz is the main responsible for the anchovy fishery in the subdivision (98% of total landings on average) and, with the exception of some years (1995, 1996, 2011 and 2016), in the entire Division 9a as well (82% of total landings on average).

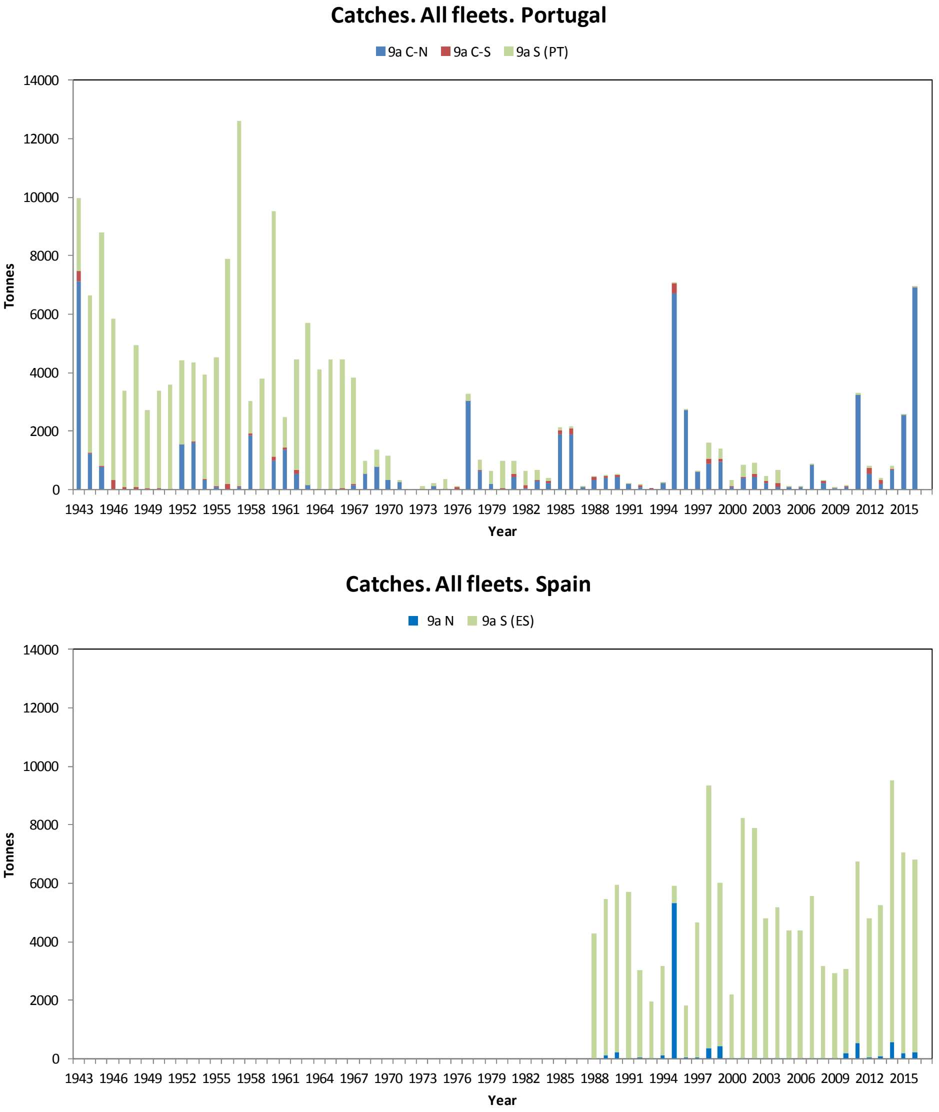


Figure 1.1.1. Ane.27.9a stock. Anchovy fishery in Division 9a. Anchovy catches (all fleets, in tonnes) in the Portuguese (top) and Spanish (bottom) fisheries by subdivision. Source: ICES (2017a).

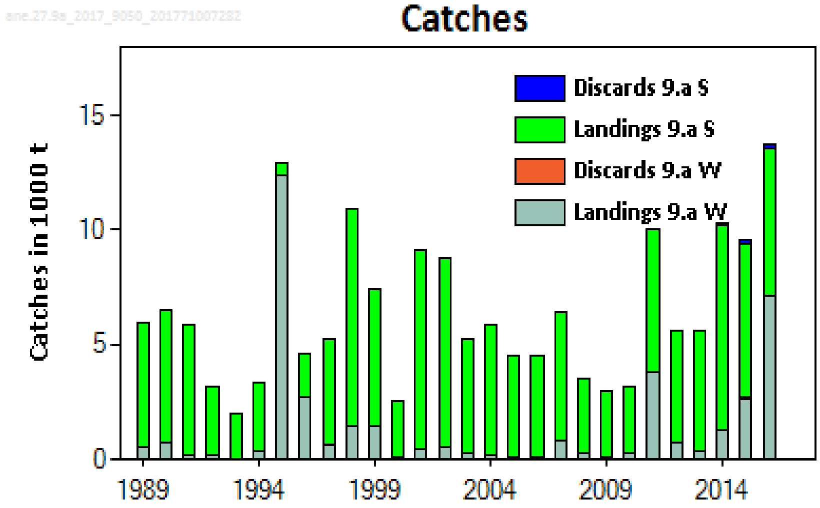


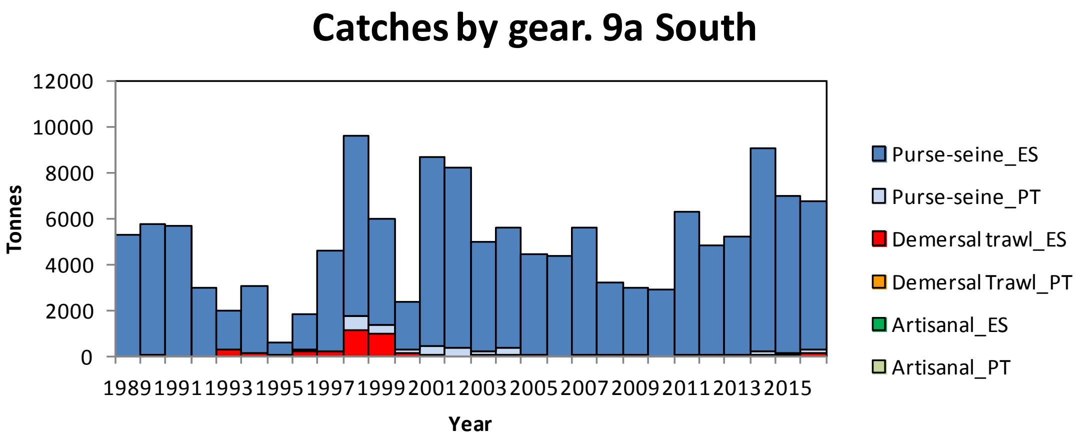
Figure 1.1.2. Ane.27.9a stock. Anchovy fishery in Division 9a. Anchovy catches (all fleets, in thousand tonnes) by stock component (9a W: western component, includes the subdivisions 9a North, 9a Central-North and 9a Central-South); 9a S: southern component (includes the subdivision 9a South). Source: ICES (2017a).

1.2. Landings by métier.

Portugal and Spain routinely provide landings statistics by métier to ICES on an annual and quarterly basis. The métiers harvesting anchovy in subdivision 9a South are the following:

- Portuguese fishery:
  - Purse-seine (PS_SPF_0_0_0):
  - Otter bottom trawl directed to demersal fish (OTB_DEF_>=55_0_0).
  - Artisanal (mixed gears) using artisanal PS (also called in their national statistics as “polyvalent” vessels) (MIS_MIS_0_0_0_HC).
- Spanish fishery:
  - Purse-seine (PS_SPF_0_0_0).
  - Otter bottom trawl directed to mixed crustacean and demersal fish species (OTB_MCD_>=55_0_0). Until 2000 anchovy was captured as by-catch. Since then anchovy is discarded.
  - Artisanal (mixed gears) (MIS_MIS_0_0_0_HC) (incidental catches).

Figure 1.2.1 shows the contribution of each of these métiers in the anchovy fishery for the period 1989-2016. The Spanish purse-seine fleet is the main responsible for the anchovy fishery in the subdivision, accounting for 95% of the total anchovy landings on average for the considered time series. The Spanish bottom trawl fleet is the following fleet in importance (c.a 3% on average), but such contribution is mainly restricted to the period 1993-2000, when this fleet fished anchovy as by-catch. The Portuguese purse-seine fleet contributed with 2% on average.



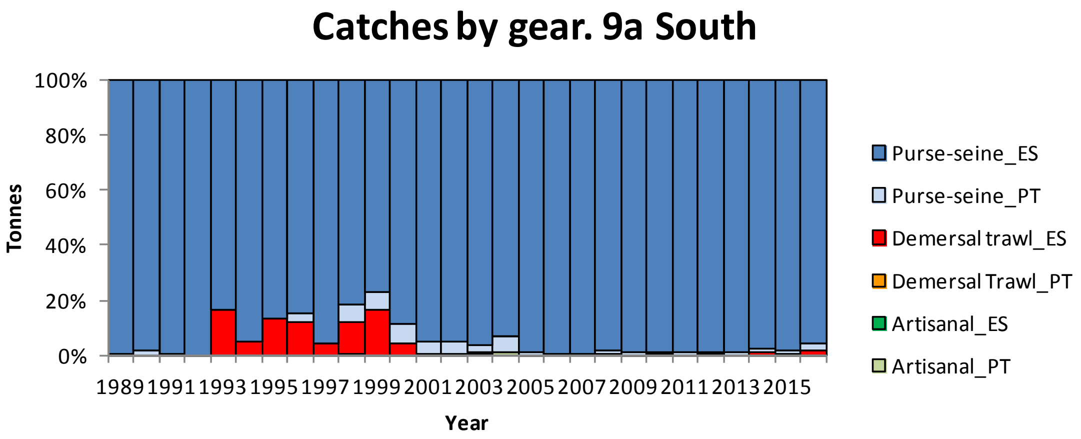


Figure 1.2.1. Ane.27.9a stock. Anchovy fishery in subdivision 9a South. Annual catches by gear in absolute (in tonnes, top) and relative (bottom) terms. Fleets-fishing gears-métiers are differentiated by country. Source: ICES WGHANSA.

2. Discards.

Discards are sampled by Portugal and Spain within their respective EC-DCR-based National Sampling Schemes. Discard sampling strategies and methods follow those adopted by the ICES Workshop on Discard Sampling Methodology and Raising Procedures (ICES, 2004a).

Discards are very difficult of measure. As with other pelagic fisheries that exploit schooling fish, discarding occurs in a sporadic way and with often extreme fluctuation in discard rates (100% or null discards). Extreme discards occur especially when the entire catch is released (“slippage”), which tend to be related to quota limitations, illegal size and mixture with unmarketable by-catch. Quantifying such discards at a population level is extremely difficult because they vary considerably between years, seasons, species targeted and geographical region (Stratoudakis & Marçalo, 2002; see also pil.27.8c9a Stock Annex).

Since 2004 official information provided to ICES states that there are no anchovy discards or they are negligible in the Portuguese fishery in the Gulf of Cadiz. Therefore, landings can be equalled to catches.

Data on anchovy discarding in the Spanish fisheries operating in 9.a South started to be gathered on a quarterly basis since the fourth quarter in 2005 on, within the Spanish National

Sampling Scheme framed into the EC Data Collection Regulation (DCR). However, the sampling intensity applied until 2013 to assess the anchovy discarding was very low because it was limited to the agreed minimum sampling scheme (2 trips per quarter, 8 trips per year). Such a sampling scheme resulted in unreliable and not representative quarterly discard estimates which were also affected by high CVs. This low sample size made their results not conclusive and hence they were not considered. Since 2014 on a more intense sampling scheme was developed which also extends to the Spanish fishery in Sub-division 9.a North. Overall annual discard ratios estimated since 2014 oscillate between 0.01 (1%)–0.026 (2.6%), hence anchovy discards can also be considered as negligible in the Spanish fishery in the 9a South. Notwithstanding the above, since 2014, discards are estimated by quarter/metier/size/age and aggregated to landings to provide catches.

3. Size composition of landings (and catches).

The sampling coverage and intensity of the length frequency distribution (LFD) of landings are very different for the Portuguese and Spanish fisheries and depends on the resource availability and commercial interest (**Table 3.1**). Thus, anchovy is not a priority fishing species for the Portuguese fishery, unless it is abundant, and this fact is reflected in the almost null LFD availability throughout the period under analysis. In fact, raw LFDs sufficiently representative to be raised to the total landings are only recorded in some quarters in 2011 and 2012, but they were not enough to derive annual LFDs in those years.

Conversely, anchovy is the target species for the Spanish fishery in this subdivision. LFDs are available since 1989 (**Figure 3.1**). During the period 1989-2008 LFDs were sampled in fishing harbours, between 2009 and 2013 from a concurrent sampling both in land and at sea, and since 2014 on, from a concurrent sampling directly at sea. For the whole period under analysis the sampled raw LFDs of landings correspond to the purse-seine fishery, the main responsible for the Spanish anchovy fishery in the subdivision. These raw LFDs are sampled on a monthly basis, raised to monthly total landings and then pooled and provided by quarter and year to ICES. LFDs from bottom trawl landings (which occurred between 1993 and 2012, especially between 1993 and 2000) were not sampled because their relatively low representativeness in the whole fishery (not higher than 18% in those years with the highest landings). **Figure 3.1** shows annual LFDs for the whole Spanish fishery. Those LFDs for the period 1989-2013 were estimated raising the purse-seine LFD to the total catches (catches from all fleets pooled) by assuming the abovementioned scarce representativeness of the other métiers than purse-seine. Since 2014, quarterly LFDs from discarded catch are sampled by métier and raised to total estimated discards, as previously described in Section 2, and then pooled to the quarterly LFDs of landings to derive the LFD of annual catches.

The anchovy size range in Spanish catches for the whole 1989-2016 period oscillated between 3.5 and 20.0 cm size classes. The lowest and highest annual mean lengths and weights were recorded in 1996 (6.6 cm, 2.6 g) and 2008 (12.3 cm, 13.1 g), respectively (**Figure 3.2**). The LFDs during the period between 1989 and 2002 were characterised by the occurrence of 2-3 modal classes, with the smallest one, at around 5.0 - 7.0 cm size classes, even being the dominant mode in some years. This smallest mode disappeared from 2003, when the LFDs became basically unimodal, with the annual modes located at about 10.0 - 11.5 cm size classes, suggesting a probable shift in the fishing pattern. Mean lengths started to show some increasing trend since 2001 on (**Figure 3.2**). One of the causes which could explain this shift in the fishing pattern may be the establishment in June 2004 of a Marine Protected Area (Fishing Reserve) in the Guadalquivir River mouth, where neither purse-seine nor bottom trawl fishing is allowed (see **Section 7** and **Figure 7.1**). This protected area is the main anchovy recruitment area in the GoC (Baldó *et al*., 2006; Catalán *et al*., 2006) and, until then, the main fishing ground for the smallest, lighters and less autonomous purse-seine vessels of the Spanish fleet (Millán, 1992; **Figure 3.3**). Additionally, a progressive strengthening of the fulfilment of the minimum landing size (10 cm) since 1995 (established by the Royal Decree 560/1995) by the Spanish Fishing Authorities may also have contributed to the abovementioned shift, although it seems that started to be more effective since 2001 on.

4. Age structure of landings (and catches).

4.1. Age reading.

The 2014 ICES Planning Group on Commercial Catch, Discards and Biological Sampling (PGCCDBS, ICES 2014a) identified the need of a full-scale European Anchovy (*Engraulis encrasicolus*) otolith exchange to take place in 2014 under the coordination of IEO and AZTI (Spain). It was the second exchange after that's of 2009 (ICES WKARA, ICES 2010) that anchovy otoliths of Atlantic and Mediterranean were included together. In view of the results of that exchange (Villamor & Uriarte, 2015), the ICES Working Group on Biological Parameters in 2015 (WGBBIOP, ICES 2015), recommended the realization of a Workshop on Age Reading of European Anchovy to discuss the results of the previous exchange and the development of validation studies in this species.

The aim of this last workshop (ICES WKARA 2, ICES 2017b) was to review the information on age determination, discuss the results of the previous exchange (2014), review the validation methods existing on these species, clarify the interpretation of annual rings and update the age reading protocol and a reference collection of well-defined otoliths.

ICES WKARA 2 suggested threshold values of agreements around 80% and of CVs around 20% in the training process as a minimum for age readers to be operative to deliver inputs for assessment. And targets should be for agreements above 90% and CV of 10% or less. Nevertheless, ageing anchovy otoliths from Division 9a is quite difficult, and much more from 9a S (ES). IEO and IPMA age readers of anchovy in Division 9a showed a 75.7% agreement (CV=33.0%), which showed as a not very bad result. The IEO expert reader for the GoC anchovy (9a S (ES)), the most important fishing area in the Division, reached a 94% agreement and ICES WKARA 2 considered that quality for age reading is good for the GoC anchovy assessment reader.

ICES WKARA 2 recommended, as far as possible, that only the age readings of the most expert readers by areas are used for the assessment inputs. Such recommendations are being applied to the Goc anchovy ageing.

4.2. Age structure of landings (and catches).

So far, no catch-at-age data are available from the Portuguese fishery in the subdivision. For the Spanish fishery, catch-at-age data (catch numbers-at-age, mean weight-at-age, mean length-at-age) are derived since 1989 from the raised national figures routinely provided by Spain. Both age length keys and length/weight relationships are compiled on a quarterly basis from monthly market samples.

Information gaps on Spanish catch-at-age data for the whole 1994 and second half in 1995 (only the size composition in catches is available) were solved by Millán (2002) from an iterated age-at-length key (IALK) by applying the Kimura & Chikuni's (1987) algorithm.

Table 3.1. Ane.27.9a stock. Anchovy fishery in subdivision 9a South. LFD sampling coverage and availability on an annual and quarterly basis for the Portuguese (PT) and Spanish (ES) fisheries. White background means no data, light blue available but not representative LFDs to estimate the size composition of landings, dark blue available and representative LFDs to estimate the size composition of landings. Source: ICES WGHANSA.

	QUARTER	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
SUB-DIV 9a S (PT)	**Q1**																							■	▨	▨	▨		▨
	Q2																					▨		■	■		▨		
	Q3																							▨	▨	▨			
	Q4																							■	■	▨	▨		

	QUARTER	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
SUB-DIV 9a S (ES)	**Q1**	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Q2	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Q3	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Q4	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

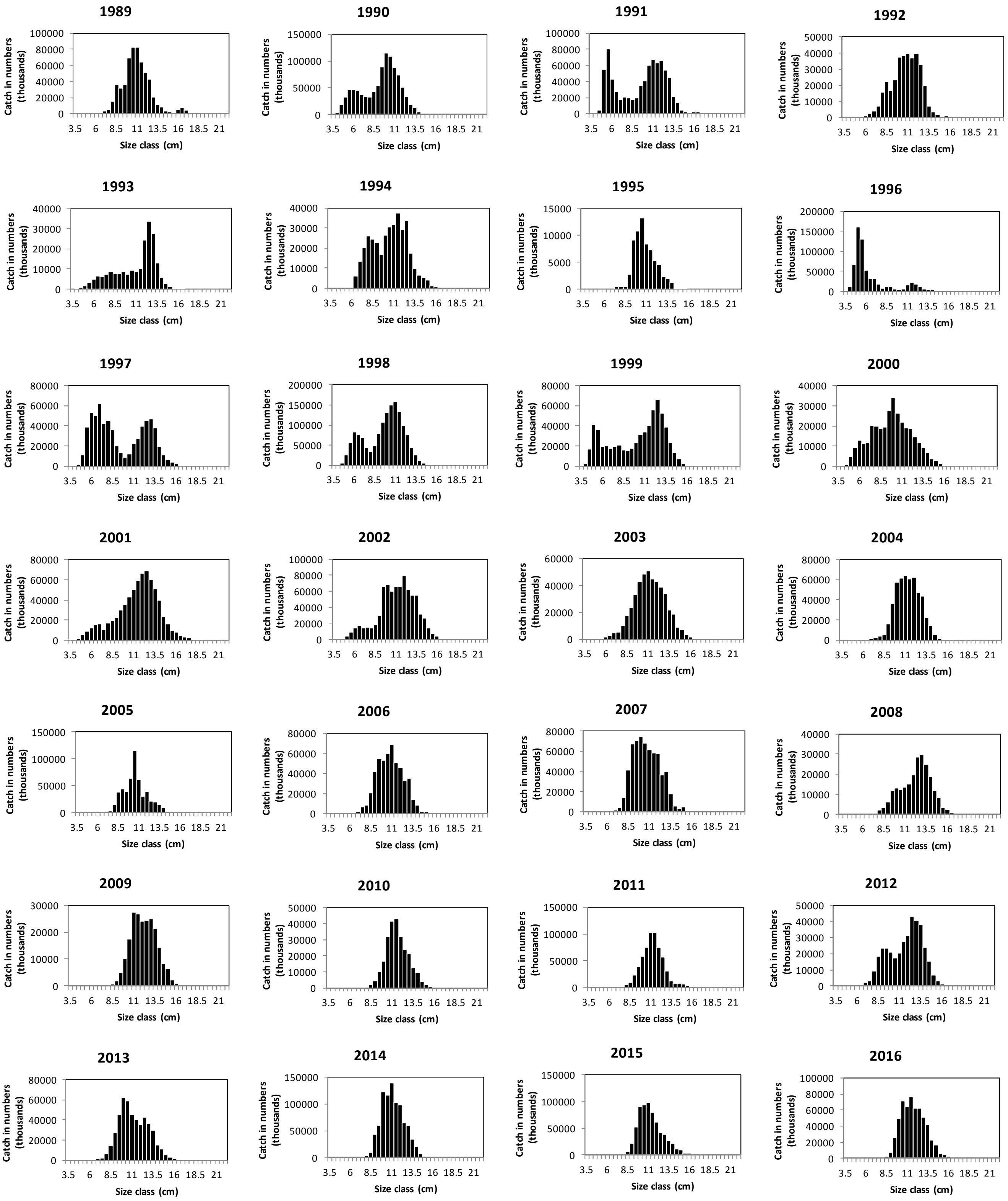


Figure 3.1. Ane.27.9a stock. Anchovy fishery in subdivision 9a South. Annual length frequency distributions (LFDs, by 0.5 cm size class) of anchovy catches in the Spanish fishery (all fleets). Source: ICES WGHANSA.

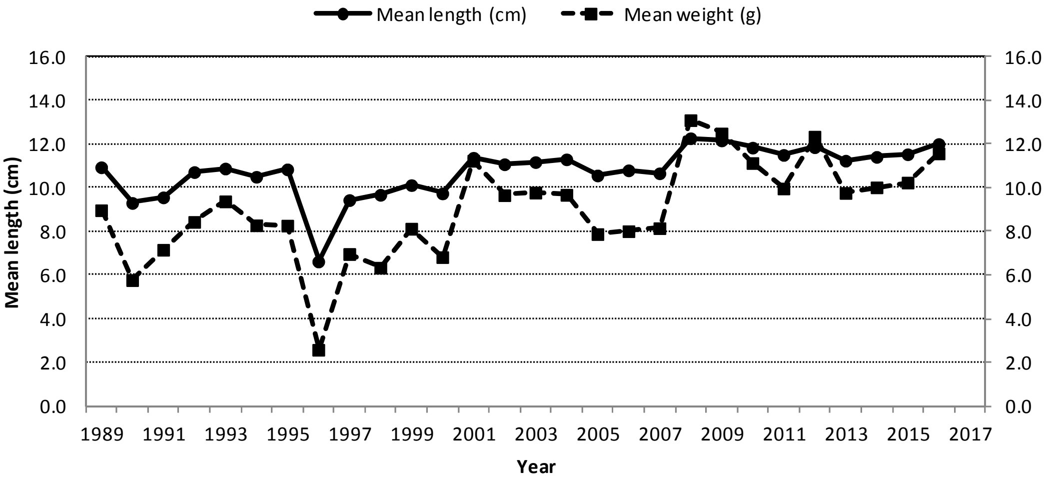


Figure 3.2. Ane.27.9a stock. Anchovy fishery in subdivision 9a South. Mean length (cm) and mean weight (g) in anchovy catches in the Spanish fishery (all fleets). Source: ICES WGHANSA.

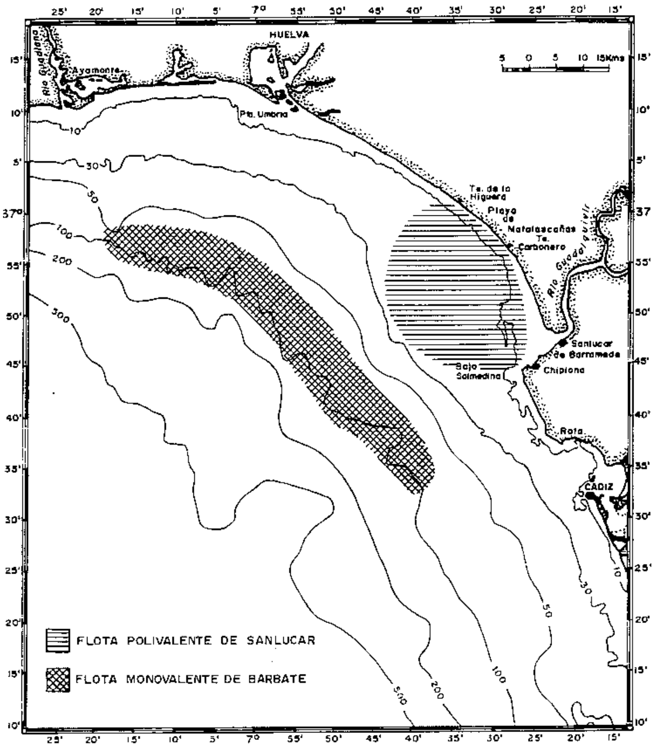


Figure 3.3. Ane.27.9a stock. Anchovy fishery in subdivision 9a South. Traditional fishing grounds for the Spanish purse-seine fleets in the Gulf of Cadiz before the establishment of the Marine Protected Area (Fishing Reserve) of the Guadalquivir River mouth in 2004. The shallower ground was mainly frequented by the lighter, smaller and less autonomous vessels. Source: Millán (1992).

Table 4.2.1. Ane.27.9a stock. Anchovy fishery in subdivision 9a South. Age sampling coverage and availability on an annual and quarterly basis for the Portuguese (PT) and Spanish (ES) fisheries. White background means no age data. Information gaps on catch-at-age data in the Spanish fishery for the whole 1994 and second half in 1995 (only LFDs are available) were solved from an iterated age-at-length key (IALK) by applying the Kimura and Chikuni's (1987) algorithm (Millán, 2002). Source: ICES WGHANSA.

SUB-DIV 9a S (PT)	QUARTER	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
	Q1																												
	Q2																												
	Q3																												
	Q4																												

SUB-DIV 9a S (ES)	QUARTER	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
	Q1	🟦	🟦	🟦	🟦	🟦		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	Q2	🟦	🟦	🟦	🟦	🟦		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	Q3	🟦	🟦	🟦	🟦	🟦			🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	Q4	🟦	🟦	🟦	🟦	🟦			🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦

Anchovy catches from the Spanish fishery in Subdivision 9a S (ES) are composed by fishes belonging to the Age 0 to Age 3 groups, although the bulk of the fishery is sustained by Age 0 and Age 1 groups, with the Age 2+ anchovies being incidental (**Figure 4.2.1**). The 1997, 1998, 2000, 2001, and 2013 cohorts seem to have been the strongest ones in the recent fishery.

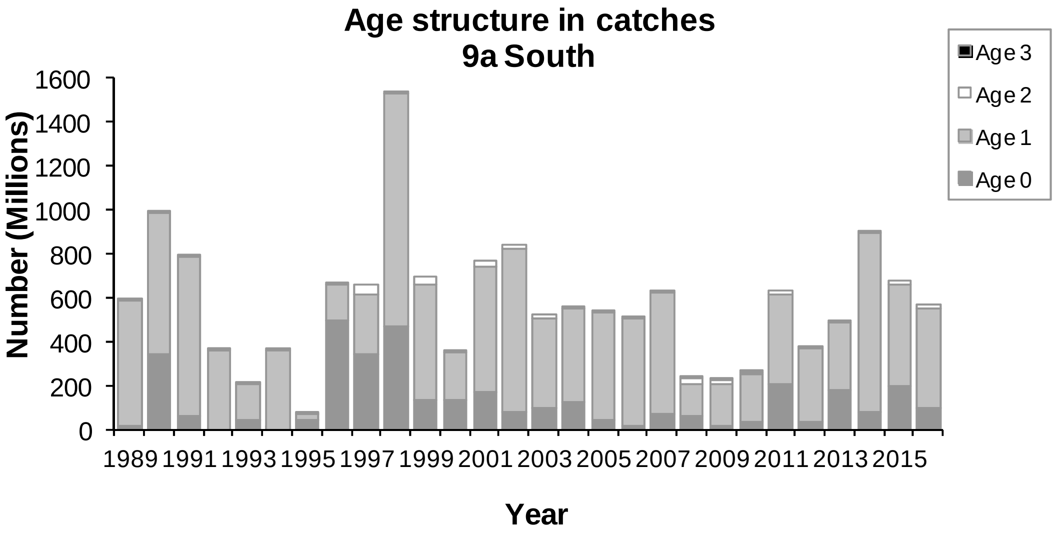


Figure 4.2.1. Ane.27.9a stock. Anchovy fishery in subdivision 9a South. Spanish annual catch in numbers (in millions) at age. Data for 1994 and second half in 1995 estimated from an iterated ALK by applying the Kimura and Chikuni's (1987) algorithm. Source: ICES WGHANSA.

5. Surveys series.

5.1. General.

Table 5.1.1 shows the list of surveys series providing direct estimates for anchovy in Sub-division 9a S. The main characteristics of these surveys are the following:

***PELAGO* spring acoustic surveys series** (until 2006 termed as SAR surveys): Portuguese surveys series conducted by IPMA with the RV *Noruega*. Originally it was routinely performed for the acoustic estimation of the sardine abundance in Division 9a off the Portuguese continental shelf and Gulf of Cadiz (20 – 200 m depth), during March-April (sardine late spawning season). Since 2007 on, the spring surveys are being planned as ‘pelagic community’ surveys. This shift in planning mainly entailed, as compared with previous years, a substantial increase in the number of fishing stations in the Sub-division 9a S, where the species diversity is higher, changing the series its former name by the one of *PELAGO* surveys. This survey series is currently financed by DCF. Gulf of Cadiz anchovy estimates from these survey series started to be available since March 1999.

***ECOCADIZ* summer acoustic surveys series**: Spanish surveys series conducted firstly by IEO with the RV *Cornide de Saavedra* (2004-2013) and afterwards with the RV *Miguel Oliver*. This is a pelagic community survey conducted in the shelf waters (20 – 200 m depth) of the Gulf of Cadiz only. Survey dates were planned to be coincident with the GoC anchovy peak spawning. The series started in 2004, but with gaps in 2005, 2008 and 2011 because available ship-time had to be invested in the conduction of the DEPM survey *BOCADEVA* (see below). Since 2014 both surveys are conducted almost synchronously. This survey series is currently financed by DCF.

***BOCADEVA* summer DEPM surveys series**: Spanish surveys series conducted firstly by IEO with the RV *Cornide de Saavedra* (until 2011) and afterwards with the combined use of RV *Ramón Margalef* (ichthyoplankton samples) and RV *Miguel Oliver* (adult samples during the *ECOCADIZ* acoustic surveys). The surveys series is aimed at the estimation of the GoC anchovy SSB hence the surveyed area is restricted to the GoC shelf waters (20 – 200 m depth). The surveys are conducted triennially, starting in 2005. This survey series is currently financed by DCF.

***SARNOV* autumn acoustic surveys series**: Portuguese surveys series conducted by IPMA with the RV *Noruega*. The survey was also originally performed for the acoustic estimation of the sardine abundance in Division 9a off the Portuguese continental shelf and Gulf of Cadiz (20 – 200 m depth), during November (early spawning and recruitment season). The series started in 1998 and finished in 2008 but showed several gaps without surveys. GoC anchovy estimates from this survey series are only those from November 1998, 2000, 2001 and 2007.

***ECOCADIZ-RECLUTAS* autumn acoustic surveys series**: Spanish surveys series conducted firstly by IEO with RV *Emma Bardán* (2012 survey) and afterwards with the RV *Ramón Margalef*. The survey series, although planned as a pelagic community survey, is aimed at the acoustic estimation of both GoC anchovy and sardine juveniles and restricted to the Sub-division 9a S (20 – 200 m depth). The surveys series, conducted during the second fortnight of October, started in 2012 (only Spanish waters sampled) and continued in 2014. A serious breakdown in the RV's propeller system prevented from deriving an acoustic estimate from the 2017 survey. This survey series is currently financed by DCF.

***ARSA* autumn bottom trawl surveys series**: Spanish surveys series conducted firstly by IEO with the RV *Cornide de Saavedra* (2004-2013) and afterwards with the RV *Miguel Oliver*. This is the IBTS survey in the GoC. The surveyed area is restricted to the Spanish GoC, between 15 and 800 m depth (separated in five depth strata: 15–30, 31–100, 101–200, 201–500 and 501–800 m). This series has also a spring (March) counterpart. The ARSA autumn series started in 1997. GoC anchovy estimates are provided by this series since 1997. This survey series is currently financed by DCF.

5.2. Methods.

Acoustic and DEPM surveys' methodologies deployed by the respective national Institutes (IPMA and IEO) are thoroughly described in ICES (2008a, 2009), (see also ane.27.9a Stock Annex). Since 2005 these surveys series are coordinated and standardized (updated surveys protocols) within the frame of the ICES Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in areas 7, 8 and 9 (WGACEGG). SISP protocols for both acoustic and egg surveys are still in progress.

ARSA groundfish surveys' protocols are standardized within ICES International Bottom Trawl Survey Working Group (IBTS). SISP protocols for surveys considered within this WG are described in ICES (2017c).

Figures 5.2.1, **5.2.2**, **5.2.3** and **5.2.4** show the sampling grids adopted in the surveys series analyzed in this WD.

Table 5.1.1. Ane.27.9a stock. Surveys providing direct estimates for anchovy in Sub-division 9a South. (1): surveys analyzed since 2008 in the trends-based qualitative assessment; (2): *ECOCADIZ-COSTA 0709*, (pilot) Spanish survey surveying shallow waters <20 m depth and complementary to the standard survey; ((Month)): surveys that were carried out but did not provide any anchovy acoustic estimate because of its very low presence and/or for an incomplete geographical coverage (some areas were not covered: either the Spanish or the Portuguese part of the Gulf of Cadiz). Sources: ICES WGHANSA, ICES WGACEGG, ICES IBTS.

Survey	**PELAGO**		**SAR**	**ECOCADIZ**		**ECOCADIZ-RECLUTAS**	**BOCADEVA**		**ARSA**
Institute (Country)	**IPMA (Portugal)**		**IPMA (Portugal)**	**IEO (Spain)**		**IEO (Spain)**	**IEO (Spain)**		**IEO (Spain)**
Method	**Acoustic**		**Acoustic**	**Acoustic**		**Acoustic**	**DEPM**		**Bottom trawl**
Year/Quarter	**Q1**	**Q2**	**Q4**	**Q2**	**Q3**	**Q4**	**Q2**	**Q3**	**Q4**
1993									Nov
1994									
1995									
1996									
1997									Nov
1998			Nov						Nov
1999	Mar (1)								Nov
2000			Nov						Nov
2001	Mar (1)		Nov						Nov
2002	Mar (1)								Nov
2003	Feb (1)		(Nov)						Nov
2004		(Jun)		Jun(1)					Nov
2005		Apr(1)	(Nov)				Jun(1)		Nov
2006		Apr(1)	(Nov)	Jun(1)					Nov
2007		Apr(1)	Nov		Jul (1)				Nov
2008		Apr(1)	(Nov)				Jun(1)		Nov
2009		Apr(1)		Jun(1)	(Jul)(2)	(Oct)			Nov
2010		Apr(1)			(Jul)(1)				Nov
2011		Apr(1)						Jul(1)	Nov
2012						Nov			Nov
2013		Apr(1)			Aug(1)				Nov
2014		Apr(1)			Jul(1)	Oct		Jul(1)	Nov
2015		Apr(1)			Jul(1)	Oct			Nov
2016		Apr(1)			Jul(1)	Oct			Nov
2017		Apr(1)			Jul(1)			Jul(1)	Nov

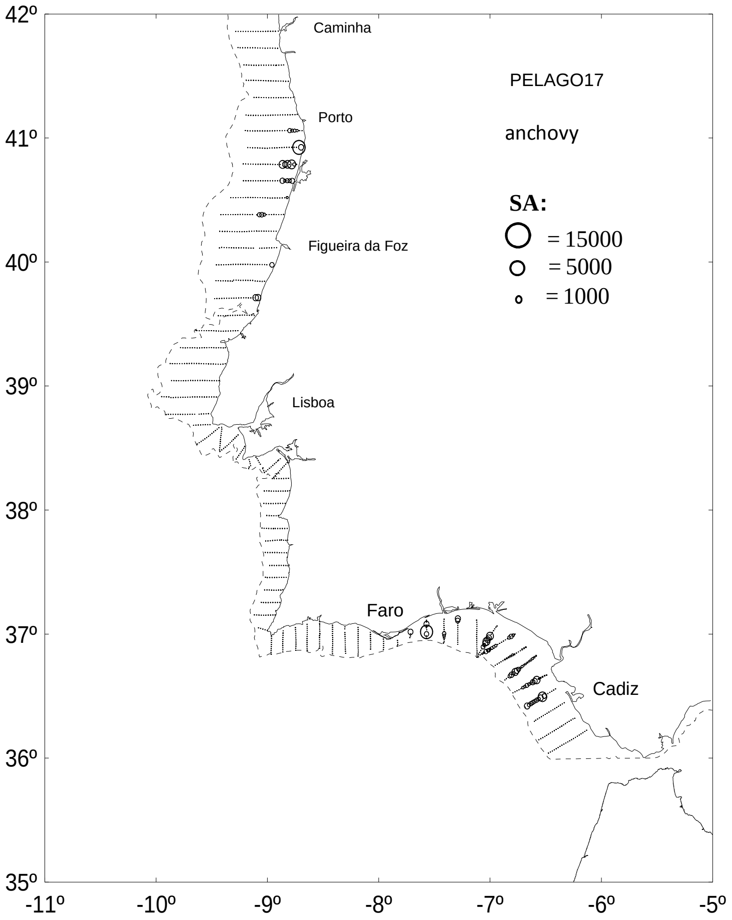


Figure 5.2.1. Ane.27.9a stock. Anchovy in 9a S. *SAR/PELAGO* (spring) and *SARNOV* (autumn) acoustic surveys. Location of the acoustic transects sampled during the survey based on the *PELAGO 2017* survey. Source: ICES WGACEGG.

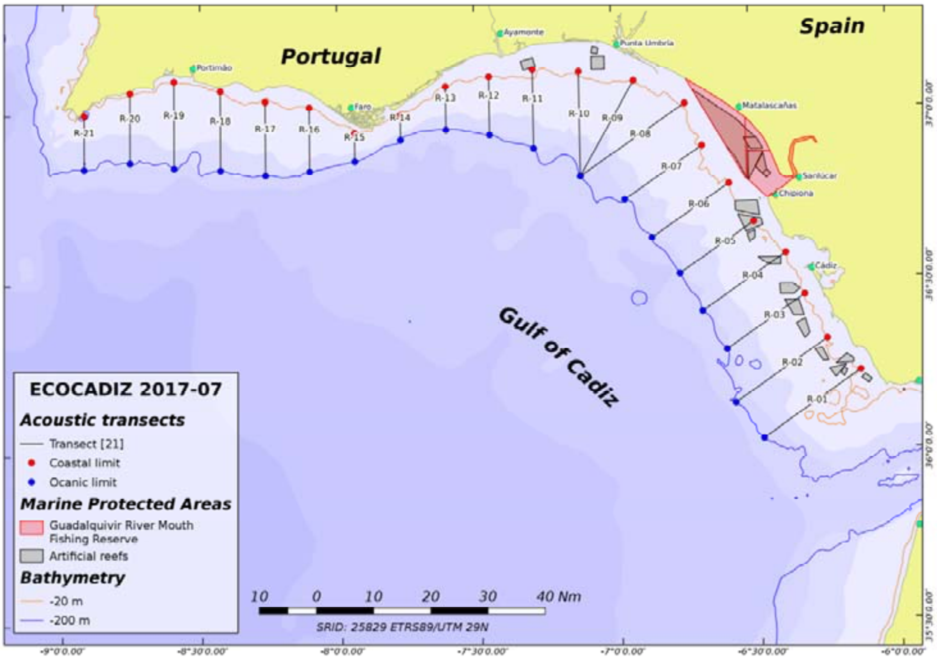


Figure 5.2.2. Ane.27.9a stock. Anchovy in 9a S. *ECOCADIZ* (summer) and *ECOCADIZ-RECLUTAS* (autumn) acoustic surveys. Location of the acoustic transects sampled during the survey based on the *ECOCADIZ 2017-07* survey. Source: ICES WGACEGG.

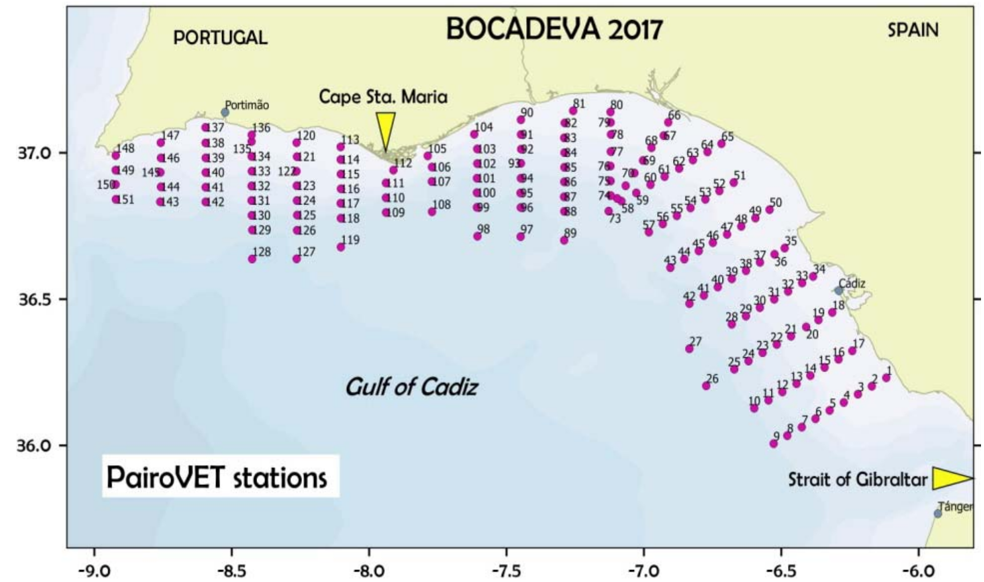


Figure 5.2.3. Ane.27.9a stock. Anchovy in 9a S. *BOCADEVA* GoC anchovy DEPM surveys series. Sampling grid adopted in the surveys based on the *BOCADEVA 2017* survey. Source: ICES WGACEGG.

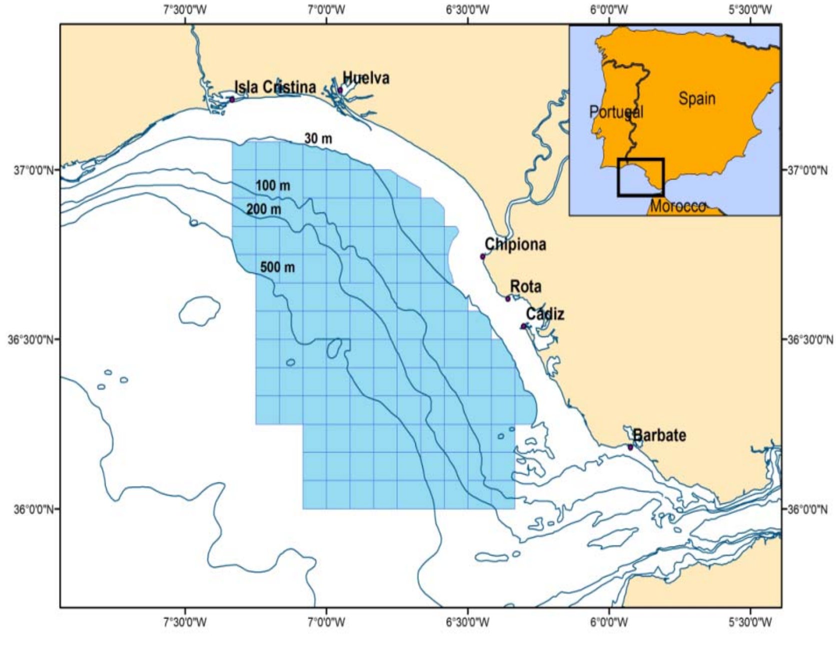


Figure 5.2.4. Ane.27.9a stock. Anchovy in 9a S. *ARSA* autumn bottom trawl survey. Depth strata and sampling grid adopted in the surveys. Only Spanish waters are surveyed by the survey. Source: IEO.

5.3. Data availability.

Table 5.3.1 summarizes the data availability from Portuguese and Spanish surveys surveying the anchovy population in 9a S.

The *PELAGO* time-series with estimates for anchovy in 9a S dates back to 1999, with gaps in 2000, 2004 and 2012. Population estimates are provided without a measure of dispersion. This series provides the size composition (LFD) of the estimated population in numbers and biomass, but age-structured estimates are provided by IPMA only since 2013 on. Aiming to achieve a complete time-series of age-structured estimates, the Spanish commercial ALKs of the quarter coinciding with the survey season was applied to the acoustic estimates from 1999 to 2011. The within- and between surveys consistency analyses of this series was carried out taking into account the above approach. However, age-based information on the population has been included in the assessment model only for the period 2014-2017, when the age-length keys from the surveys were available. The *SARNOV* surveys providing GoC anchovy estimates were only those ones conducted in 1998, 2000, 2001 and 2007. These estimates neither were provided by IPMA with age-structure, but in this case, the approach of applying the Spanish commercial ALKs was not possible to be adopted for lack of time before the preparation of this WD preventing the realization of the surveys' consistency analysis.

The *ECOCADIZ* surveys dates back to 2004, but also show some gaps in 2005, 2008, 2011 (because the triennial *BOCADEVA* DEPM surveys were carried out instead) and 2012 (no survey). Population estimates are provided without a measure of dispersion. This series provides the size composition (LFD) and age-structure of the estimated population in numbers and biomass.

The *ECOCADIZ-RECLUTAS* (autumn in 9a S) acoustic surveys series is still a very short one, with surveys in 2012 (only Spanish waters) and 2014-2016. Population estimates are provided without a measure of dispersion. This series provides the size composition (LFD) and age-structure of the estimated population in numbers and biomass.

The *BOCADEVA* GoC anchovy DEPM surveys series is so far composed by the 2005, 2008, 2011, 2014 and 2017 data points. SSB estimates are provided with a CV estimate but without size composition and age structure. SSB estimate in 2014 was estimated with the spawning fraction estimate from the 2011 survey, whereas the SSB estimate in 2017 has been preliminary computed making use of the time-series average spawning fraction estimate.

The *ARSA* autumn groundfish survey is a relatively long time-series that dates back to 1997 (there is a previous isolated data point in 1993). The series provide relative indices (cpue in number and g/trawling hour) and absolute indices (after applying the swept area method). Both types of indices are provided with estimates of bias. Size-based estimates of the relative abundance indices are routinely estimated. LFDs for the absolute indices have also been estimated for this benchmark. Although they have not been considered in the assessment model, age-structured estimates from this surveys series have also been computed by applying the corresponding Spanish quarterly commercial ALKs.

Table 5.3.2 lists the surveys finally considered in the assessment analytical model after the analyses of survey series consistency described in the corresponding sections below.

Table 5.3.1. Ane.27.9a stock. Anchovy fishery in subdivision 9a South. Data availability of surveys estimates from the Portuguese (PT) and Spanish (ES) surveys. All but *BOCADEVA* survey (DEPM) and *ARSA* (bottom trawl) are acoustic surveys. White background means no data, orange: aggregated biomass only-based estimates; blue: length-based estimates available and green: both length- and age-based estimates. Sources: ICES WGACEGG, ICES WGHANSA and ICES IBTS.

SURVEY	SUB-DIVISION	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
PELAGO	9a S (PT)								🟦		🟦	🟦	🟦		🟦	🟦	🟦	🟦	🟦	🟦	🟦		🟩	🟩	🟩	🟩	🟩
	9a S (ES)								🟦		🟦	🟦	🟦		🟦	🟦	🟦	🟦	🟦	🟦	🟦		🟩	🟩	🟩	🟩	🟩
ECOCADIZ	9a S (PT)													🟩		🟩	🟩		🟩				🟩	🟩	🟩	🟩	🟩
	9a S (ES)													🟩		🟩	🟩		🟩	🟩			🟩	🟩	🟩	🟩	🟩

SURVEY	SUB-DIVISION	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
BOCADEVA	9a S (PT & ES)														🟧			🟧			🟧			🟧			🟧

SURVEY	SUB-DIVISION	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
SAR (AUT)	9a S (PT)							🟦		🟦	🟦						🟦										
	9a S (ES)							🟦		🟦	🟦						🟦										
ECOCADIZ-RECLUTAS	9a S (PT)																							🟩	🟩	🟩	
	9a S (ES)																					🟩		🟩	🟩	🟩	

SURVEY	SUB-DIVISION	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
ARSA	9a S (ES)		🟦				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦

🟧	Aggregated biomass estimates
🟦	Length-based estimates
🟩	Length- and age-structured estimates

Table 5.3.2. Ane.27.9a stock. Anchovy fishery in subdivision 9a South. Surveys finally considered in the assessment model. White background means no data, orange: aggregated biomass only-based estimates; blue: length-based estimates available and violet: both length- and age-based estimates with a survey's own age-length key. Sources: ICES WGACEGG, ICES WGHANSA and ICES IBTS.

SURVEY	SUB-DIVISION	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
PELAGO	9a S (PT)								🟦		🟦	🟦	🟦		🟦	🟦	🟦	🟦	🟦	🟦	🟦		🟦	🟪	🟪	🟪	🟪
	9a S (ES)								🟦		🟦	🟦	🟦		🟦	🟦	🟦	🟦	🟦	🟦	🟦		🟦	🟪	🟪	🟪	🟪
ECOCADIZ	9a S (PT)													🟪		🟪	🟪		🟪				🟪	🟪	🟪	🟪	🟪
	9a S (ES)													🟪		🟪	🟪		🟪	🟪			🟪	🟪	🟪	🟪	🟪
BOCADEVA	9a S (PT & ES)														🟧			🟧			🟧			🟧			🟧

🟧	Aggregated biomass estimates
🟦	Length-based estimates
🟪	Length- and age- based estimates, with own age-length key

5.4. Survey consistency.

Two methods of examining survey consistency have been used for anchovy in 9a South: within-survey consistency and between-survey consistency. These methods mainly follow to those adopted in the 2004 ICES Study Group on Assessment Methods Applicable to Assessment of Norwegian Spring-Spawning Herring and Blue Whiting Stocks (SGAMHBW; ICES, 2004b; see also Payne *et al*., 2009).

Within-survey consistency:

$N_{a,y,s}$ is the abundance index for age a, year y, and survey s. Within-survey consistency may be expressed as correlation coefficients calculated over years between the $N_{a,y,s \text{ and}}$ $N_{a+1,y+1,s}$ offer an indication of the ability of survey s to track year class strength effects. This has been done in the linear domain to allow for zeros as these are often present in the data, if correlation of log(N) was preferred the log of (N+k) would need to be used where k is a small constant depending on the scaling of N. A value of k of half of the min{N} might be preferred (ICES, 2004b). In addition to the correlation coefficients, bi-variate plots were examined to check for linearity and the absence of a spuriously high correlation resulting from one or two outliers.

There are limits to the interpretation of such correlation coefficients. If for a stock the variability of the true year class strength is low within the observed period, this leads to lower correlations and conversely high variability in recruitment leads to potentially high correlation. Also, when we calculate a correlation coefficient between the two variables X1(y) and X2(y) with X1(y) = $N_{a,y,s}$ and X2(y) = $N_{a+1,y+1,s}$ we are measuring the adequacy of a linear relation of the form X2(y) = α X1(y) + β . We accept or assume that the corresponding value for α may not be equal to one due to mortality or survey catchability. But this also implies that we may need to accept that the catchability coefficients associated to age a and/or a+1 may vary with year class strength. In most cases, in assessments this is not allowed. However, for the sake of simplicity it was decided to use basic correlation coefficients, as they prove a useful indicator. They may highlight specific difficulties, including phenomena that would deserve further biological interpretation, for instance when it appears that a survey can efficiently track year class strength effects within an age range, but not necessarily the same age range as another survey. This implies even for adult it may be preferable to limit the upper ages used for tuning for some surveys.

To visualize the correlation in the surveys plots were made where the numbers at age a are plotted versus the numbers at age a+1 in the same survey. The points are marked as the year class so it is possible to follow the year classes through the survey. A linear regression was made where the line is forced through the origin. The fitted line is shown.

Within-survey consistency is completed with survey-based catch curves for each of the year classes (i.e. cohorts) present in the assessed population. In this case, natural logarithms of abundance indices (ln(N)) for successive ages composing the cohort are plotted and a regression line and model is fitted to the right descending limb of the curve. The abundance index for age 0 (not fully recruited to the adult population), when present (e.g. in juvenile surveys conducted in autumn and in summer surveys conducted in later dates than usual) was neither plotted nor fitted to the regression line for the purposes of graphical representation. This analysis allows rapid assessment of the consistency of the abundance indices with the presumed model that such indices (in numbers) should decline consistently with age, as influenced by natural and fishing mortality and appropriate catchabilities at age for survey catches. If cohorts are poorly tracked due to fluctuating distribution patterns, poor sampling or other factors influencing seasonal or annual catchability, then catch curves should not demonstrate consistent descending right-hand limbs.

Between-survey consistency

Correlations for a given age between abundance indices provided by two surveys, s_1 and s_2, the corresponding two time series being:

$X1_y = U_{a,y,s1}$ and $X2_y = U_{a,y,s2.}$

A review of the corresponding correlation coefficients makes it possible to assess the consistency between surveys for each age. Identification of a strong correlation pattern between independently conducted surveys could pave the way for tuning techniques that would recognize them. A comparison of within-survey consistency and between-survey consistency may be used as a first stage to identifying ages that may be unsuitable for tuning (ICES, 2004b).

To see if there are correlations between surveys, plots were made where the numbers at the same age in the surveys were plotted against each other. A linear regression was made where the line was forced through the origin. The fitted line is shown in the plots.

5.5. Spring acoustic survey series *SAR/PELAGO*.

5.5.1. Acoustic estimates

Figure 5.5.1.1 shows the time series of abundance and biomass estimates. The estimated abundances oscillated between 891 (2013) and 9,811 (2016) million fish (time-series average: 2,744 million fish). The range of biomass estimates oscillates between 7,395 (2010) and 65,345 (2016) t (time-series average: 26,120 t). The most recent estimates show a strong drop in the population levels after the historical maximum recorded in 2016.

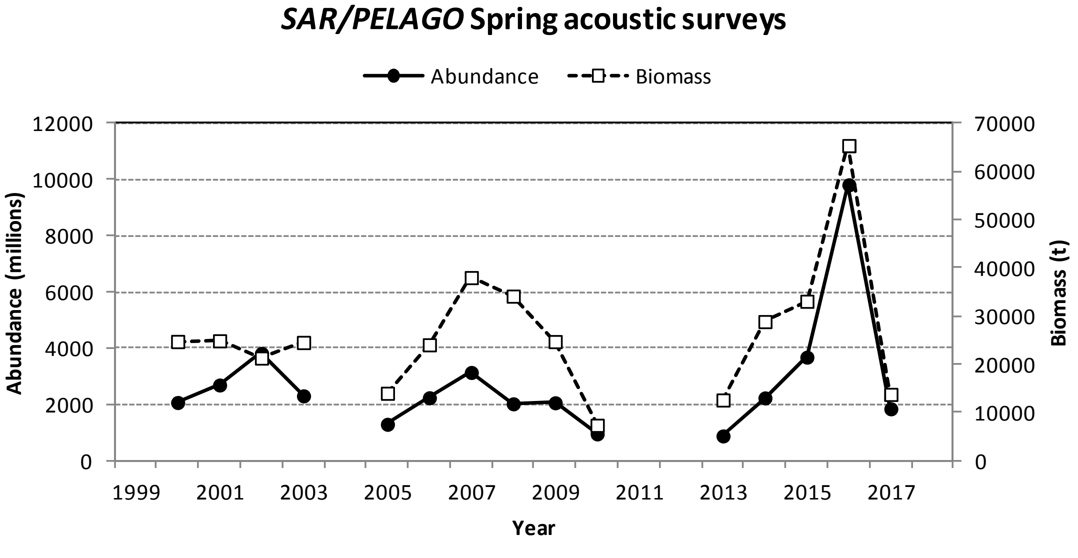


Figure 5.5.1.1. Anchovy in 9a South. *SAR/PELAGO* spring acoustic surveys. Time series of abundance (millions) and biomass (t) acoustic estimates.

The *PELAGO 2011* survey estimated a null occurrence of anchovy in 9a S as a result of a null acoustic detection of anchovy and its absence in the ground-truthing fishing hauls. However, the survey was conducted under very bad weather conditions which could have affected both the echosounding and fishing. In fact, anchovy egg density sampled with CUFES during this survey showed relatively high, confirming the occurrence of the species in the area. On the other hand, the *BOCADEVA* DEPM survey conducted in summer this year estimated 32,757 t (see **Section 5.7**). These reasons led to the ICES WGACEGG to reject the *PELAGO 2011* null estimate.

The discrimination of anchovy echo-traces is very difficult in the Spanish waters of the Gulf of Cadiz since anchovy schools are usually found embedded in a very dense (demersal) plankton layer. This layer may continuously extend over the inner-middle shelf of the central part of this area (**Figure 5.5.1.2**). In these situations are evident the advantages of using multi-frequency echo-sounding because its greater discriminatory power and the improvement of the echogram "lecture". For the time being, *PELAGO* surveys only use the 38 kHz working frequency.

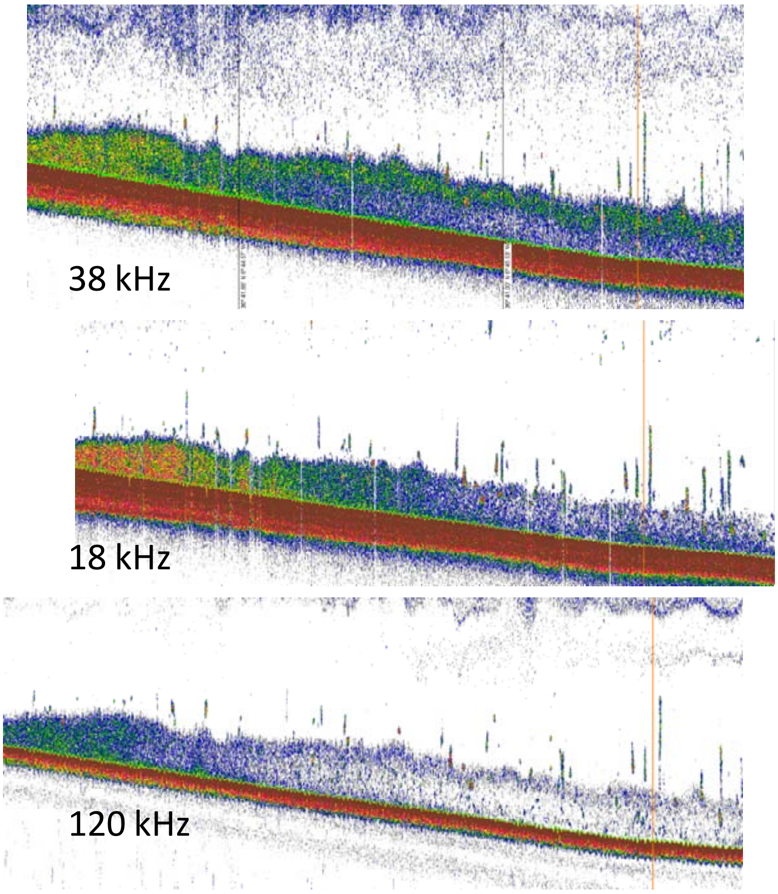


Figure 5.5.1.2. Anchovy in 9a South. Echograms of a typical situation of Gulf of Cadiz anchovy schools embedded inside a dense plankton layer recorded at different frequencies. Source: IEO and ICES WGACEGG.

Size composition of the estimated population ranged between 5.5 and 17.5 cm size classes (**Figure 5.5.1.3**). The time series of LFDs of the estimated population usually shows uni-modal LFDs, with the mode at around 10.0 – 13.0 cm size classes. In some years (2002, 2009, 2010, 2016) 2 modes, at around 8.5-9.0 cm and 11.0-13.0 cm, are found in the LFDs. In 2003 were also observed 2 modes, the smallest one at 6.0 cm and second one at 13.0 cm. The survey was conducted earlier in that year, in February; hence some late recruitment was still detected.

Age-structure of the estimated population is shown in **Figure 5.5.1.4**. In the surveyed population in spring are present from 1 to 4 years old anchovies, with the bulk of the population being composed by 1 and 2 olds. The 2001, 2006, 2014 and 2015 year classes outstand as stronger cohorts.

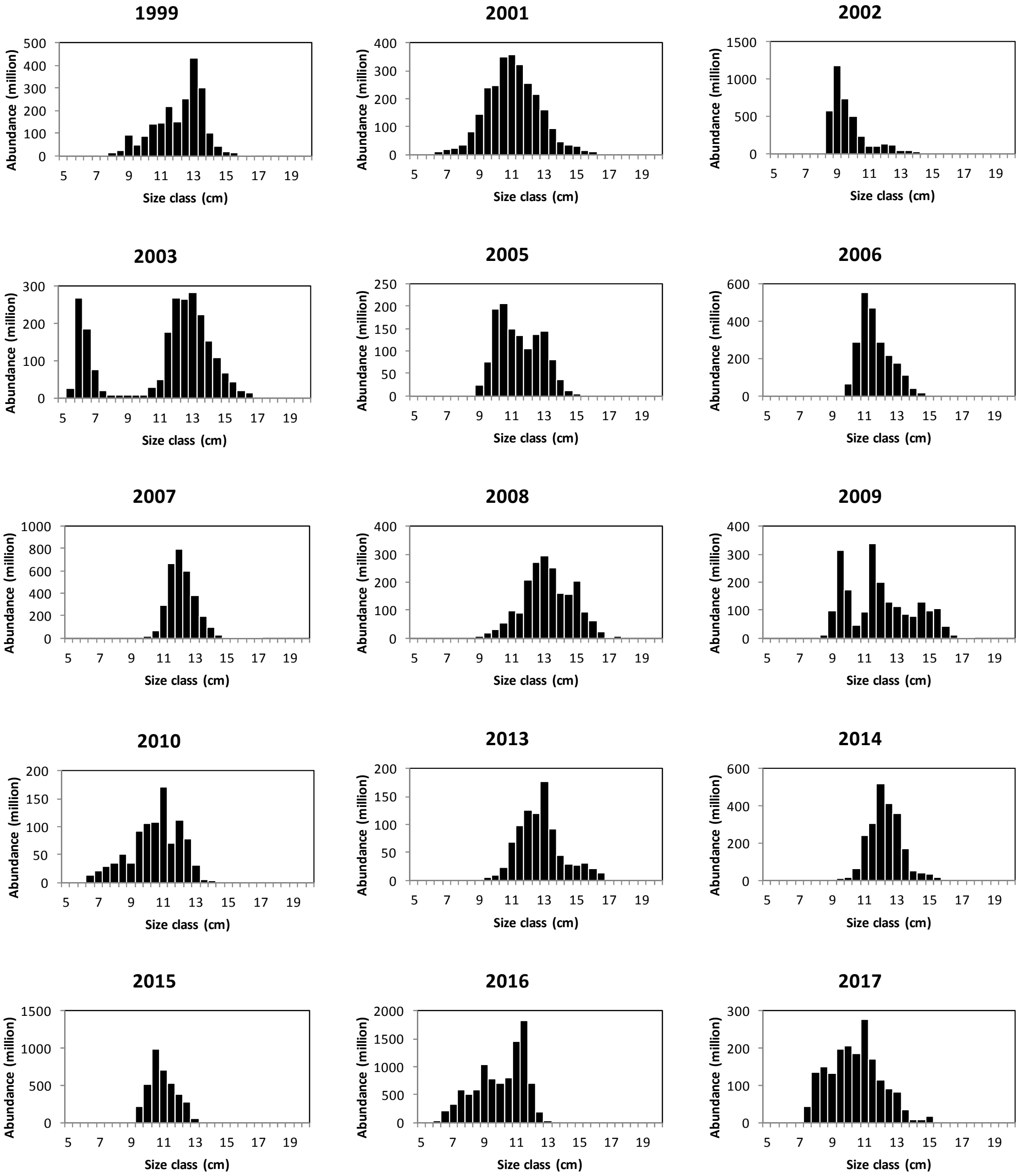


Figure 5.5.1.3. Anchovy in 9a South. *SAR/PELAGO* spring acoustic surveys. Size composition (0.5 cm size classes) of the estimated population (millions). Note the different scale of the y axis and the occurrence of gaps through the series.

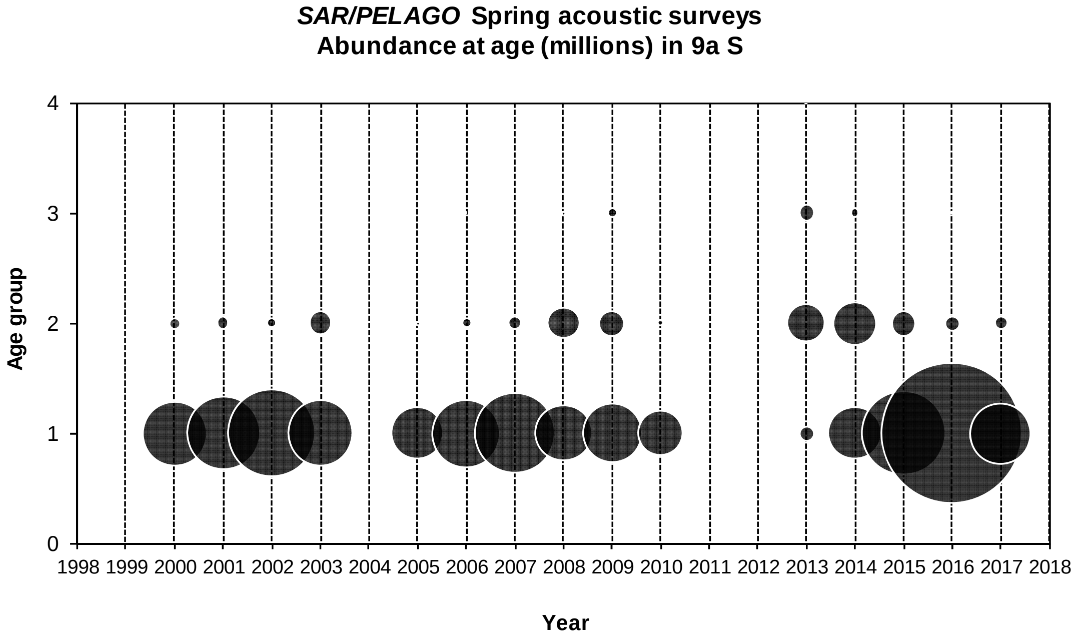


Figure 5.5.1.4. Anchovy in 9a South. *SAR/PELAGO* spring acoustic surveys. Age structure of the estimated population (millions). The age structure for the 2000-2010 estimates was derived by applying IEO ALKs from commercial samples from the Spanish fishery in the corresponding quarter. Since 2013 on age structured estimates were computed with their corresponding IPMA surveys' ALKs.

5.5.2. Within-survey consistency

Within-survey consistency is illustrated with scatter plots and correlations of $N_{a',y,PELAGO}$ against $N_{a+1,y+1',PELAGO}$ in **Figure 5.5.2.1** and with catch curves of different year classes in **Figures 5.5.2.2** and **5.5.2.3**.

Scatterplots and correlation values indicate a negative correlation between ages 1 and 2 (r= -0.33; n=12) and an absence of correlation between ages 3 and 4 (r =0.00; n= 13). Occurrence of ages 3 and 4 in the population during the survey season is accidental. The only ages that are tracked, although not relatively well, by this surveys series are the ages 2 and 3 (r=0.49; n=12). Catch curves indicate a poor cohort tracking ($R^2 < 0.80$) for the 1998, 2000, 2003 and 2012 year classes because inconsistencies between ages 1 and 2 (in 2012 year class) and ages 2 and 3 (in 2000 and 2003 year classes).

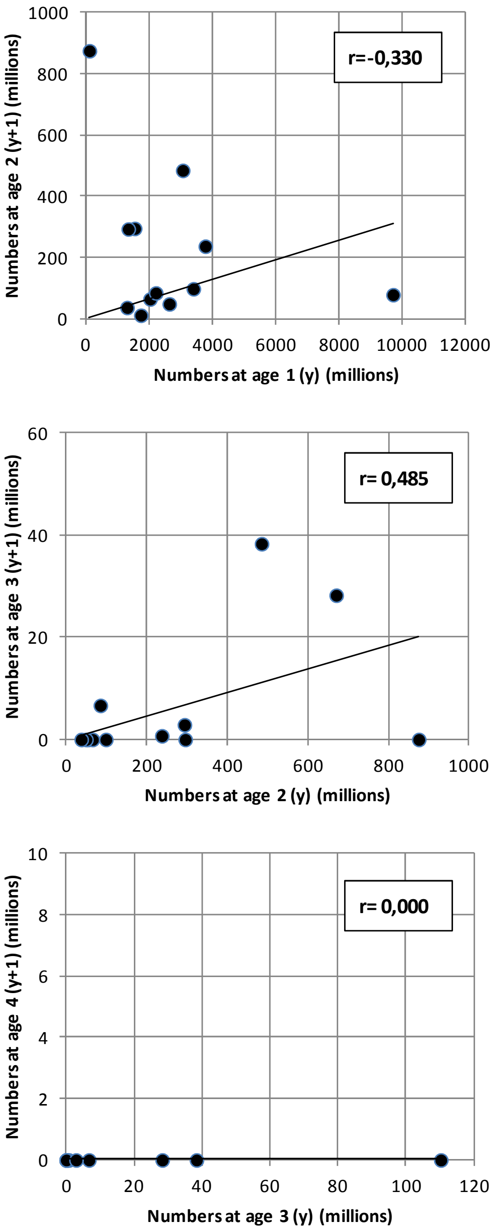


Figure 5.5.2.1. Anchovy in 9a South. *SAR/PELAGO* spring acoustic surveys. Correlation within survey. Pearson correlation coefficient and the fitted linear regression line (forced through the origin) are also shown.

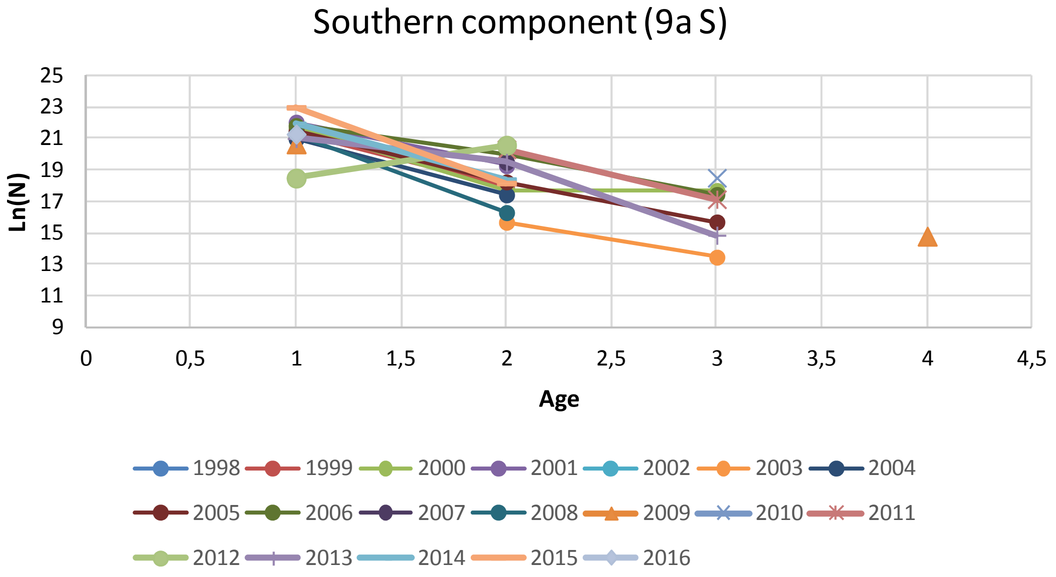
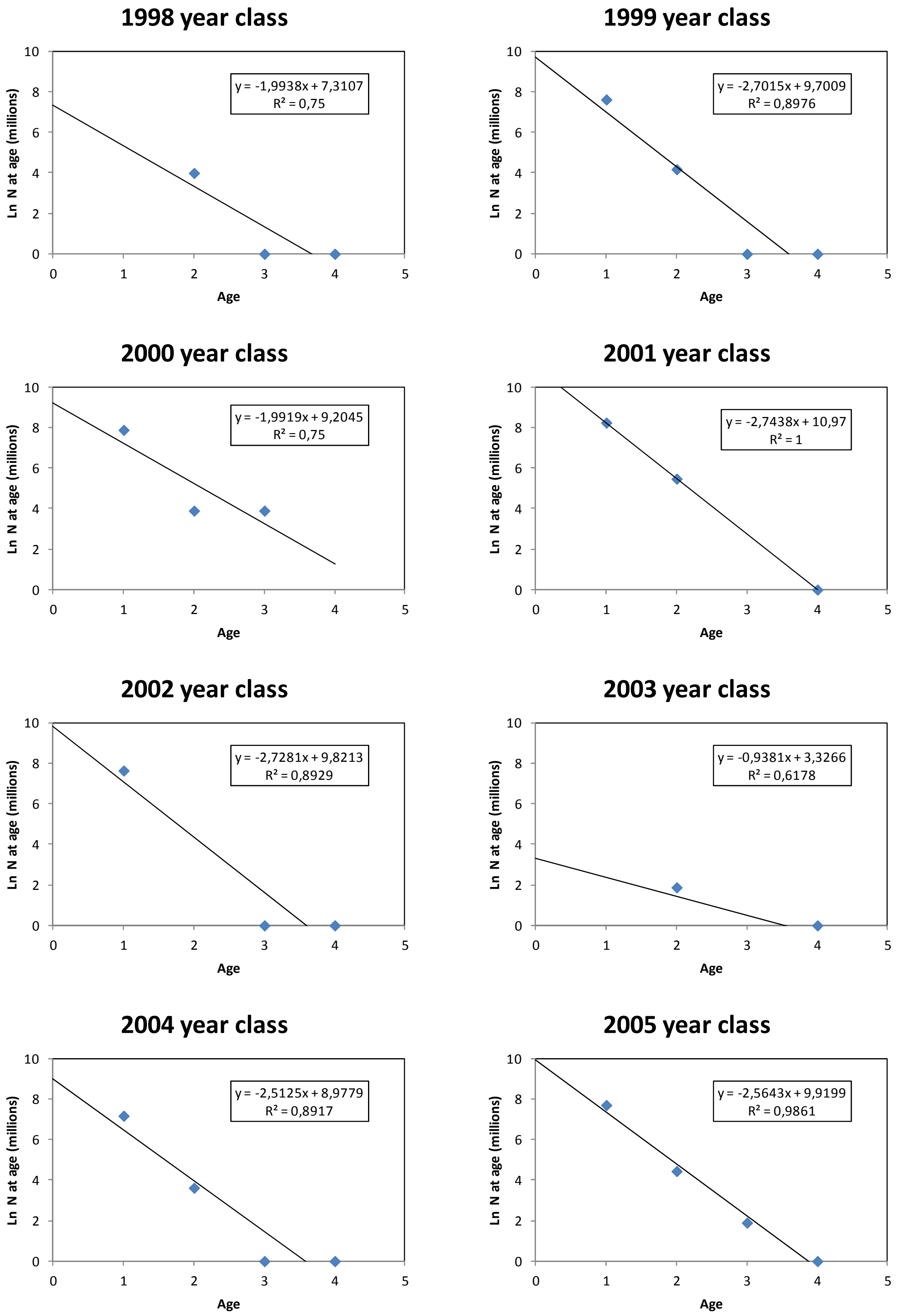


Figure 5.5.2.2. Anchovy in 9a South. *SAR/PELAGO* spring acoustic surveys. Cohorts (ln(N) per age group) tracked by the survey series. The age structure for the 2000-2010 estimates was derived by applying IEO ALKs from commercial samples from the Spanish fishery in the corresponding quarter. Since 2013 on age structured estimates were computed with their corresponding IPMA surveys' ALKs.

5.5.3. Between-survey consistency

Figure 5.5.3.1 shows the scatterplots and correlation coefficients at age analyzing the consistency between *PELAGO* spring and *ECOCADIZ* summer acoustic surveys. Information on this last surveys series is given in **Section 5.6**. Age 0 index not showed any correlation between surveys (r=0.00; n=8). Age 0 anchovies only occurred in the *ECOCADIZ* surveys conducted since 2010 on because a delay in the survey dates (late July-early August), which coincides with the start of the recruitment of juveniles to the adult population. Age 2 (r=-0.40; n=8) and Age 4 (r=-0.14; n=8) showed negative correlations between surveys suggesting inconsistencies in these indices. The accidental occurrence of age 4 anchovies in the population as sampled by both surveys may be the reason for the bad performance of this index. For Age 2 the inconsistency is explained by the different relative importance of this age group in both surveys. For *PELAGO* it would be expected higher indices for all the fully recruited ages to the population than in *ECOCADIZ* surveys because an added total mortality for this last survey. However, this is only fulfilled in 4 of the 8 data pairs (2009, 2013, 2014, and 2015), whereas in the rest of pairs (2006, 2007, 2010 and 2016) occurred the contrary. Age 1 index is the only one which shows a relative consistency (r=0.25; n=8). This low performance is because to the lower estimates of this index from 2006, 2013 and 2014 *PELAGO* surveys than in their summer counterparts.

Figure 5.5.3.2 shows the scatterplots and correlation coefficients at age analyzing the consistency between *PELAGO* spring and *ECOCADIZ-RECLUTAS* autumn acoustic surveys. Information on this last surveys series is given in **Section 5.8**. Results from these correlation analyses should be considered with caution because the low number of data pairs (n=3) as a result of the shortness of the *ECOCADIZ-RECLUTAS* series. Age 0 index not showed between-survey consistence since the spring survey does not sample this age because the survey season. The negative correlation found for the Age 1 index (r=-0.65) is because the inconsistency in the values for the surveys in 2014, when the autumn survey estimated a higher abundance of age 1 anchovies than the previous spring survey. Age 3 and Age 4 indices neither showed between-survey correlation (r=0.00 in both cases): Age 4 anchovies were absent in the pairs considered in the analysis, and Age 3 anchovies occurred in the spring surveys but not in the autumn ones. Age 2 was the only index showing a good performance regarding the between-survey consistency (r=0.95).


1998 year class

1999 year class

2000 year class

2001 year class

2002 year class

2003 year class

2004 year class

2005 year class

Figure 5.5.2.3. Anchovy in 9a South. *SAR/PELAGO* spring acoustic surveys. Catch curves by year class for anchovy in 9a South. The regression coefficient and the fitted linear regression line and model are also shown.

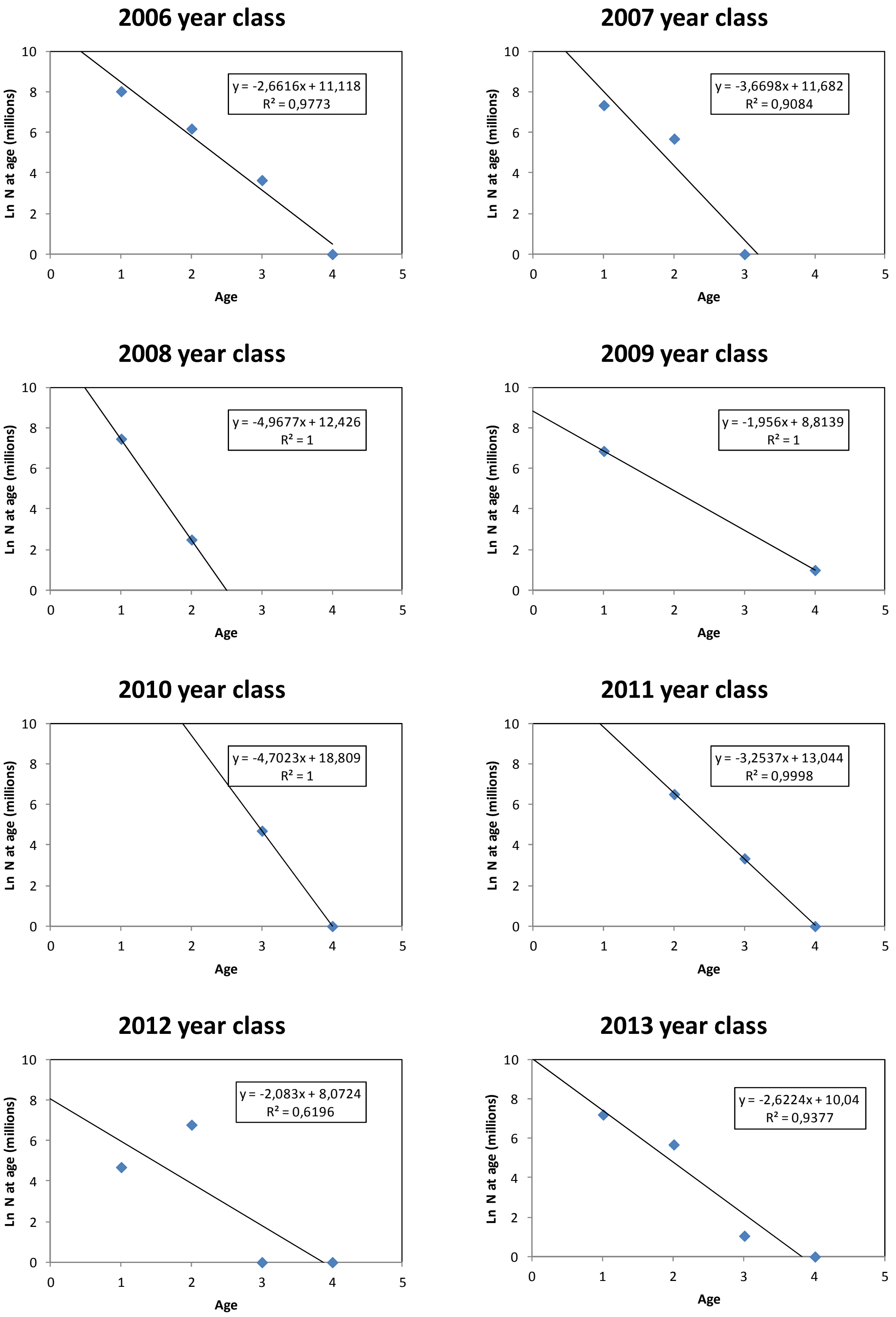


Figure 5.5.2.3. Anchovy in 9a South. *SAR/PELAGO* spring acoustic surveys. Catch curves by year class for anchovy in 9a South. The regression coefficient and the fitted linear regression line and model are also shown. Cont'd.

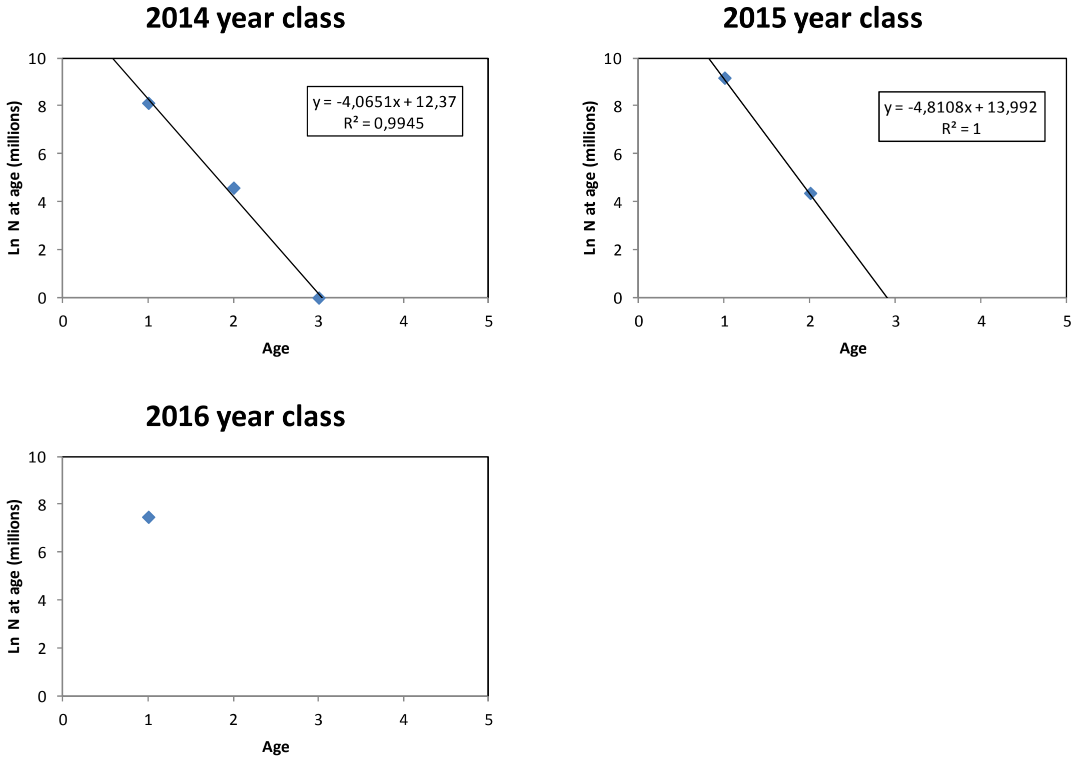


Figure 5.5.2.3. Anchovy in 9a South. *SAR/PELAGO* spring acoustic surveys. Catch curves by year class for anchovy in 9a South. The regression coefficient and the fitted linear regression line and model are also shown. Cont'd.

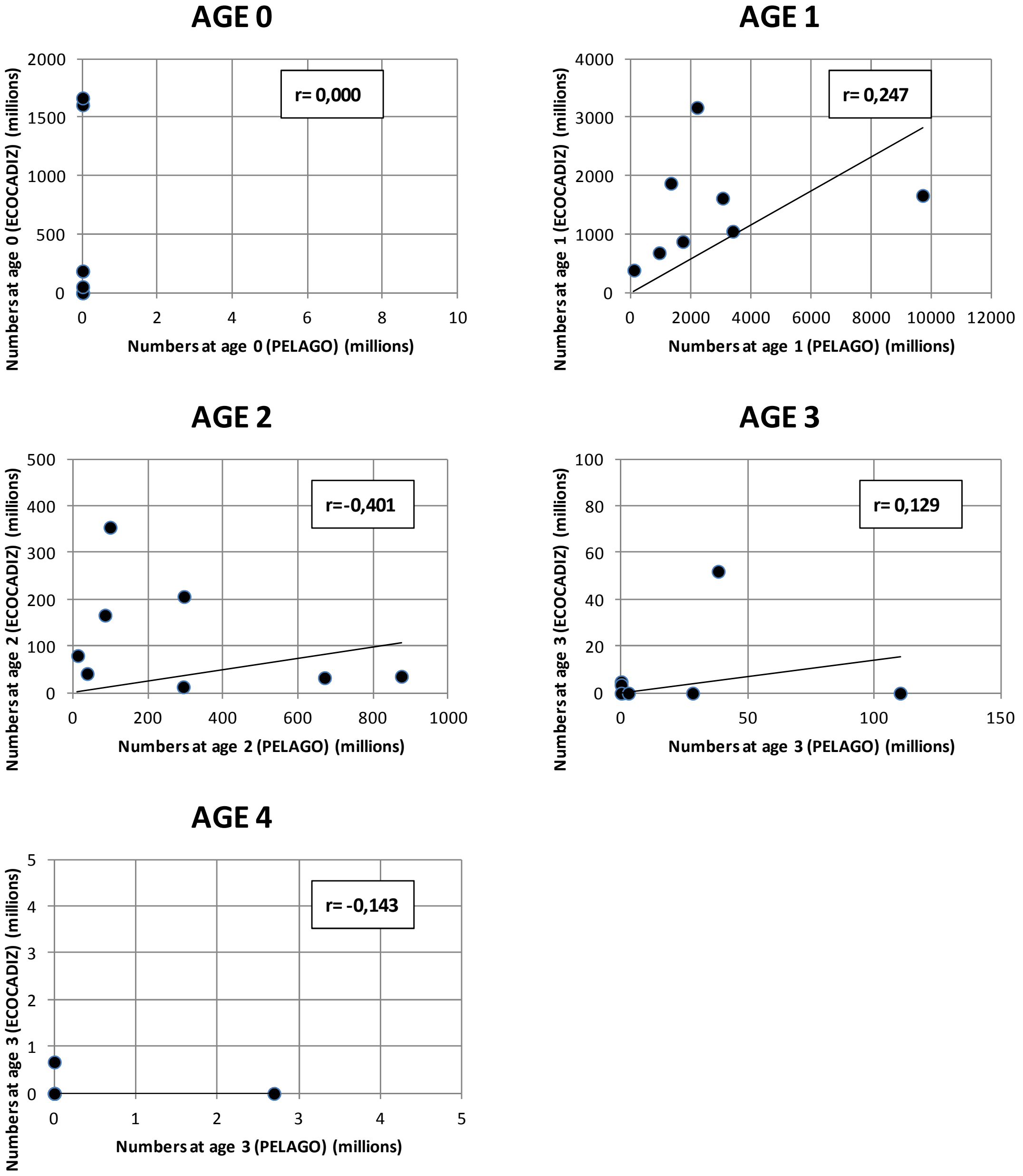


Figure 5.5.3.1. Anchovy in 9a South. Correlation between *PELAGO* (spring) and *ECOCADIZ* (summer) surveys. Pearson correlation coefficient and the fitted linear regression line (forced through the origin) are also shown.

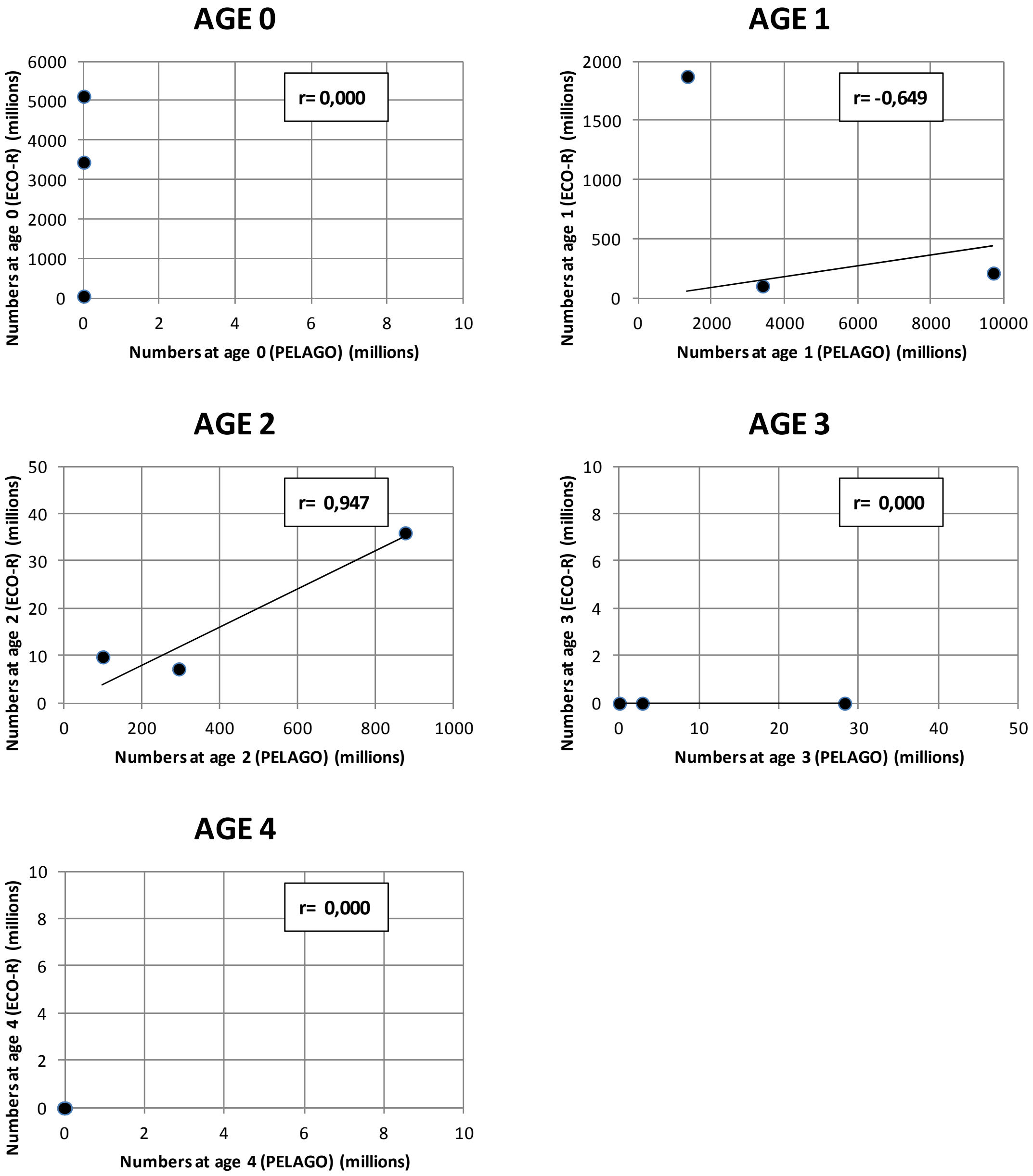


Figure 5.5.3.2. Anchovy in 9a South. Correlation between *PELAGO* (spring) and *ECOCADIZ-RECLUTAS* (autumn-juvenile) surveys. Pearson correlation coefficient and the fitted linear regression line (forced through the origin) are also shown.

5.6. Summer acoustic survey series *ECOCADIZ*.

5.6.1. Acoustic estimates.

Figure 5.6.1.1 shows the time series of abundance and biomass estimates. The estimated abundances oscillated between 609 (2013) and 3,686 (2016) million fish (time-series average: 1,876 million fish). The range of biomass estimates oscillates between 8,487 (2013) and 35,539 (2006) t (time-series average: 22,194 t). Trends in abundance and biomass are quite similar to the ones described for the *PELAGO* spring surveys series. The most recent summer estimates also show a strong drop in the population levels after the second historical maximum recorded in 2016.

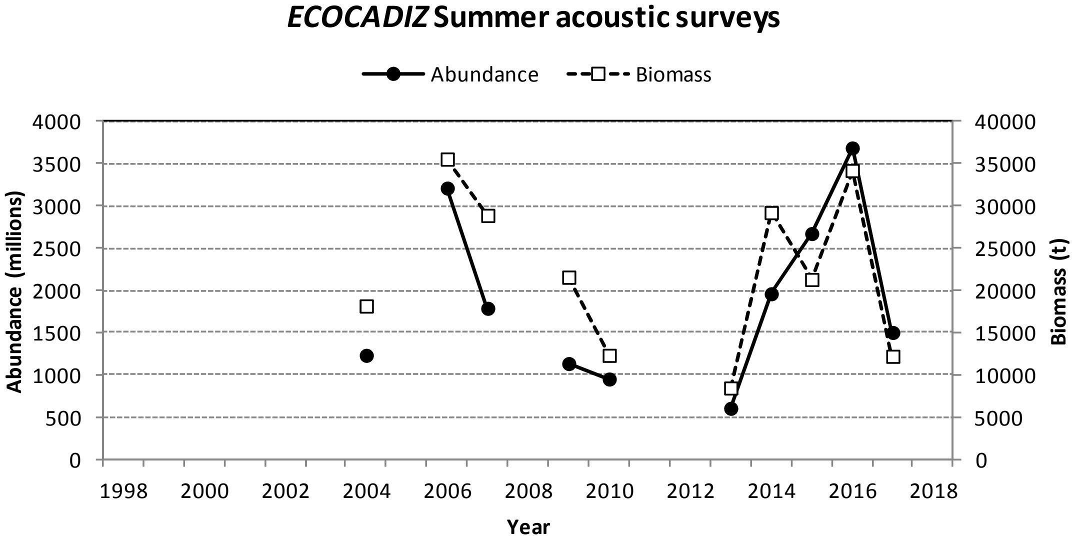


Figure 5.6.1.1. Anchovy in 9a South. *ECOCADIZ* summer acoustic surveys. Time series of abundance (millions) and biomass (t) acoustic estimates.

Size composition of the estimated population ranged between 6.5 and 18.5 cm size classes (**Figure 5.6.1.2**). The time series of LFDs of the estimated population usually shows uni-modal LFDs, with the mode at around 12.0 – 13.0 cm size classes. In some years (2010, 2013, 2015) 2 modes, at around 8.0-11.0 cm and 10.5-14.5 cm, are found in the LFDs.

Age-structure of the estimated population is shown in **Figure 5.6.1.3**. In the surveyed population in summer are present from 0 to 4 years old anchovies, with the bulk of the population being composed by 1 and 2 olds in those surveys conducted between 2004 and 2009, and by 0 and 1 olds in the later surveys. The relative importance of age 0 anchovies in the surveys conducted since 2010 is due to a delay in the survey dates (late July-early August). The 2005, 2006, 2013, 2014 and 2015 year classes outstand as stronger cohorts.

5.6.2. Within-survey consistency.

Within-survey consistency is illustrated with scatter plots and correlations of $N_{a,y,ECOCADIZ}$ against $N_{a+1,y+1,ECOCADIZ}$ in **Figure 5.6.2.1** and with catch curves of different year classes in **Figures 5.6.2.2** and **5.6.2.3**.

Scatterplots and correlation values indicate positive but low correlations between ages. The track from Age 0 to Age 1 is not well sampled by the survey (r=0.39; n=5) since age 0 anchovies started to occur in the surveys since 2010 on which were conducted in delayed dates. The low correlation between Age 1 and Age 2 indices (r= 0.09; n=5) is mainly caused by the low estimate for age 2 anchovies in 2015. If the data pair affected by this value is not considered in the analysis, the correlation rises up to 0.79. The decay between Age 2 and Age 3 indices seems to be relatively consistent for the available data pairs (r=0.51; n=5). Finally, the absence of correlation between Age 3 and Age 4 is due to the incidental occurrence of both ages in the sampled population.

Available data allows the tracking of 2002 to 2014 year classes. Catch curves indicate a relative good cohort tracking ($R^2 > 0.80$) for all the year classes but 2010 and 2011 year classes.

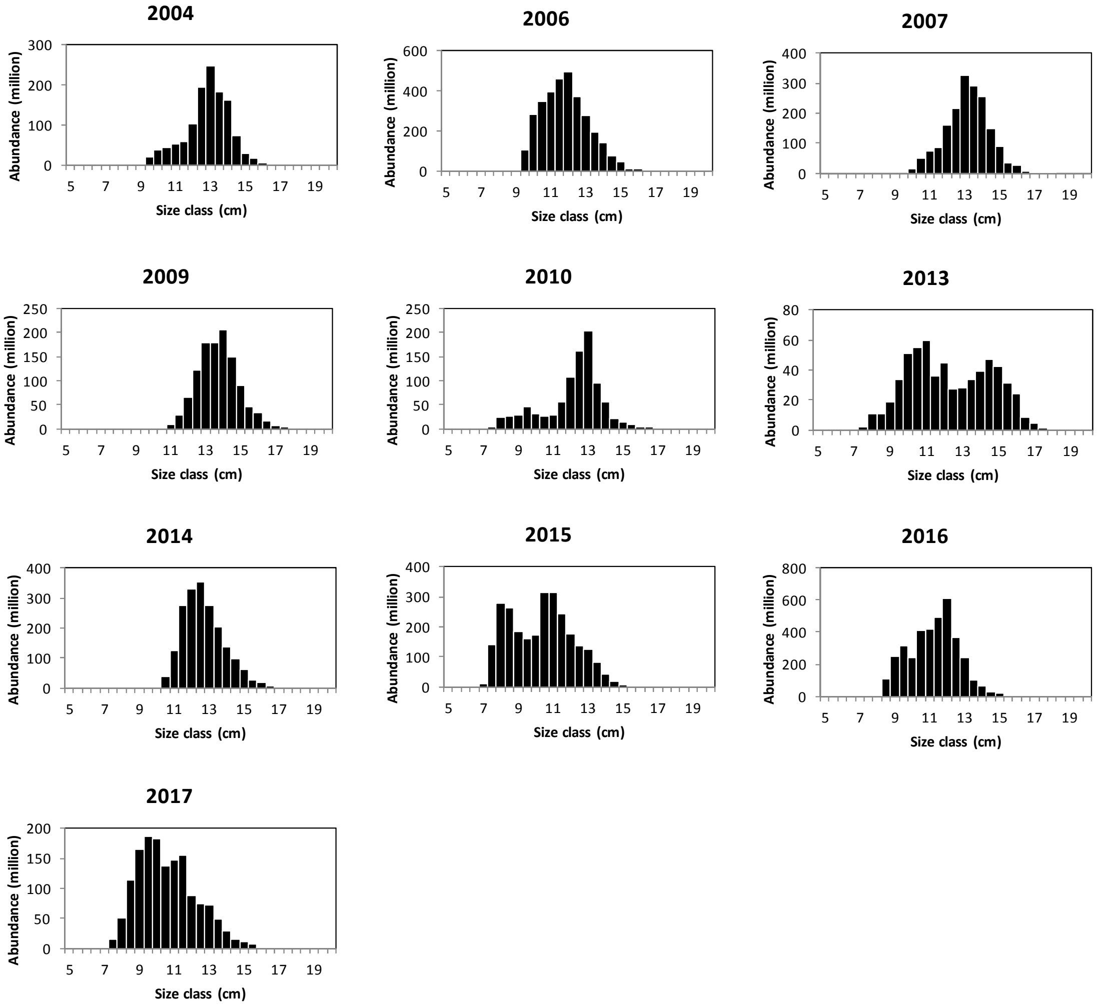


Figure 5.6.1.2. Anchovy in 9a South. *ECOCADIZ* summer acoustic surveys. Size composition (0.5 cm size classes) of the estimated population (millions). Note the different scale of the y axis and the occurrence of gaps through the series. The 2010 survey only surveyed the waters comprised between Cape Santa Maria and Cape Trafalgar.

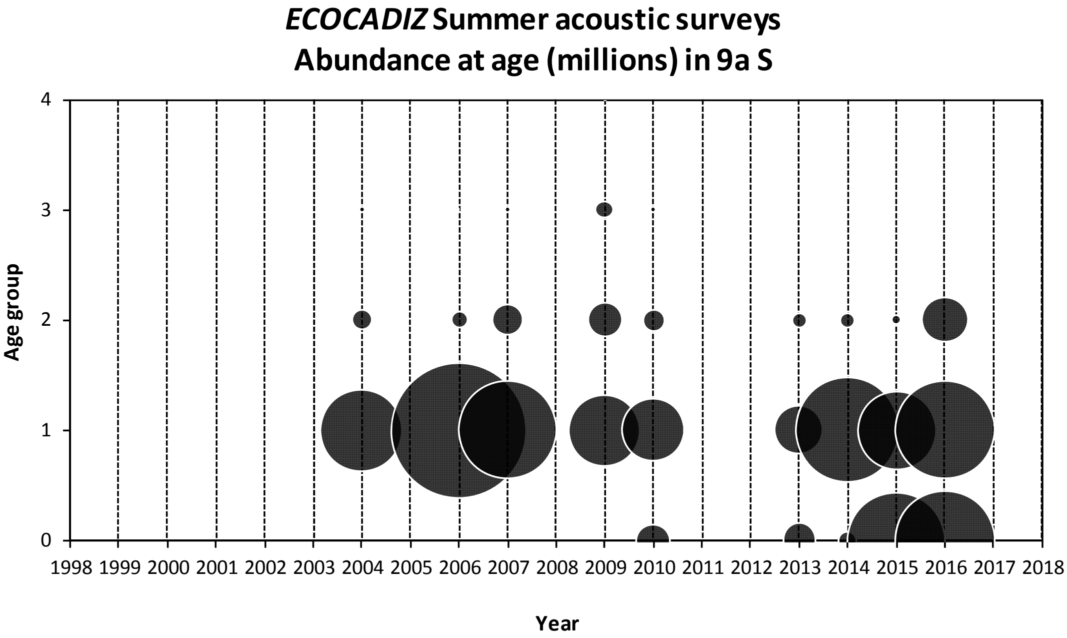


Figure 5.6.1.3. Anchovy in 9a South. *ECOCADIZ* summer acoustic surveys. Age structure of the estimated population (millions). The age structure of the estimated population in the 2017 survey is not yet available.

5.6.3. Between-survey consistency

The consistency between *ECOCADIZ* and *PELAGO* surveys series has been analyzed in **Section 5.5.3**. **Figure 5.6.3.1** shows the scatterplots and correlation coefficients at age analyzing the consistency between *ECOCADIZ* and *ECOCADIZ-RECLUTAS* autumn acoustic surveys. Information on this last surveys series is given in **Section 5.8**. Results from these correlation analyses should be considered with caution because the low number of data pairs (n=3) as a result of the shortness of the *ECOCADIZ-RECLUTAS* series.

Taking into account the above, Age 0 and Age 1 indices showed a relatively good between-survey consistency (r=0.94 and r=0.74, respectively), but that is not the case for the older ages surveyed by both surveys. Notwithstanding the above, Age 3 and Age 4 anchovies were absent in the pairs considered in the analysis. The negative correlation found for the Age 2 index is because the inconsistency in the values for the surveys in 2014.

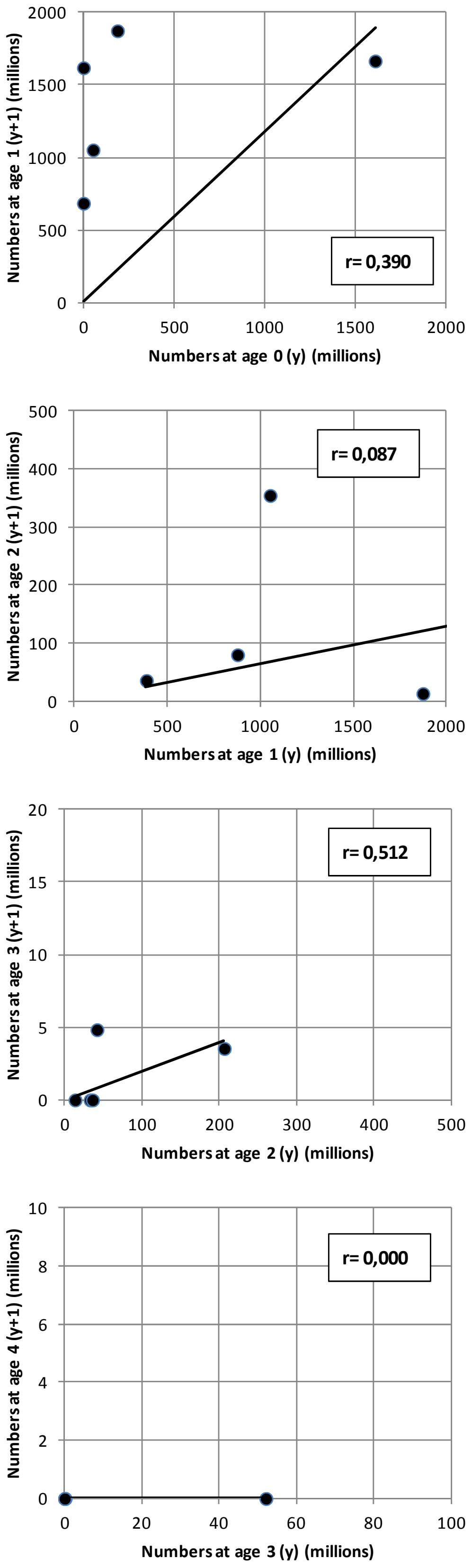


Figure 5.6.2.1. Anchovy in 9a South. *ECOCADIZ* summer acoustic surveys. Correlation within survey. Pearson correlation coefficient and the fitted linear regression line (forced through the origin) are also shown.

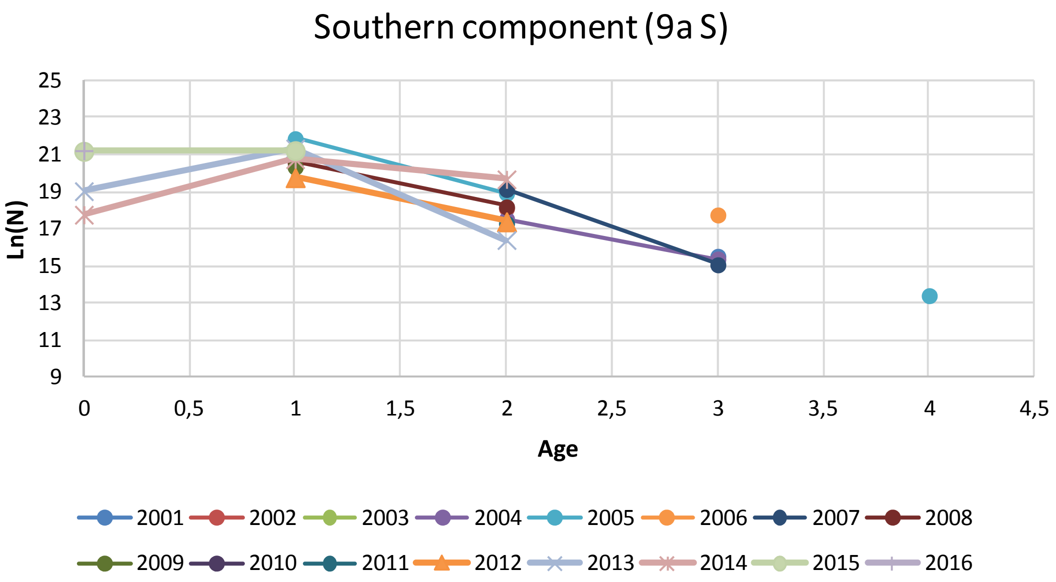


Figure 5.6.2.2. Anchovy in 9a South. *ECOCADIZ* summer acoustic surveys. Cohorts (ln(N) per age group) tracked by the survey series. Age 0 anchovies were present in the population in the surveys conducted since 2010 on because some delay in the survey dates. The age structure of the estimated population in the 2017 survey is not yet available.

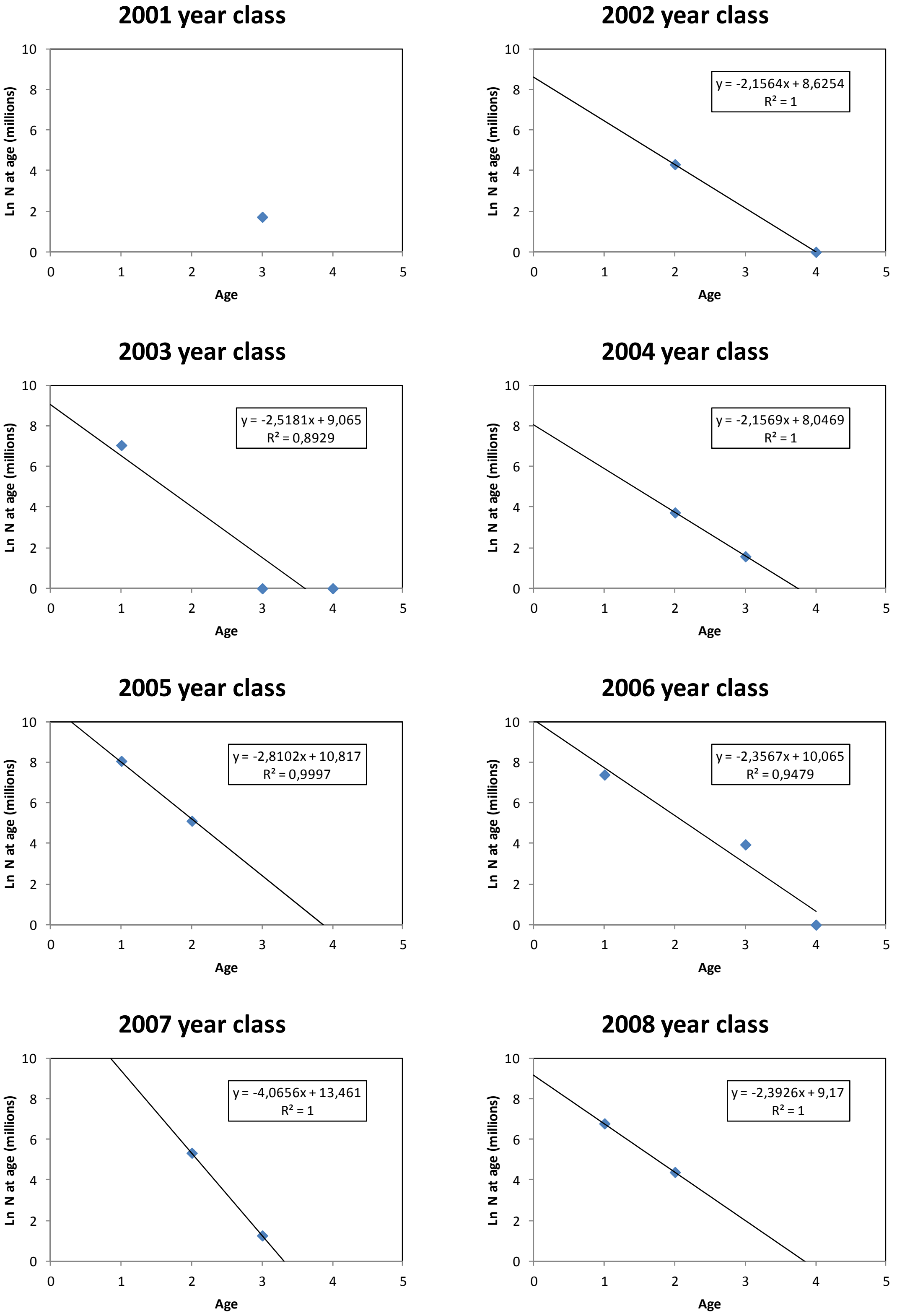


Figure 5.6.2.3. Anchovy in 9a South. *ECOCADIZ* summer acoustic surveys. Catch curves by year class for anchovy in 9a South. The regression coefficient and the fitted linear regression line and model are also shown. Age 0 anchovies were present in the population in the surveys conducted since 2010 on, but, for simplicity in the linear fitting, they have not been included in the graphs since during the survey season age 0 was not fully recruited to the adult population (only the right limb of the catch curve is shown).

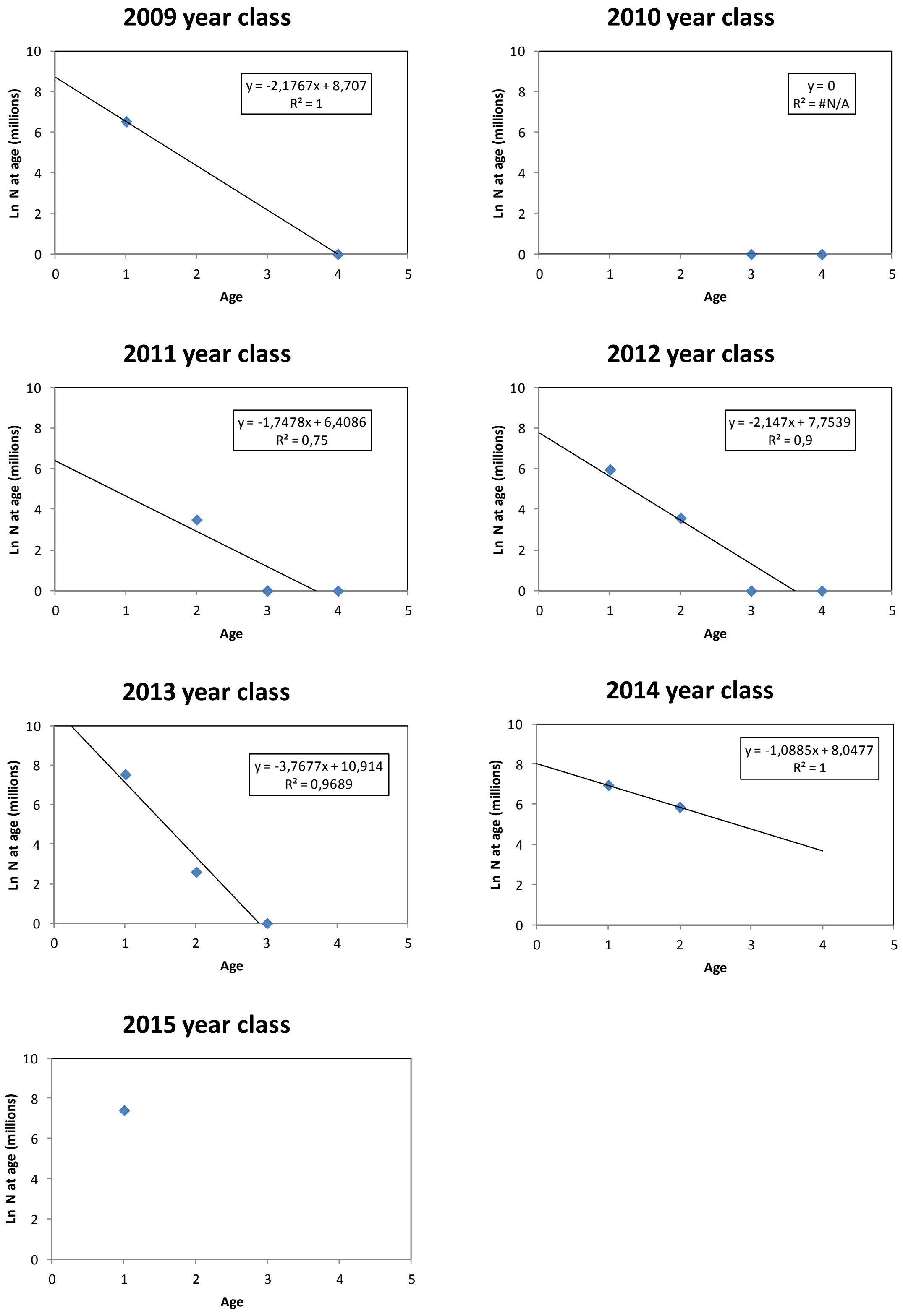


Figure 5.6.2.3. Anchovy in 9a South. *ECOCADIZ* summer acoustic surveys. Catch curves by year class for anchovy in 9a South. The regression coefficient and the fitted linear regression line and model are also shown. Age 0 anchovies were present in the population in the surveys conducted since 2010 on, but, for simplicity in the linear fitting, they have not been included in the graphs since during the survey season age 0 was not fully recruited to the adult population (only the right limb of the catch curve is shown). Cont'd.

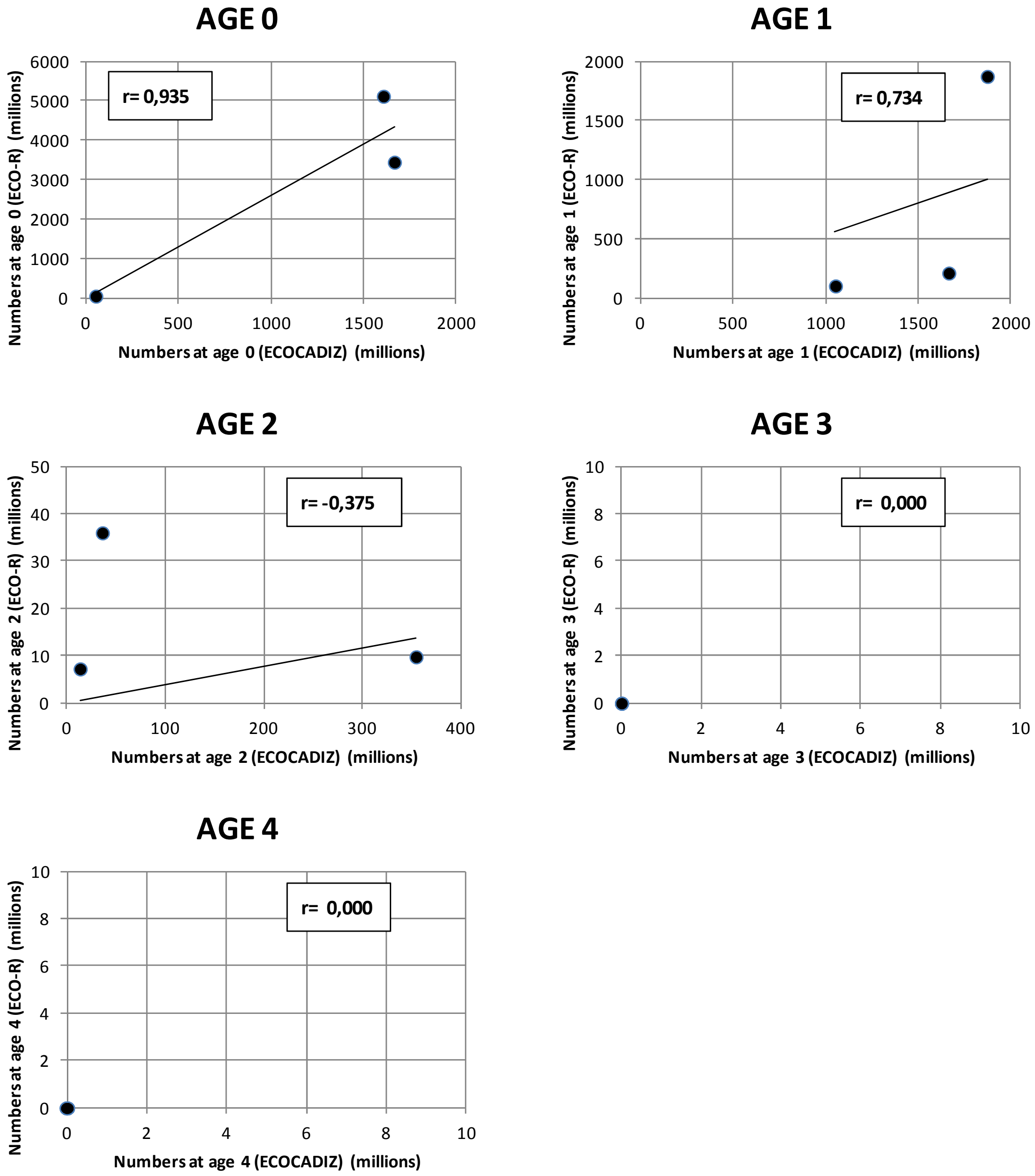


Figure 5.6.3.1. Anchovy in 9a South. Correlation between *ECOCADIZ* (summer) and *ECOCADIZ-RECLUTAS* (autumn-juvenile) surveys. Pearson correlation coefficient and the fitted linear regression line (forced through the origin) are also shown.

5.7. DEPM survey series, *BOCADEVA*.

5.7.1. Egg and adult estimates.

Table 5.7.1.1 summarizes the DEPM-based eggs and adults' parameter estimates recorded during the triennial series of *BOCADEVA* surveys. SSB estimates have oscillated between 12,422 t (2017) and 32,757 t (2011), with the most recent estimate in 2017 being the lowest one within the series. All of these estimates, however, are affected by relatively high CVs, oscillating between 0.30 and 0.62 (**Figure 5.7.1.1**). The time-series average SSB is 24,582 t.

Table 5.7.1.1. Anchovy in 9a South. *BOCADEVA* DEPM surveys series. Summary of eggs and adults' parameters estimates and SSB estimates. (1): SSB computed with the 2011 Spawning fraction estimate; (2): SSB computed with the time-series average Spawning fraction estimate.

Year	**2005**	**2008**	**2011**	**2014**	**2017**
P_0 (eggs/m^2/day)	50.8 / 224.5	184 / 348	276	314	146
Z (day^{-1})	-0.039	-1,43	-0.29	-0.33	-0,16
P_{total} (eggs/day) (x10^{12})	1,13	2,11	1,87	1,95	0,74
Surveyed area (km^2)	11982	13029	13107	14595	15556
Positive area (km^2)	6139	6863	6770	6214	5080
Female Weight (g)	25.2 / 16.7	23,7	15,2	18,2	16,2
Batch Fecundity	13820/ 11160	13778	7486	7502	7507
Sex Ratio	0.53 / 0.54	0,528	0,531	0,54	0,53
Spawning Fraction	0.26 / 0.21	0,218	0,276	0.276$^{(1)}$	0,243$^{(2)}$
Spawning Biomass (t)	14673	31527	32757	31569	12422
Spawing Biomass (CV)	na	0.32	0.40	0.30	0.61

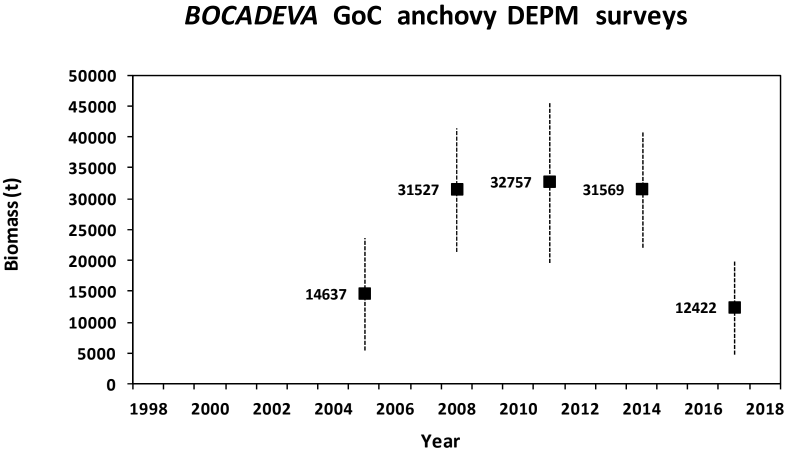


Figure 5.7.1.1. Anchovy in 9a South. *BOCADEVA* DEPM surveys series. Time series of SSB (t) estimates. 2014 SSB computed with the 2011 Spawning fraction estimate; 2017 SSB computed with the time-series average Spawning fraction estimate.

5.7.2. Between-survey consistency.

Figure 5.7.2.1 shows a comparison between biomass estimates from those surveys estimating the GoC anchovy population with different methods. *PELAGO* and *ECOCADIZ* acoustic biomass estimates showed highly correlated with the *BOCADEVA* DEPM ones (r= 0.98 for the *BOCADEVA vs PELAGO* comparison; r= 1.00 for the *BOCADEVA vs ECOCADIZ* comparison), although the comparison of *BOCADEVA* with *ECOCADIZ* is only based on 2 years of coincident surveys (2014 and 2017). At first sight, DEPM point estimates seem to be quite consistent with the acoustic estimates. However, this surprisingly coincidence should be considered with caution because the high CV associated to the DEPM-based estimates and the lack of information about the associated errors to the acoustic estimates. In any case, these different sources of information provide estimates about the same order of magnitude indicating some consistency.

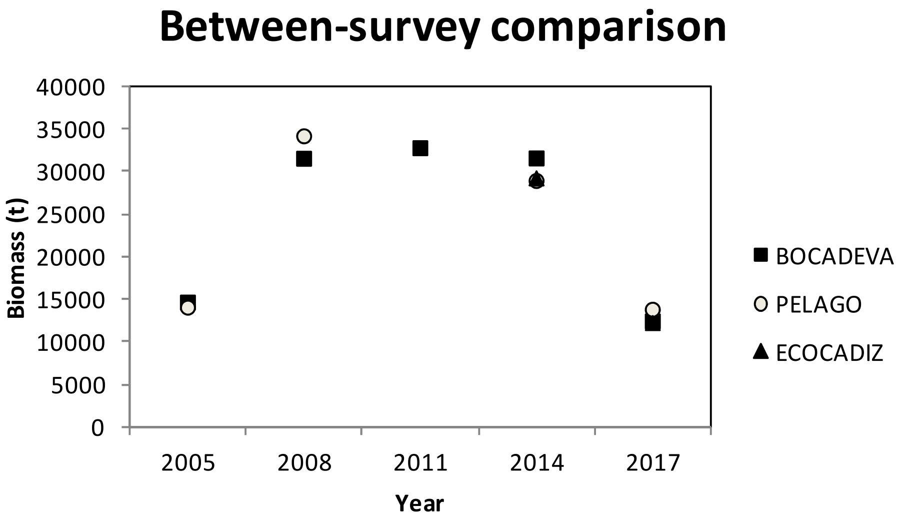


Figure 5.7.2.1. Anchovy in 9a South. *BOCADEVA* DEPM surveys series. Between-survey comparison of biomass estimates (t).

Despite being only based in 5 observations, the *BOCADEVA* DEPM survey series will be included as tuning series in the Gadget model. Reasons for the inclusion in the model are: i) there is one observation available for 2017; ii) these DEPM SSB estimates are consistent with the *PELAGO* and *ECOCADIZ* acoustic estimates for years 2005, 2008, 2014 and 2017; iii) it is the only series reporting a reliable estimate in 2011 (recall that the null *PELAGO 2011* estimate has been rejected by the ICES WGACEGG; see **Section 5.5.1**) and iv) *BOCADEVA* series also represents an independent source of data in relation to the others acoustic-based sources of direct information on the stock.

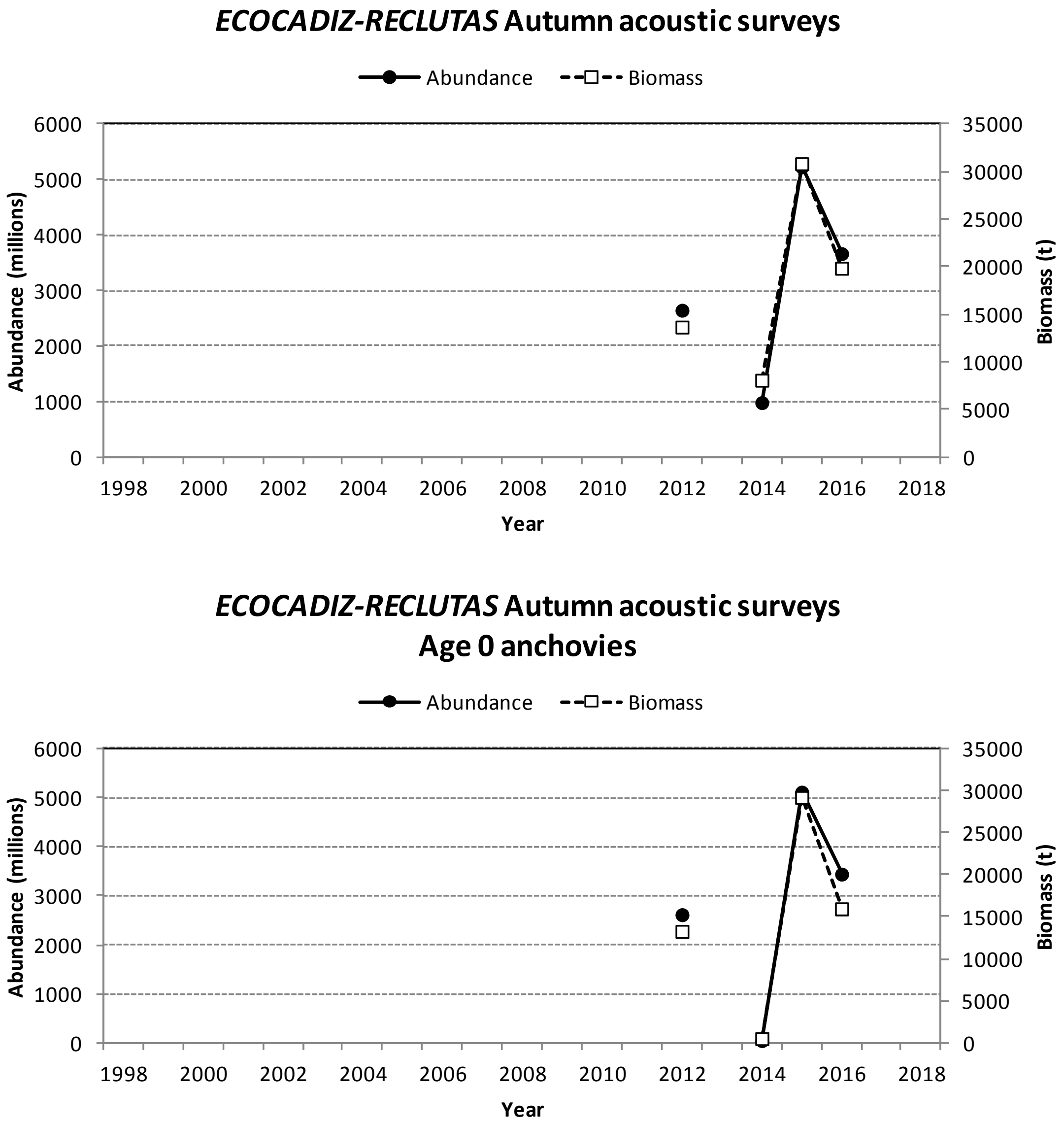
5.8. Autumn acoustic surveys series, *ECOCADIZ-RECLUTAS*.

5.8.1. Acoustic estimates.

Figure 5.8.1.1 shows the (short) time series of abundance and biomass estimates. The estimated abundances for the whole population oscillated between 986 (2014) and 5,227 (2015) million fish (time-series average: 3,132 million fish). The range of biomass estimates oscillates between 8,113 (2014) and 30,827 (2015) t (time-series average: 18,120 t). Estimates for Age 0 anchovies ranged between 51 (2014) and 5,117 (2015) million fish (time series average: 2,808 million fish) for abundance and between 541 (2004) and 29,219 (2015) t (time series average: 14,754 t) for biomass.

Size composition of the estimated population ranged between 4.5 and 17.5 cm size classes (**Figure 5.8.1.2**). The time series of LFDs of the estimated population usually shows bi-modal LFDs, with the smallest, and usually the dominant mode at around 7.5 – 10.0 cm size classes and the largest one at around 10.0 - 15.0 cm size classes depending on the year.

Age-structure of the estimated population is shown in **Figure 5.8.1.3**. In the surveyed population in autumn are only present from 0 to 2 years old anchovies, with the bulk of the population, excepting in 2014, being composed by age 0 juveniles (with contributions of 94-99% in abundance, and 80-97% in biomass). Juveniles in the anomalous 2014 only contributed with 5% in abundance and 7% in biomass. Only the 2013 year class clearly outstand as a strong cohort (as age 1 anchovies in 2014). The 2015 year class started to strongly recruit to the population in autumn 2015, and such strength still persists in the following year, at least as Age 1 anchovies estimated by the *PELAGO* spring- and *ECOCADIZ* summer surveys (**Figures 5.5.1.4** and **5.6.1.3**). The 2016 year class, however, showed weaker as incoming year class in 2017.



ECOCADIZ-RECLUTAS Autumn acoustic surveys

ECOCADIZ-RECLUTAS Autumn acoustic surveys
Age 0 anchovies

Figure 5.8.1.1. Anchovy in 9a South. *ECOCADIZ-RECLUTAS* autumn acoustic surveys. Time series of abundance (millions) and biomass (t) acoustic estimates. The 2012 survey only surveyed the Spanish waters of the Gulf of Cadiz. Upper panel: total population estimates. Bottom panel: Age 0 fish estimates.

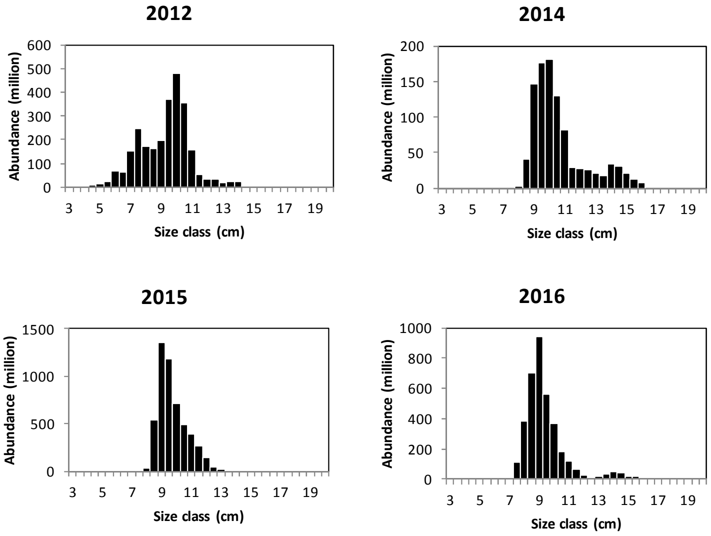


Figure 5.8.1.2. Anchovy in 9a South. *ECOCADIZ-RECLUTAS* autumn acoustic surveys. Size composition (0.5 cm size classes) of the estimated population (millions). Note the different scale of the y axis and the occurrence of gaps through the series. The 2012 survey only surveyed the Spanish waters of the Gulf of Cadiz.

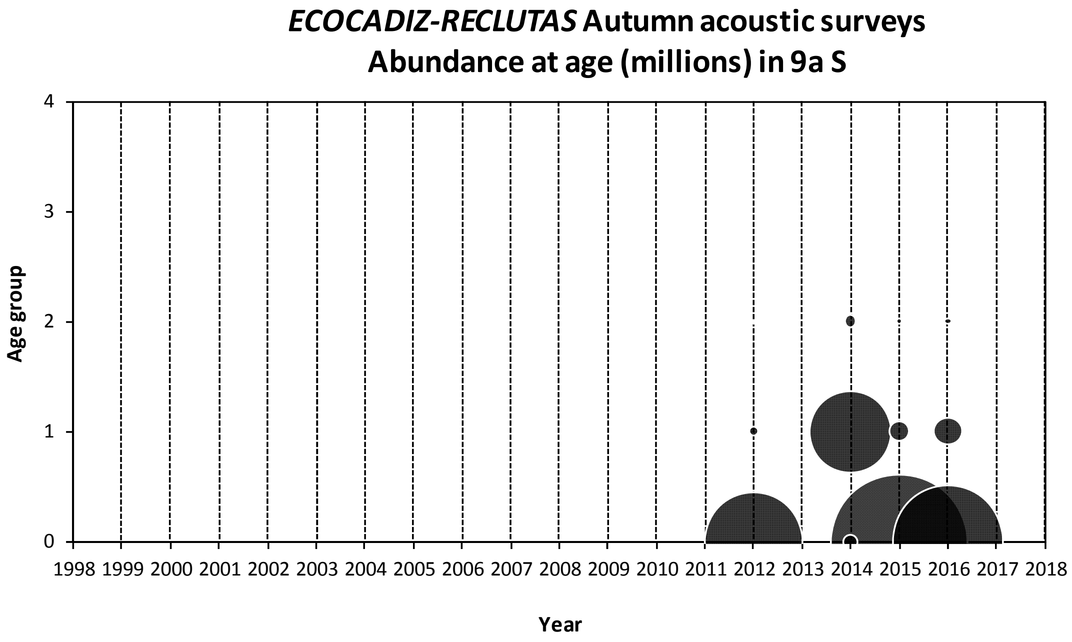


Figure 5.8.1.3. Anchovy in 9a South. *ECOCADIZ-RECLUTAS* autumn acoustic surveys. Age structure of the estimated population (millions). The 2012 survey only surveyed the Spanish waters of the Gulf of Cadiz.

5.8.2. Within-survey consistency.

Within-survey consistency is illustrated with scatter plots and correlations of $N_{a,y,\mathrm{ECOCADIZ\text{-}RECLUTAS}}$ against $N_{a+1,y+1,\mathrm{ECOCADIZ\text{-}RECLUTAS}}$ in **Figure 5.8.2.1** and with catch curves of different year classes in **Figures 5.8.2.2** and **5.8.2.3**.

Scatterplots and correlation values indicate positive and high correlations between Age 0, Age 1, and Age 2 indices, but these results should be considered with caution because are based on a not representative sample (only 2 data pairs).

Available data allows the tracking of 2010 to 2014 year classes. Catch curves indicate a relative good cohort tracking ($R^2 > 0.80$) for all the year classes but 2012 year class.

5.8.3. Between-survey consistency.

See **Sections 5.5.3** and **5.6.3** for between-survey consistency for the *PELAGO* spring and *ECOCADIZ* summer acoustic surveys.

Figure 5.8.3.1 shows the correlation analyses between the Age 0 abundance index in year y in *ECOCADIZ-RECLUTAS* (autumn-juvenile) surveys and Age 1 abundance index in year y+1 in *PELAGO* (spring; top) and *ECOCADIZ* (summer, bottom) surveys. The number of data points for the *ECOCADIZ-RECLUTAS*/*ECOCADIZ* surveys comparison is lower since age structure for the *ECOCADIZ* estimates in 2017 are not yet available. Both comparisons indicate some between-survey consistence (for the comparison with the *PELAGO* spring survey series $r=0.53$; $n=4$; for the comparison with the *ECOCADIZ* summer survey series $r=0.47$; $n=3$).

The results from the above analyses on survey consistency, although very promising, are not yet representative enough to consider the inclusion of this surveys series in the Gadget model. *ECOCADIZ-RECLUTAS* series could be used in the future as a good indicator of the recruitment (which is the basis of the fishery) once a longer time-series is available. As described before, there is no estimate in 2017, and a time-series with at least 6 observations will not be available until 2020, when the suitability of this series for its inclusion in the assessment could be re-evaluated.

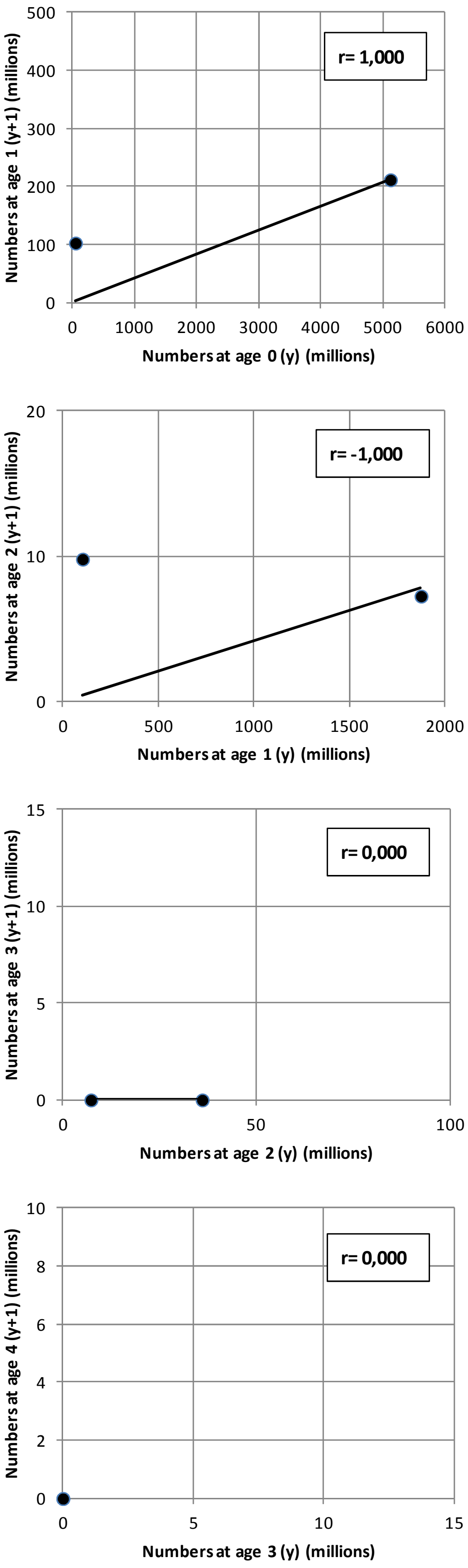


Figure 5.8.2.1. Anchovy in 9a South. *ECOCADIZ-RECLUTAS* autumn acoustic surveys. Correlation within survey. Pearson correlation coefficient and the fitted linear regression line (forced through the origin) are also shown.

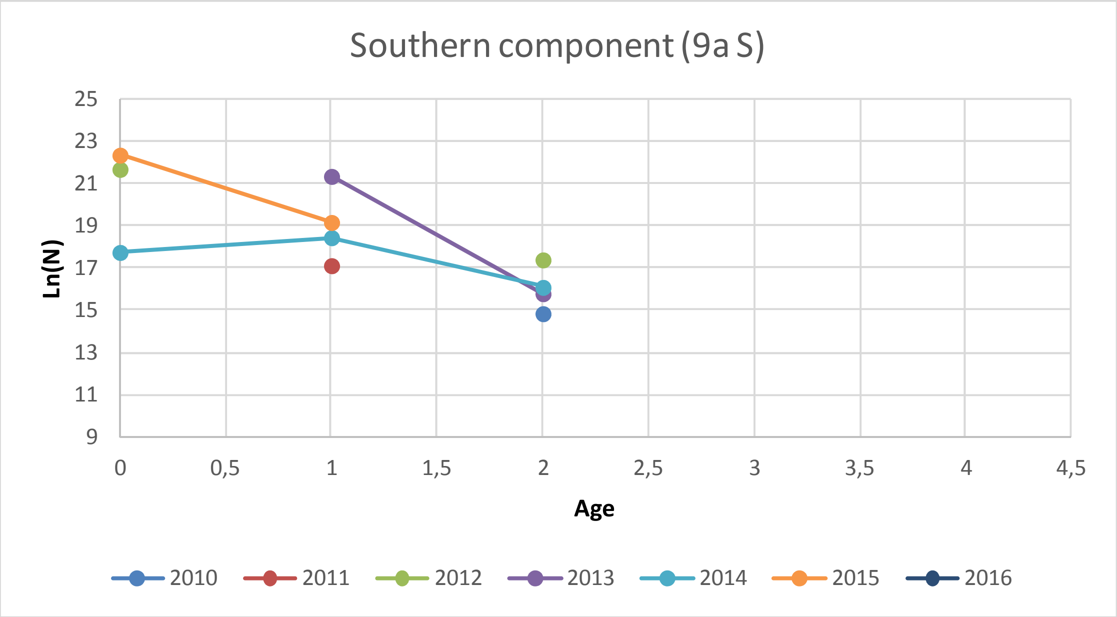


Figure 5.8.2.2. Anchovy in 9a South. *ECOCADIZ-RECLUTAS* autumn acoustic surveys. Cohorts (ln(N) per age group) tracked by the survey series.

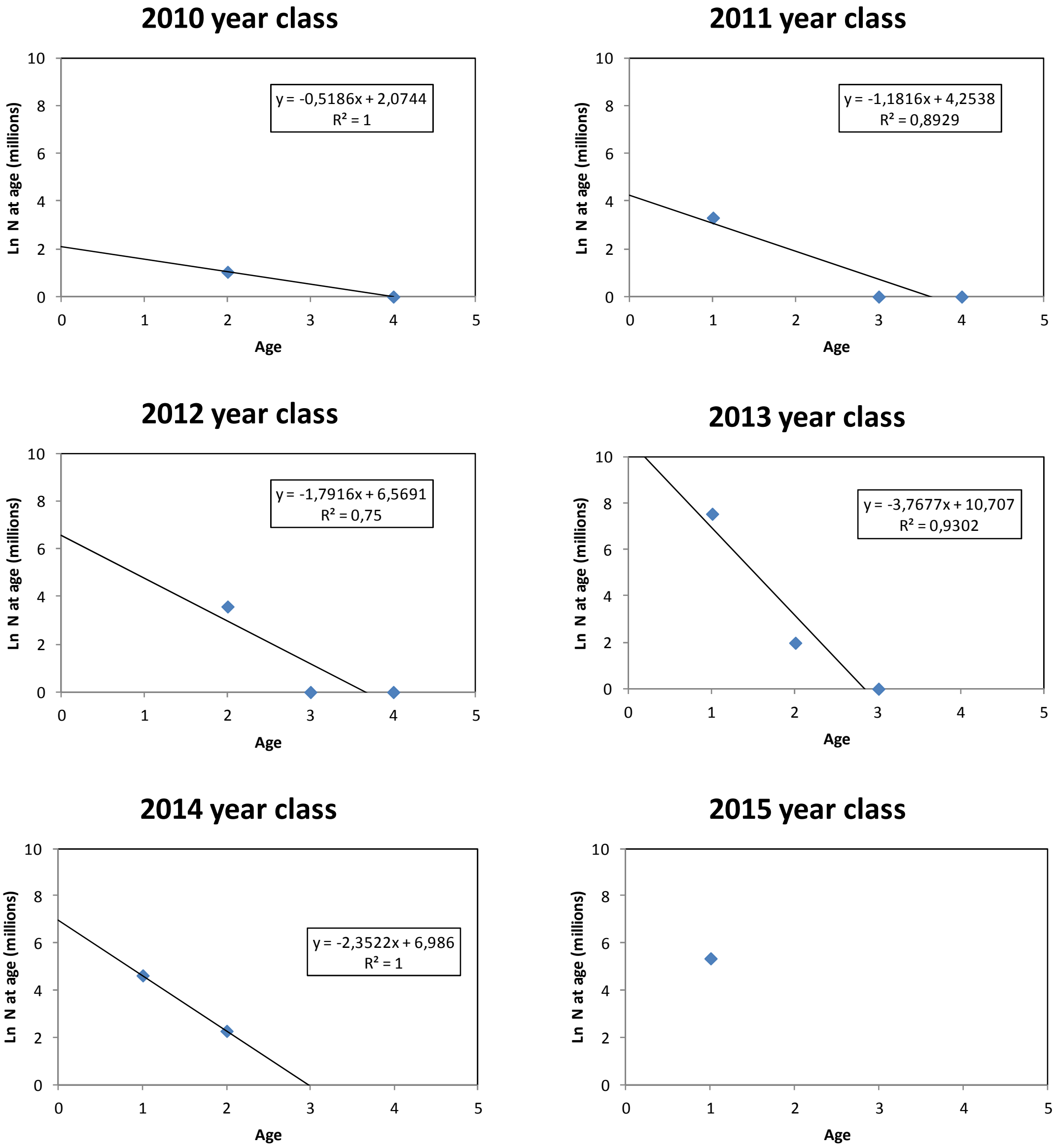
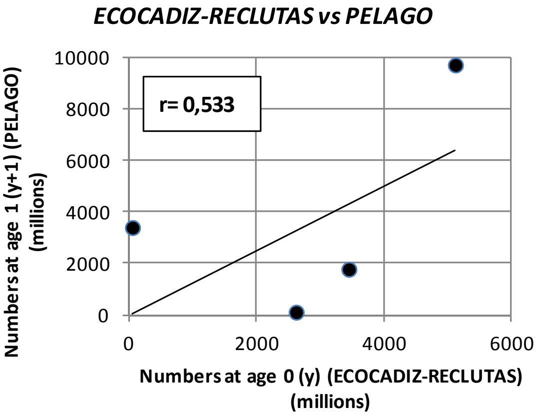


Figure 5.8.2.3. Anchovy in 9a South. *ECOCADIZ-RECLUTAS* autumn acoustic surveys. Catch curves by year class for anchovy in 9a South. The regression coefficient and the fitted linear regression line and model are also shown. Age 0 anchovies, for simplicity in the linear fitting, have not been included in the graphs (only the right limb of the catch curve is shown).



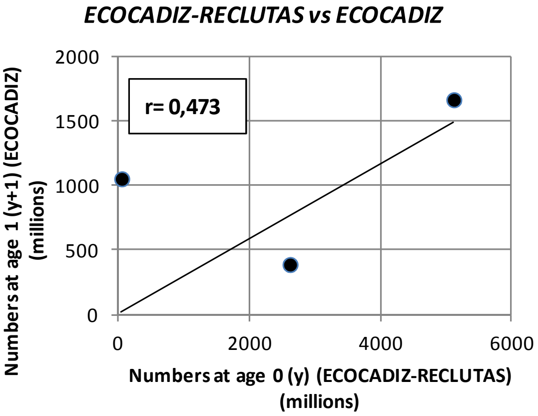
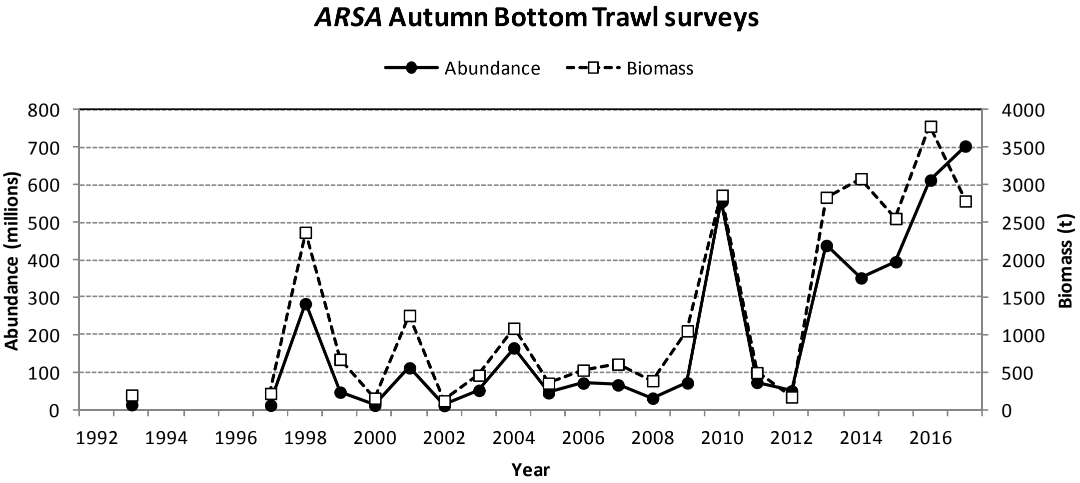


Figure 5.8.3.1. Anchovy in 9a South. *ECOCADIZ-RECLUTAS* autumn acoustic surveys. Correlation between Age 0 abundance index in year y in *ECOCADIZ-RECLUTAS* (autumn-juvenile) surveys and Age 1 abundance index in year y+1 in *PELAGO* (spring; top) and *ECOCADIZ* (summer, bottom) surveys. Pearson correlation coefficient and the fitted linear regression line (forced through the origin) are also shown. The number of data points for the *ECOCADIZ-RECLUTAS*/*ECOCADIZ* surveys comparison is lower since age structure for the ECOCADIZ estimates in 2017 are not yet available.

5.9. Autumn bottom trawl survey in GoC Spanish waters, *ARSA*.

5.9.1. Absolute estimates.

Figure 5.9.1.1 shows the time series of abundance and biomass estimates. The estimated abundances for the anchovy population in the Spanish waters of the GoC oscillated between 12 (2012) and 612 (2016) million fish (time-series average: 190 million fish). The range of biomass estimates oscillates between 123 (2012) and 3,780 (2016) t (time-series average: 1,276 t). Estimates for Age 0 anchovies ranged between 4 (1997) and 517 (2010) million fish (time series average: 129 million fish) for abundance and between 36 (2002) and 2,668 (2010) t (time series average: 764 t) for biomass. All of these estimates are one order of magnitude lower than those estimated by the *ECOCADIZ-RECLUTAS* autumn acoustic survey for a comparable time series. Although the groundfish survey is restricted to the Spanish waters, the surveyed area includes the main recruitment area for the species in the subdivision. However, differences in catchability should be keeping in mind because the gear used (2 m vertical opening trawl gear) and the sampling method.



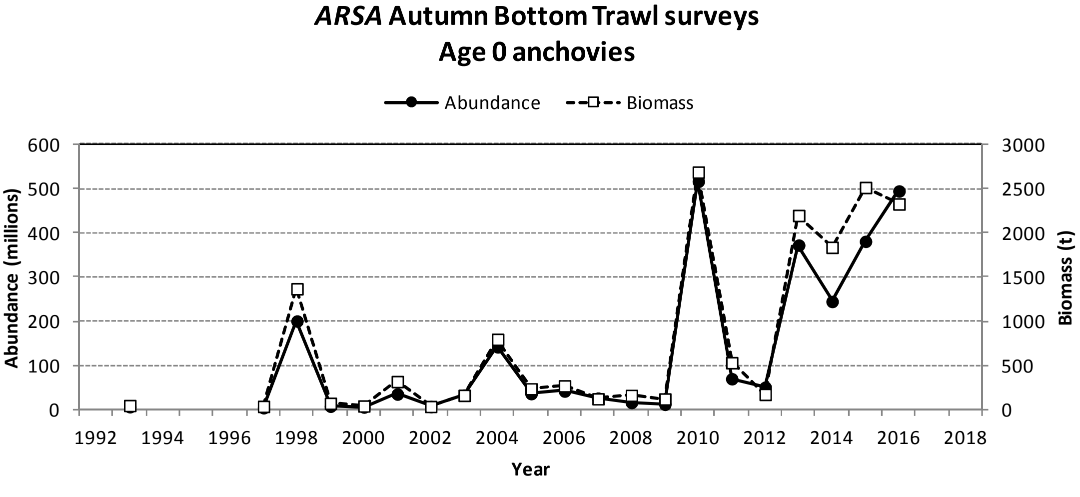


Figure 5.9.1.1. Anchovy in 9a South. *ARSA* autumn bottom trawl surveys in GoC Spanish waters. Time series of abundance (millions) and biomass (t) acoustic estimates. Upper panel: total population estimates. Bottom panel: Age 0 fish estimates. The 2017 estimates are not yet available.

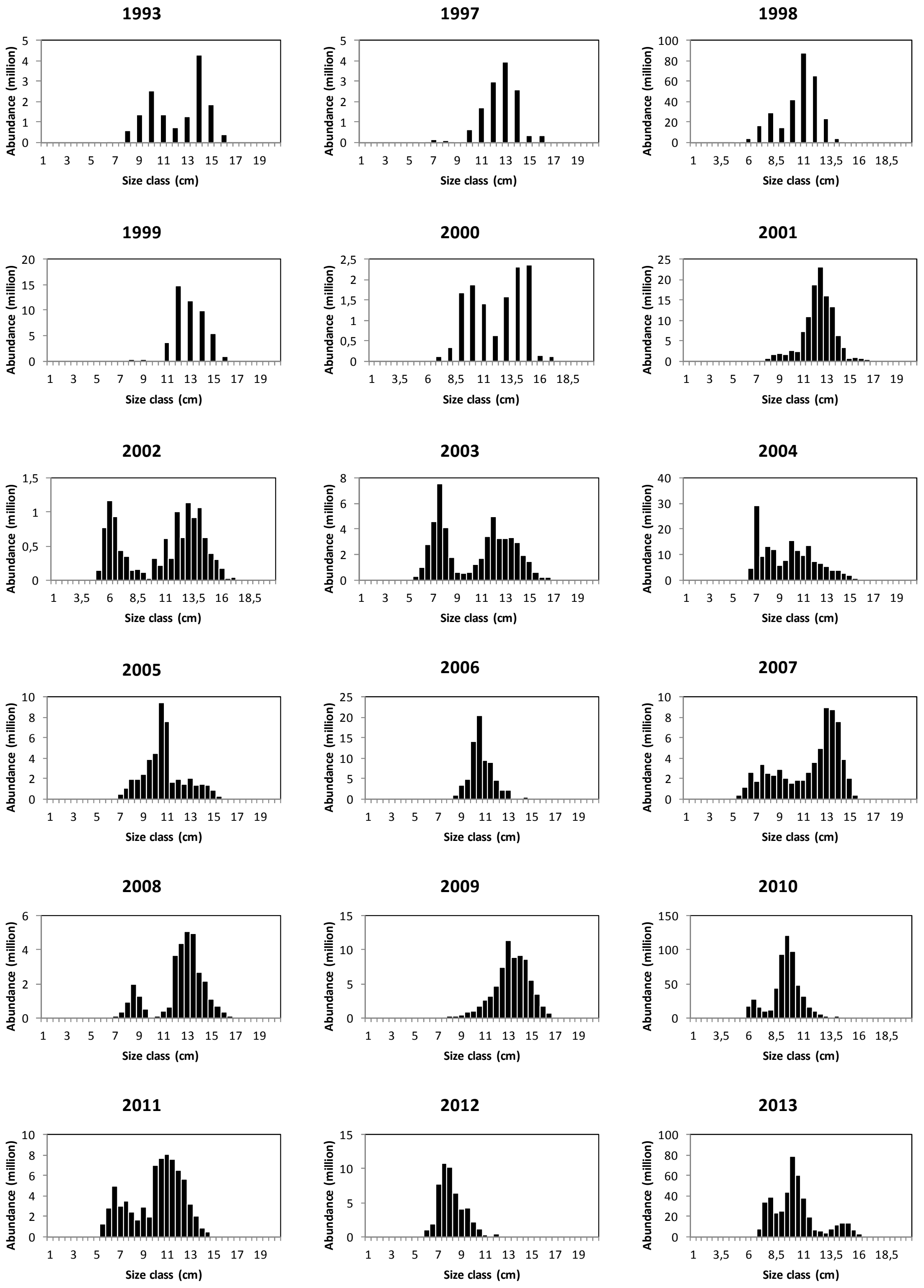


Figure 5.9.1.2. Anchovy in 9a South. *ARSA* autumn bottom trawl surveys in GoC Spanish waters. Size composition (1 cm size classes until 2000; 0.5 cm size classes since 2001 on) of the estimated population (millions). Note the different scale of the y axis and the occurrence of gaps through the series.

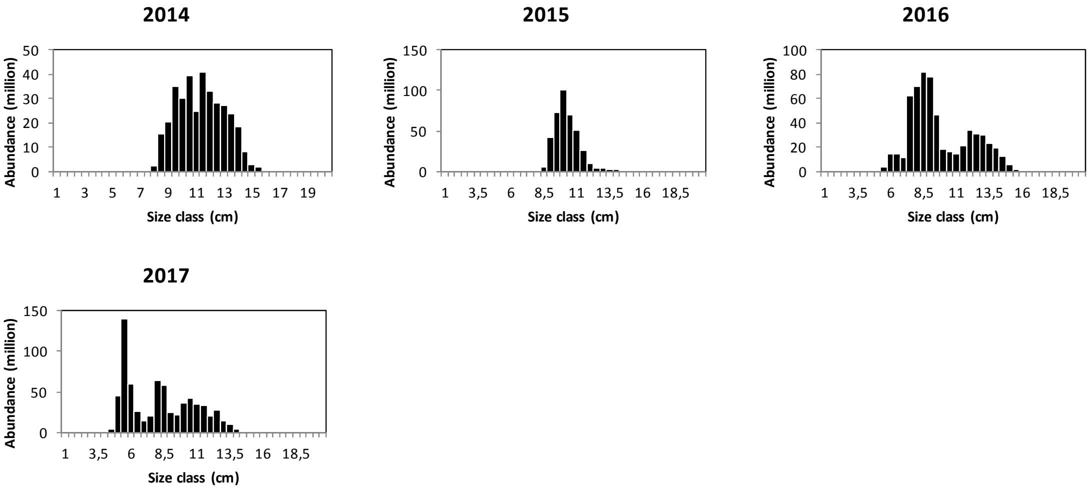


Figure 5.9.1.2. Anchovy in 9a South. *ARSA* autumn bottom trawl surveys in GoC Spanish waters. Size composition (1 cm size classes until 2000; 0.5 cm size classes since 2001 on) of the estimated population (millions). Note the different scale of the y axis and the occurrence of gaps through the series. Cont'd.

Size composition of the estimated population ranged between 4.0 and 18.5 cm size classes, although in some years (1999, 2001, 2002, 2008) anchovy larvae (1.0-3.0 cm size classes) are also occasionally captured (**Figure 5.9.1.2**). The time series of LFDs of the estimated population usually shows bi-modal LFDs, with the smallest mode at around 5.5 – 8.5 cm size classes and the largest one at around 11.0 - 13.0 cm size classes depending on the year.

Age-structure of the estimated population is shown in **Figure 5.9.1.3**. In the surveyed population in autumn are only present from 0 to 3 years old anchovies, with the bulk of the population being composed by ages 0 and 1. The contribution of age 0 anchovies in the population, as estimated by the survey, is variable throughout the time series. An increase in the relative importance of anchovy juveniles is observed since 2010 on (with contributions of 70-100% in abundance, and 60-99% in biomass). The 1997, 2013 and 2015 year classes outstand as stronger cohorts. The strength of these last two year classes was also tracked by the *ECOCADIZ-RECLUTAS* autumn acoustic survey (**Figure 5.8.1.3**).

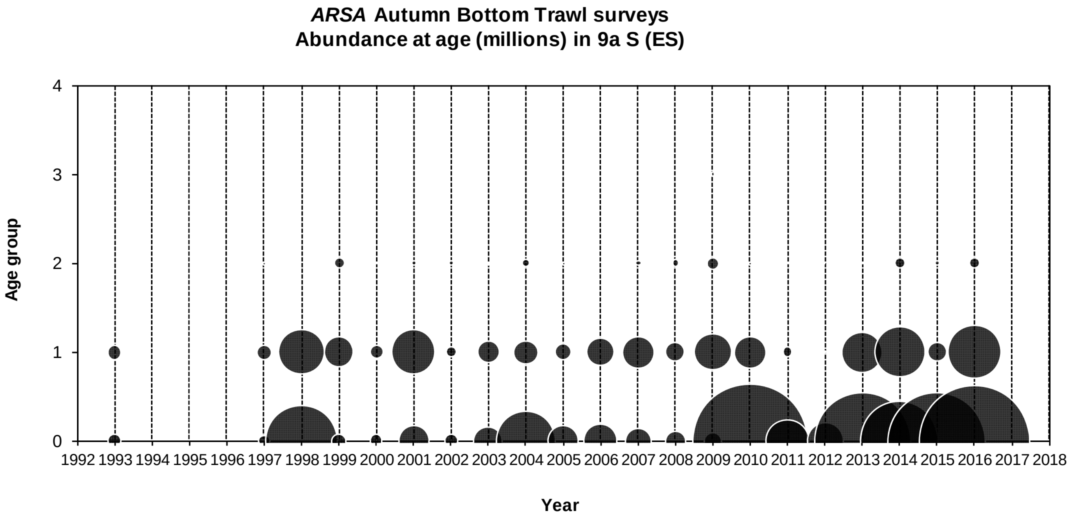


Figure 5.9.1.3. Anchovy in 9a South. *ARSA* autumn bottom trawl surveys in GoC Spanish waters. Age structure of the estimated population (millions).

5.9.2. Within-survey consistency.

Within-survey consistency is illustrated with scatter plots and correlations of $N_{a,y,ARSA}$ against $N_{a+1,y+1,ARSA}$ in **Figure 5.9.2.1** and with catch curves of different year classes in **Figures 5.9.2.2** and **5.9.2.3**.

Scatterplots and correlation values indicate positive although poor correlations between Age indices (r< 0.21; n=19).

Available data allows the tracking of 1995 to 2014 year classes. Catch curves indicate a relative good cohort tracking ($R^2 > 0.80$) only for the 1997, 2007, 2012 and 2014 year classes.

5.9.3. Between-survey consistency.

Figure 5.9.3.1 shows the consistency between the *ARSA* autumn bottom trawl survey and *ECOCADIZ-RECLUTAS* autumn acoustic survey. The results from this correlation analysis should be considered with caution because the low number of data pairs (n=3). Correlations are positive but poor for Age 0 (r=0.69), Age 1 (r=0.47) and Age 2 (r=0.41) indices. Age 3+ olds are absent in the data pairs considered.

Figure 5.9.3.2 shows the correlation analyses between the Age 0 abundance index in year y in *ARSA* surveys and Age 1 abundance index in year y+1 in *PELAGO* (spring; n=15) and *ECOCADIZ* (summer; n=9) surveys. Both comparisons indicate a relatively low between-survey consistence (for the comparison with the *PELAGO* spring survey series r=0.36; for the comparison with the *ECOCADIZ* summer survey series r=0.20).

These low correlations lead to consider the non-inclusion of this series in the Gadget assessment model. Some additional studies are still needed to measure the consistency of this surveys series and its suitability for assessment purposes.

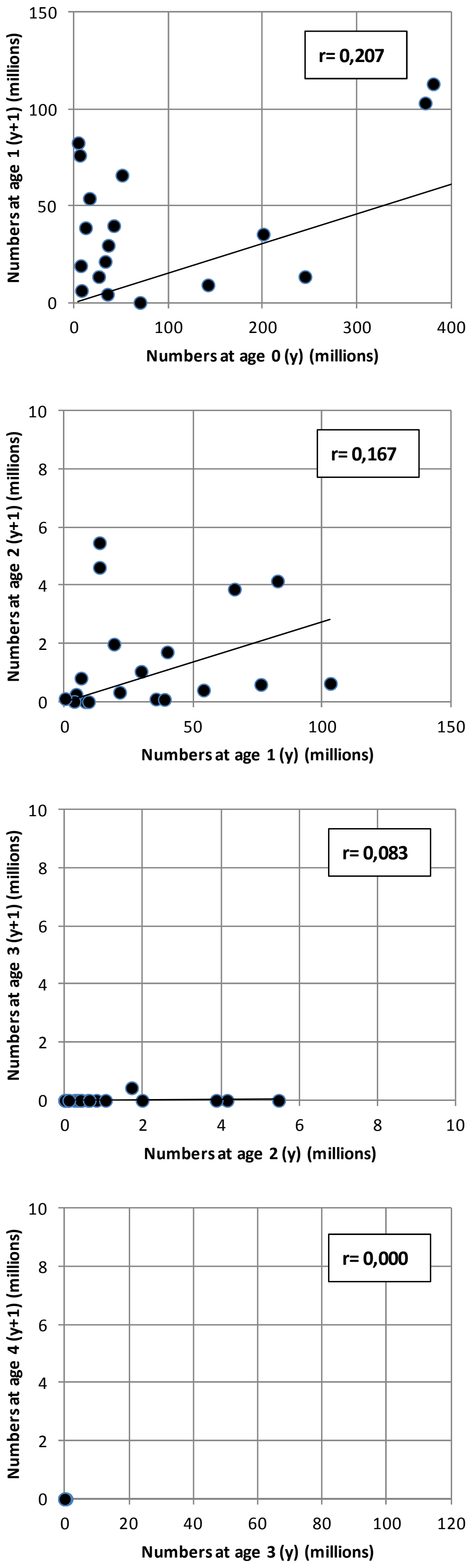


Figure 5.9.2.1. Anchovy in 9a South. *ARSA* autumn bottom trawl surveys in GoC Spanish waters (9a S (ES)). Correlation within survey. Pearson correlation coefficient and the fitted linear regression line (forced through the origin) are also shown.

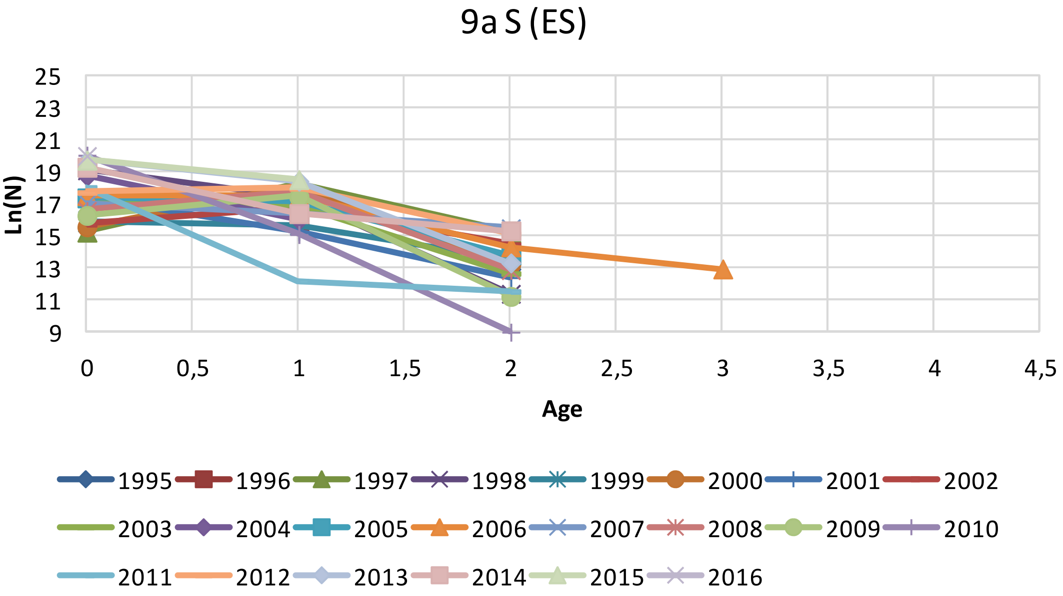


Figure 5.9.2.2. Anchovy in 9a South. *ARSA* autumn bottom trawl surveys in GoC Spanish waters (9a S (ES)). Cohorts (ln(N) per age group) tracked by the survey series. The age structure of the abundance indices was derived by applying IEO ALKs from commercial samples from the Spanish fishery in the fourth quarter.

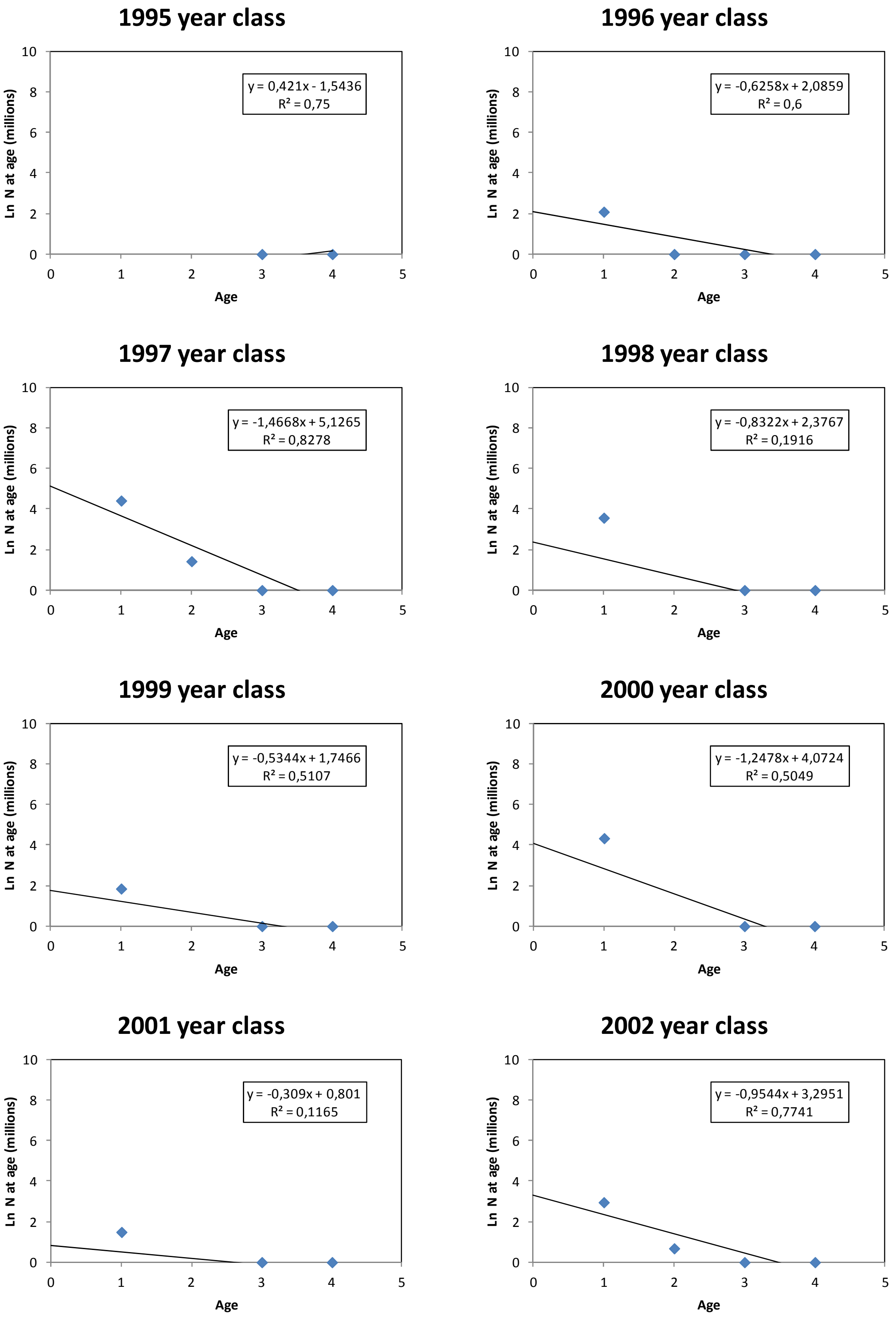


Figure 5.9.2.3. Anchovy in 9a South. *ARSA* autumn bottom trawl surveys in GoC Spanish waters. Catch curves by year class for anchovy in 9a South(ES). The regression coefficient and the fitted linear regression line and model are also shown. Age 0 anchovies, for simplicity in the linear fitting, have not been included in the graphs (only the right limb of the catch curve is shown).

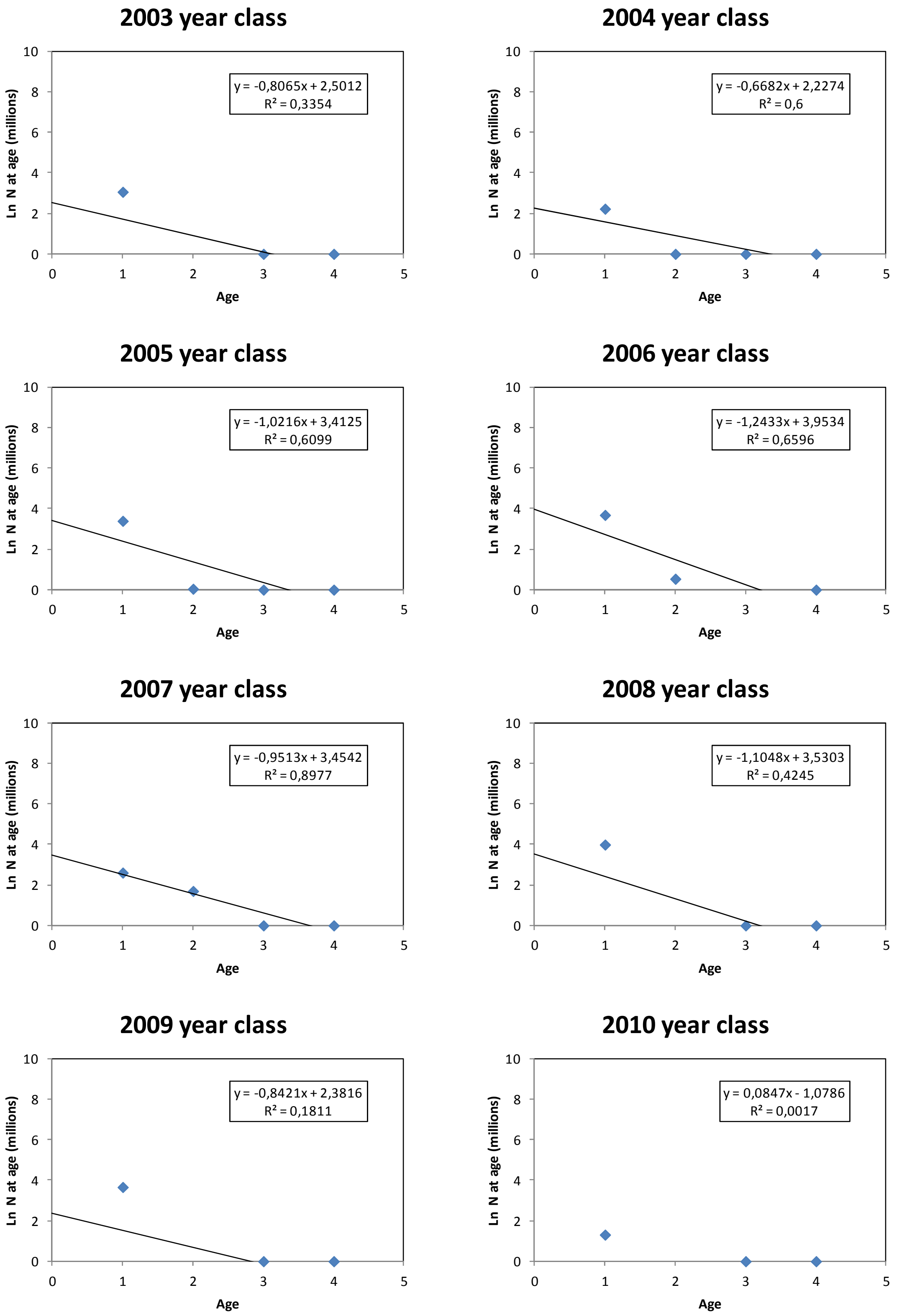


Figure 5.9.2.3. Anchovy in 9a South. *ARSA* autumn bottom trawl surveys in GoC Spanish waters. Catch curves by year class for anchovy in 9a South(ES). The regression coefficient and the fitted linear regression line and model are also shown. Age 0 anchovies, for simplicity in the linear fitting, have not been included in the graphs (only the right limb of the catch curve is shown). Cont'd.

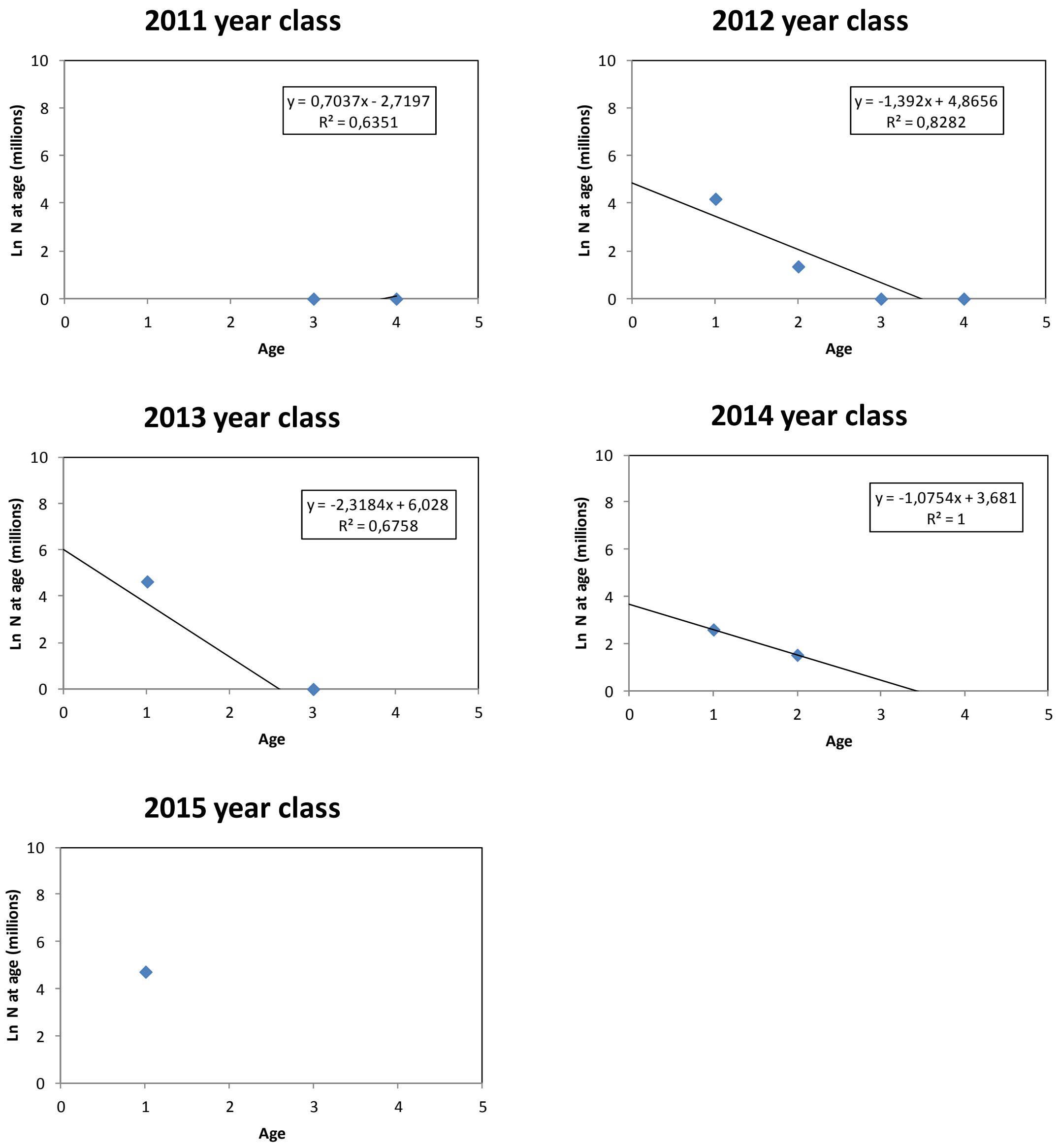


Figure 5.9.2.3. Anchovy in 9a South. *ARSA* autumn bottom trawl surveys in GoC Spanish waters. Catch curves by year class for anchovy in 9a South(ES). The regression coefficient and the fitted linear regression line and model are also shown. Age 0 anchovies, for simplicity in the linear fitting, have not been included in the graphs (only the right limb of the catch curve is shown). Cont'd.

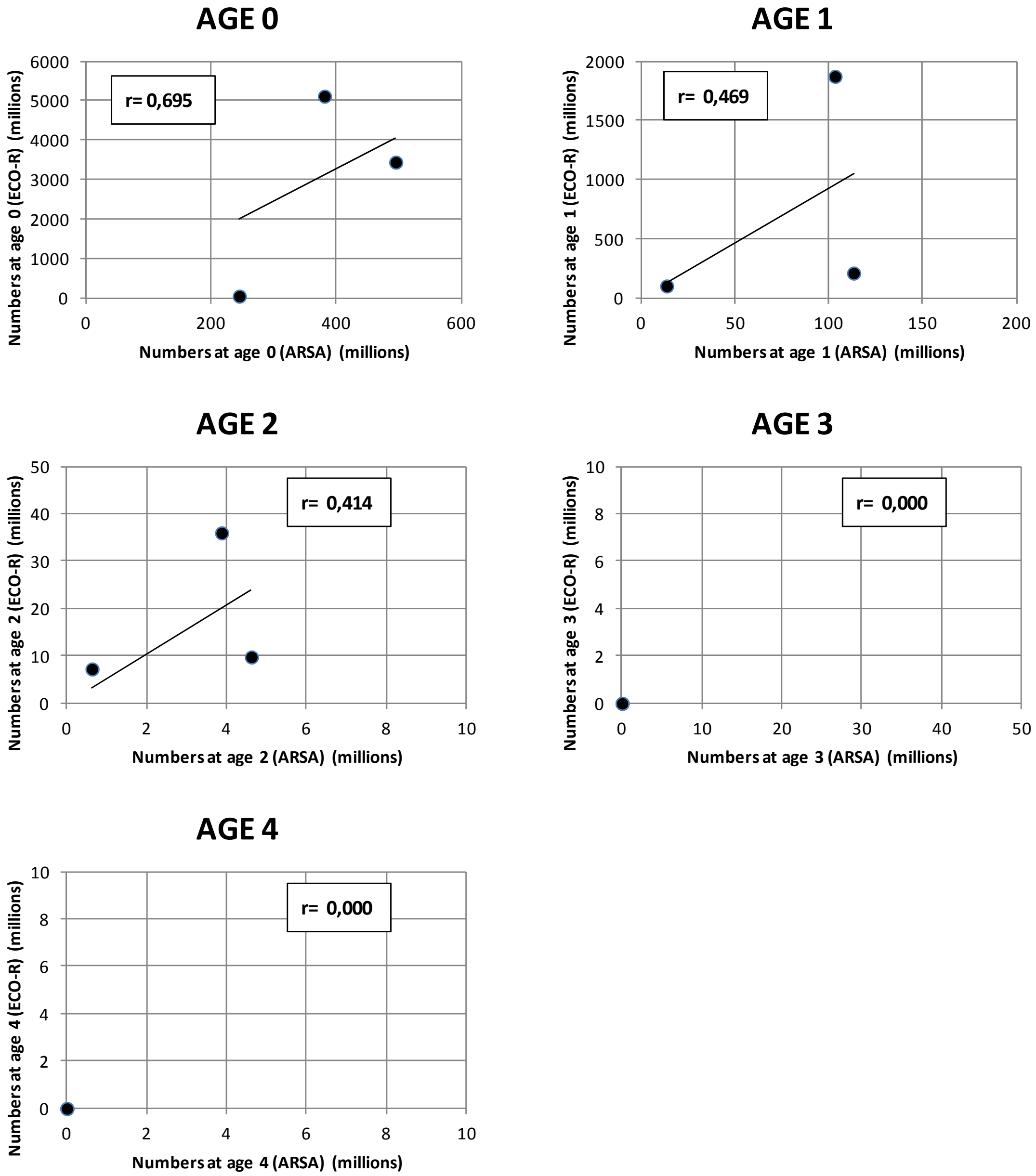


Figure 5.9.3.1. Anchovy in 9a South. Correlation between *ARSA* (autumn; bottom-trawl) and *ECOCADIZ-RECLUTAS* (autumn-juvenile; acoustic) surveys. Pearson correlation coefficient and the fitted linear regression line (forced through the origin) are also shown.

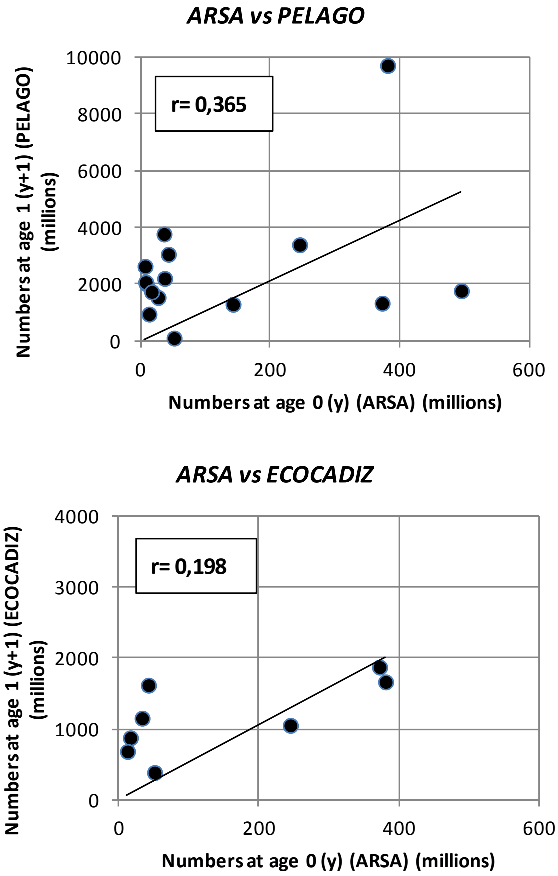


Figure 5.9.3.2. Anchovy in 9a South. *ARSA* autumn bottom trawl surveys in GoC Spanish waters. Correlation between Age 0 abundance index in year y in *ARSA* (autumn; bottom trawl) surveys and Age 1 abundance index in year y+1 in *PELAGO* (spring, acoustic; top) and *ECOCADIZ* (summer, acoustic, bottom) surveys. Pearson correlation coefficient and the fitted linear regression line (forced through the origin) are also shown.

5.10. Stock biomass size indicators in the trend-based qualitative assessment.

The anchovy stock in Division 9a (ane.27.9a) has not been yet analytically assessed. ICES considers this stock as a stock belonging to the ICES Stock Data Category 3, and It is qualitatively assessed through a survey biomass trend-based assessment without catch advice (ICES, 2017a). No catch advice can be given for the next year to the assessment year because of lack of available data for the year classes that will constitute the bulk of the biomass and catches.

From 2009 to 2014 the provision of advice for the whole Division 9a has been restricted to Sub-division 9a south as this is the only area showing a persistent population and fishery. It relies in an update of the qualitative assessment carried out in 2008 and accepted by the ICES Review Groups (RG) of the 2008 and 2009 ICES WGANC (2008 & 2009 RGANC). This qualitative assessment is based on the joint analysis of trends showed by the available data for the Subdivision 9a S, both fishery-dependent and –independent information (*i.e.*, landings, fishing effort, cpue, survey estimates).

Since 2015, stock size biomass indicators for the western (subdivisions 9a N, 9a CN and 9a CS) and southern (subdivision 9a S) components of the stock have been computed to illustrate biomass trends at a regional scale. For the western component this indicator is estimated as the sum of spring acoustic estimates from *PELACUS* and *PELAGO* spring acoustic surveys (*PELACUS* surveys series is the Spanish acoustic survey series surveying the subarea 8c and subdivision 9a N) (**Figure 5.10.1**).

For the southern component this indicator is estimated as the average of the annual estimates provided by each of the spring-summer surveys conducted in the Subdivision (*i.e*. *PELAGO* spring acoustic surveys, *ECOCADIZ* summer acoustic surveys, and *BOCADEVA* summer DEPM triennial surveys) (**Figure 5.10.1**). The uncertainties and difficulties found by the *PELAGO* surveys in the anchovy acoustic assessment in the Spanish waters area (9a S (ES)) and the gaps occurring in the *ECOCADIZ* series up to 2012, led to consider this averaging procedure under the assumption of equal catchabilities between surveys.

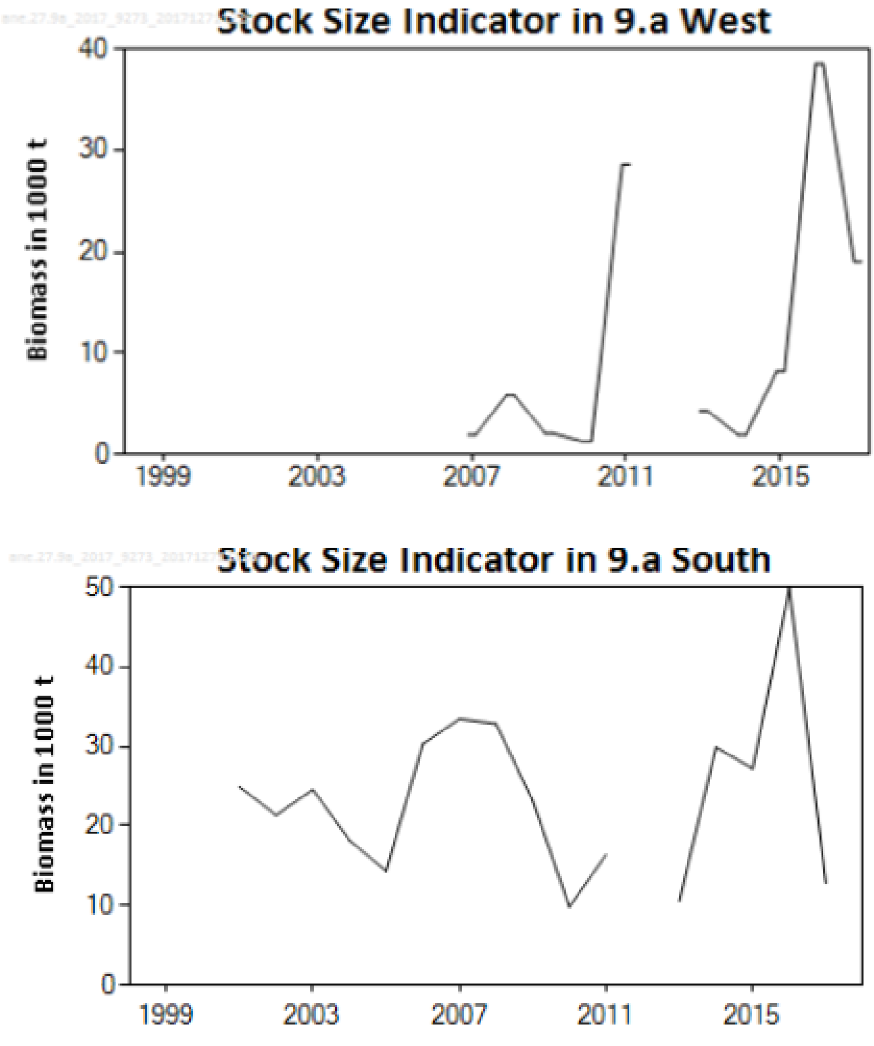


Figure 5.10.1. Anchovy in Division 9a. Upper panel: Stock biomass size indicator (in thousand tonnes) for the western component of the stock or stock unit 9a West (sum of survey biomass estimates, from spring acoustic -*PELACUS* and *PELAGO* - surveys). Lower panel: stock size indicator for the southern component of the stock or stock unit 9a South (average of survey biomass estimates, from spring and

summer acoustic (*PELAGO*, *ECOCADIZ*) and summer Daily Egg Production Method (*BOCADEVA*) surveys). Source: ICES WGHANSA

Notwithstanding the above, the adoption of this approach evidences some problems: first, in the moment of the provision of advice by ICES (late June), summer surveys estimates are not yet available. Therefore, the resulting indicator for the southern component in the assessment year is incomplete, since it is only based on the *PELAGO* spring estimate. The value for that year is then re-computed in the next year meeting with all the estimates available, which results in a not a very consistent approach. Secondly, there are serious doubts about the suitability of this computation method because the data points through the time series are estimated with a different number of surveys depending on their availability (recall that *BOCADEVA* is triennially conducted). In fact, the ICES ADGANE9a in October 2016 was concerned about this way of combining survey biomass estimates to reach a total estimate of biomass for Division 9a and recommended to WGHANSA to look at methods to combine survey indices for each stock component. ICES ADGANE9a recommended that the agreement on a method to combine the different survey estimates should be carefully considered and reviewed through a full benchmark process before it is used to provide advice. This issue was also discussed in the ICES WGACEGG 2017 meeting, where the following suggestions about how to deal with the above problems were posed:

- *PELAGO 2011* estimate for 9a S should not be considered.
- The sum of *PELACUS* (9aN) and *PELAGO* (9aCN-9aCS) estimates to derive the Stock Size Indicator for the western component in the trend-based qualitative assessment is possible (as it is done with the Iberian-Atlantic sardine stock).
- Averaging the *PELAGO* and *ECOCADIZ* survey estimates to derive the Stock Size Indicator for the southern component in the trend-based qualitative assessment may be possible since we're dealing with relative indices and trends. The DEPM *BOCADEVA* estimate should be not included in the average.
- However, some problems still persist for the southern component stock indicator following the above approach:
    - It is based on one only estimate (*PELAGO* estimate) in the assessment year.
    - It is based on one only estimate (*PELAGO* estimate) is some years in the series, when *ECOCADIZ* was not conducted.

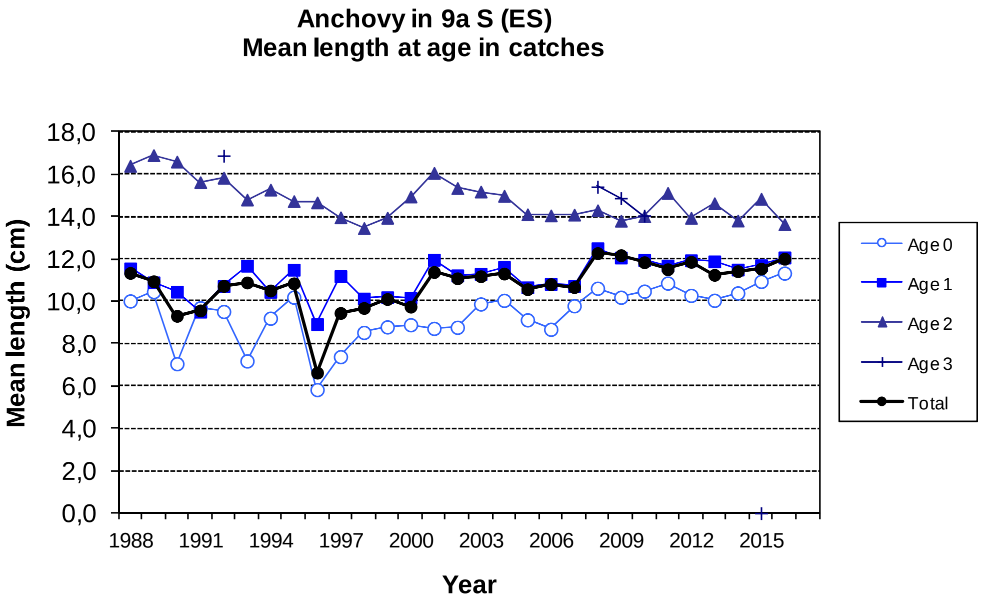
6. Biological parameters.

6.1. Mean length and mean weight in catches.

Estimates are only available from the Spanish fishery in 9a S (ES). **Figure 6.1.1** shows the recent history of the evolution of such estimates. Anchovy mean length and weight at age in the Spanish annual catches have oscillated as follows:

- Age 0: 5.8 cm (1996) – 11.3 cm (2016); 1.3 g (1996) – 8.8 g (2016).
- Age 1: 8.9 cm (1996) – 12.5 cm (2008); 6.4 g (1996) – 13.6 g (2008).
- Age 2: 13.5 cm (1998) – 16.9 cm (1989); 14.9 g (1998) – 33.5 g (1989).
- Age 3: 14.0 cm (2010) – 16.9 cm (1992); 21.5 g (2010) – 30.2 g (1992).

Age 0 and age 1 anchovies have showed a noticeable increasing trend in both estimates in the most recent years, with the 2008-2016 estimates of mean size in catches being between the highest ones in the historical series. Conversely, since 2002 on age 2 anchovies experienced a remarkable decreasing trend in mean size and weight in catches, excepting the punctual relative increases observed in 2011 and 2015. Three year olds were firstly recorded in the sampled landings in 1992. New occurrences of these anchovies have been observed only from 2008 to 2010.



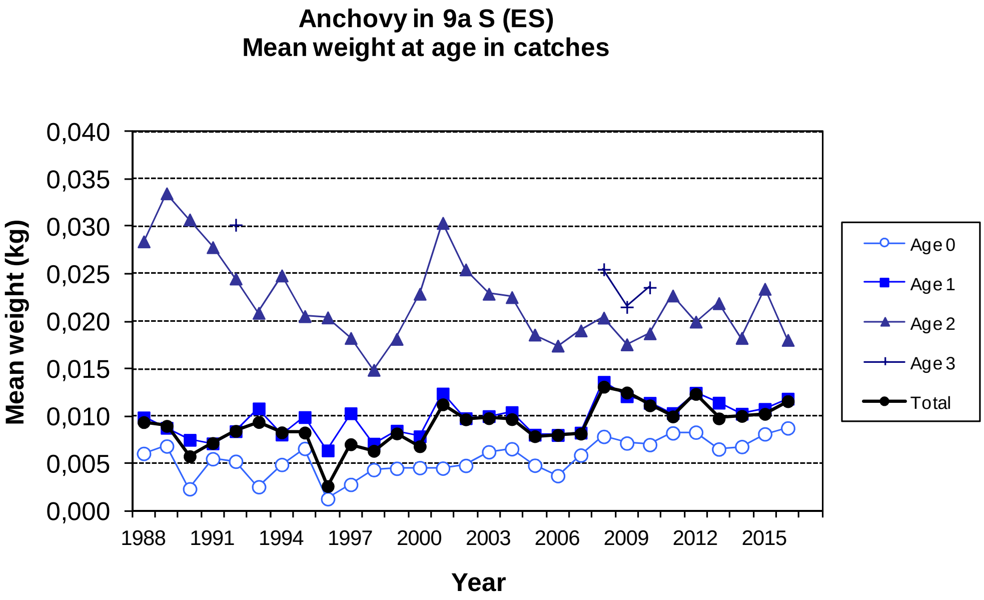


Figure 6.1.1. Anchovy in 9a South.. Spanish fishery (all métiers). Annual mean length (TL, in cm) and weight (kg) at age in the Spanish catches of Gulf of Cadiz anchovy (1988-2016).

6.2. Maturity ogives.

Previous biological studies based on commercial samples of GoC anchovy (9a S (ES)) indicate that the species' spawning season extends from late winter to early autumn with a peak spawning time for the whole population occurring from June to August (Millán, 1999). Length at first maturity was estimated in that study at 11.09 cm in males and 11.20 cm in females. However, it was evidenced that size at maturity may vary between years, suggesting a high plasticity in the reproductive process in response to environmental changes.

Maturity stage assignment criteria were agreed between national institutes involved in the biological study of the species during the *Workshop on Small Pelagics (Sardina pilchardus, Engraulis encrasicolus) maturity stages* (WKSPMAT; ICES, 2008b).

Annual maturity ogives for anchovy in 9a S (ES) for both sexes pooled are routinely provided to ICES (since 1988). They are fishery data-based and represent the estimated proportion of mature fish at age in the total catch during the spawning period (second and third quarters) after raising the ratio of mature-at-age by size class in commercial monthly samples to the monthly catch numbers-at-age by size class (**Table 6.2.1**).

Table 6.2.1. Anchovy in 9.a South. Maturity ogives (ratio of mature fish at age) for Gulf of Cadiz anchovy. Source: ICES WGHANSA.

Year	**Age**		
	0	**1**	**2+**
1988	0	0.82	1
1989	0	0.53	1
1990	0	0.65	1
1991	0	0.76	1
1992	0	0.53	1
1993	0	0.77	1
1994	0	0.60	1
1995	0	0.76	1
1996	0	0.49	1
1997	0	0.63	1
1998	0	0.55	1
1999	0	0.74	1
2000	0	0.70	1
2001	0	0.76	1
2002	0	0.72	1
2003	0	0.69	1
2004	0	0.95	1
2005	0	0.95	1
2006	0	0.77	1
2007	0	0.91	1
2008	0	0.97	1
2009	0	0.99	1
2010	0	0.97	1
2011	0	0.97	1
2012	0	0.89	1
2013	0	0.94	1
2014	0	0.91	1
2015	0	0.92	1
2016	0	0.97	0.98

This approach was adopted because the absence of direct information from surveys during the first 12 years of the available time-series and the discontinuity in this kind of information (i.e. occurrence of some years without survey) during the remaining years.

The % mature at age 0 in these annual fishery-based ogives need to be checked since these anchovies may also contribute to the (first-) spawners' population fraction during the third quarter in the year. The annual length-based ogives from this data set have not been updated since those provided by Millán (1999).

The potential of the maturity data from the different surveys series surveying the southern component either in spring (*PELAGO*) or summer (*ECOCADIZ* and *BOCADEVA*) also needs to be explored.

6.3. Mean weight at age in the stock.

Weights at age in the stock for the GoC anchovy correspond to yearly estimates calculated as the weighted mean weights-at-age in the catches for the second and third quarters (i.e. throughout the spawning season; **Table 6.3.1**).

Survey-based estimates, especially those ones coming from the DEPM *BOCADEVA* survey are also available, but the data points only correspond to 2005, 2008, 2011 and 2017. *ECOCADIZ* acoustic surveys may also provide estimates since 2004 for those years not sampled by the DEPM survey but 2012. However, no direct information is available for the period 1989-2003. The potential of these estimates needs to be explored.

6.4. Growth parameters.

Length-based estimates of VBGF parameters (ELEFAN) for GoC anchovy (9a S (ES)) were estimated by Bellido *et al*. (2000). An asymptotic length, L_∞= 19 cm estimated by the above authors (with lower and upper bounds set at 15 and 20 cm), will be adopted for the proposed Gadget assessment model to be evaluated during this benchmark. The growth rate, k, is estimated by the model. More specifications about how the model simulates the fish growth are described in Rincón *et al*. (WD 2018).

6.5. Natural mortality.

Natural mortality, M, is unknown for this stock. For the Bay of Biscay anchovy stock the parameter estimates are 0.8 y^{-1} for age 1; 1.2 y^{-1} for age 2+. Torres *et al*. (2013) developed an Ecopath with Ecosim Model for the Gulf of Cadiz which provided estimates of natural mortality for anchovy caused both by predation (1.397 y^{-1}) and other causes (0.101 y^{-1}), with a total M of 1.498 ≈ 1.5 y^{-1} for all ages.

The proposed Gadget assessment model to be evaluated in during this benchmark will adopt the following approaches regarding M (Rincón *et al*., WD 2018):

- M age 0 = 1.17 y^{-1}; M age 1= 0.43 y^{-1} (i.e. values used in the assessment of the Alboran Sea anchovy (Giráldez *et al*., 2009)). M values for ages 2 and 3 were chosen higher enough (M age 2= 0.80 y^{-1}; M age 3= 1.00 y^{-1}) to be coherent with catches at age data, where there is rarely to find individuals older than two years.
- M age 0=1.5 y^{-1}; M age 1=1 y^{-1}; M2+=1.5 y^{-1}.

- M values will be estimated by the model.

Table 6.3.1. Anchovy in 9.a South. Mean weight at age in the stock (in g).

Year	Age 0	Age 1	Age 2	Age 3
1989	4,3	9,9	33,5	
1990	5,1	8,4	32,3	
1991	7,5	11,0	27,5	
1992	5,2	9,6	23,5	
1993	1,7	11,1	21,1	
1994	5,1	9,6	25,1	
1995	7.0	10.7	22.6	
1996	1.1	6.3	20.0	
1997	2.6	11.1	20.9	
1998	2.6	7.4	20.4	
1999	3.2	12.8	20.0	
2000	3.1	10.0	23.8	
2001	6.2	13.3	31.8	
2002	3.3	10.5	26.3	
2003	6.0	10.6	26.8	
2004	6.6	12.0	21.9	
2005	4.9	9.2	22.6	
2006	3.6	8.2	21.0	
2007	5.4	9.4	20.4	
2008	7.2	14.9	21.8	23.1
2009	4.1	12.2	20.3	24.2
2010	6.9	11.3	19.1	23.0
2011	8.2	10.3	22.7	
2012	8.3	14.3	22.5	
2013	6.4	11.9	21.8	
2014	6.6	10.9	19.0	
2015	7.7	10.5	20.7	
2016	8.7	12.9	18.2	

7. Management technical measures.

No EU management plan exists for the anchovy fisheries in Division 9.a. The recent history of the regulatory measures in force for the anchovy fishery in the Division (with a special reference to the Spanish fishery in the Gulf of Cadiz) are described in the ane 27.9a Stock Annex (see also pil.27.8c9a Stock Annex for the Portuguese fishery). Updated information of the Spanish technical measures is given in the 2014 WGHANSA report (ICES, 2014b).

The regulatory technical measures in force for the Spanish (ES) and Portuguese (PT) anchovy purse-seine fishing in the Division 9a (since mid 1980’s) are summarized as follows:

- Minimum landing size:
    - 9a N (ES), 9a CN-9a CS-9a S (PT): 12 cm.

    - 9a S (ES): 10 cm.
- Minimum vessel tonnage: of 20 GRT with temporary exemption (ES).
- Maximum engine power: 450 hp (ES).
- Purse-seine maximum length: 450 m (9a S, ES); 600 m (9a N, ES); 800 m (PT).
- Purse-seine maximum height: 80 m (9a S, ES); 130 m (9a N, ES) 150 m (PT).
- Minimum mesh size: 14 mm (ES); 16 mm (PT).
- Fishing time: 5 days per week (PT, ES).
- Seasonal closures:
    - PT (for sardine): 1.5-2 months (winter/spring) in 9a CN. Since 2015 in 9a CN-9a CS-9a S.
    - ES (for anchovy): voluntarily 3 months (Dec-Feb; until 1997), 1.5 months (Nov-Dec 2004-2005), 2 months (Nov-Dec 2006), 3 months (Nov-Feb 2007-2008), 1 month (Dec 2009-2010), 2 months (Dec-Jan 2011 on) in 9a S, under different GoC purse-seine fishery management plans.
- Spatial closures:
    - PT: ¼ nm distance to the coastline. 1 nm if below 20 m depth.
    - ES: inside bays and estuaries and internal waters in 9a N and 9a S. A Marine Protected Area, MPA (the Guadalquivir River mouth fishing reserve) was created in June 2004 in 9a S (**Figure 7.1**). The protected area corresponds to the main nursery area of fish (including anchovy) and crustacean decapods in the GoC. Fishing in the reserve is only allowed (with pertinent regulatory measures) to gill-nets and trammel-nets, although outside the riverbed. Neither purse-seine nor bottom trawl fishing is allowed all over this MPA.

Between 2006 and 2012 Spain implemented successive GoC purse-seine fishery management plans (9a S, ES). A new regulation approved in October 2006 established that up to 10% of the total catch weight could be constituted by fish below the established minimum landing size (10 cm) but fish must always be ≥9 cm.

Since April 2013 Spain implemented a new management plan for fishing vessels operating in its national fishing grounds, so it affects the purse-seine fishing in Galician (9a N) and GoC waters (9a S (ES)). One of the main measures in this new plan is the introduction of an individual quota (IQ) system to allocate annual national quotas. In the case of the GoC purse-seine fishery this measure involves to shift from a system of a fixed daily catch quota system for all the fleet to a new one based on the implementation of a IQ system managed quarterly by each fishery association after resolution of the National Fishery Administration on the annual allocation of the national quota by association.

By way of from Article 15(1) of Regulation (EU) No 1380/2013, which aims to progressively eliminate discards in all Union fisheries through the introduction of a landing obligation for catches of species subject to catch limits, the purse seine fishery in ICES zones 8, 9. and 10 and in CECAF areas 34.1.1, 34.1.2 and 34.2.0 targeting anchovy has a final *de minimis* exemption to the quantities that may be discarded of up to a maximum of 2% in 2015 and 2016, and 1% in 2017, of the total annual catches of this species. STECF concluded that this exemption is supported by reasoned arguments which demonstrate the difficulties of improving the selectivity in this fishery. Therefore, the exemption concerned has been included in the Commission Delegated Regulation (EU) No 1394/2014 of 20 October 2014 establishing a discard plan for certain pelagic fisheries in southwestern waters.

Finally, the joint recommendation includes a minimum conservation reference size (MCRS) of 9 cm for anchovy caught in ICES Subarea 9 and CECAF area 34.1.2 with the aim of ensuring the protection of juveniles of that species. The STECF evaluated this measure and concluded that it would not impact negatively on juvenile anchovy, that it would increase the level of catches that could be sold for human consumption without increasing fishing mortality, and that it may have benefits for control and enforcement. Therefore, the MCRS for anchovy in the fisheries concerned should be fixed at 9 cm.

Figure 7.1. Ane.27.9a stock. Anchovy fishery in subdivision 9a South. Limits of the Fishing Reserve off the Guadalquivir River mouth (Spanish waters of the Gulf of Cadiz).

8. Ecosystem drivers.

The Gulf of Cadiz (GoC) is a sub-basin between the Iberian Peninsula and the African Continent that connects the Atlantic Ocean and the Mediterranean Sea through the Strait of Gibraltar (**Figure 8.1**). The northern half of the GoC is the southernmost Atlantic European regional sea.

The GoC is placed in the northern area of the *Canary Current Large Marine Ecosystem* and shares many of the oceanographic characteristics typical of the *Eastern Boundary Upwelling Systems* (*EBUS*s) in middle latitudes (*e.g.*, seasonal alternation of a regime of winds favourable to the coastal upwelling, a high biological productivity associated to this process, a system of zonal fronts and currents, and a coastal transition zone with a set of meso-scale structures that deform the fronts favouring the coast-open ocean exchange). Its main distinctive features are (**Figure 8.2**): i) the rupture at Cape São Vicente of the N-S orientation of the coastline typical of the *EBUS*s by an E-W orientated coastline, which frees most of the GoC from the tight control of the upwelling regime off Portugal (Fiúza 1983; Relvas & Barton, 2002). This is particularly true to the east of Cape Santa Maria, where the influence of the Portuguese upwelling vanishes, the shelf widens and waters here reach the highest temperatures in the region; ii) the influence of a northern branch of the Azores Current; iii) the presence of the Strait of Gibraltar with its Atlantic-Mediterranean water exchanges and mixing, and iv) the seasonality, that produces alternant regimes in the surface waters and an intense generation of meso-scale, which modulate and are modulated by the exchange in the Strait (see *e.g.*, García-Lafuente & Ruiz, 2007; Sánchez *et al*., 2006; ICES, 2012).

Figure 8.1. Satellite view of the Gulf of Cadiz featuring a high turbidity event that illustrates the influence of the Guadalquivir River. NASA MODIS, 12/11/2012. Source: earthobservatory.nasa.gov. NASA image courtesy Jeff Schmaltz, LANCE MODIS Rapid Response Team at NASA GSFC. Source: Llope (2017).

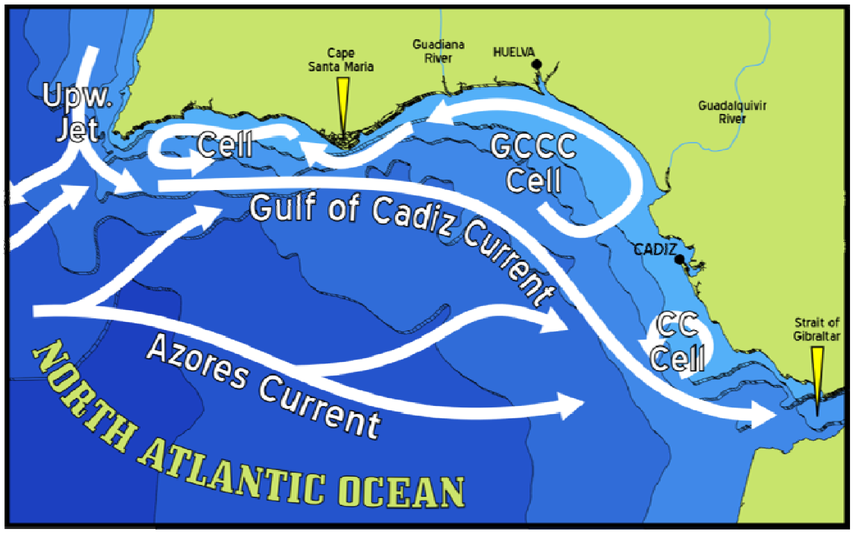


Figure 8.2. Surface circulation in the GoC. CC Cell: cyclonic cell over the shoals in front of Cape Trafalgar; GCCC Cell: Gulf of Cadiz Counter Current; Upw. Jet: Portuguese upwelling. Source: Sánchez *pers. comm.* (after Folkard *et al.*, 1997; Peliz and Fiuza, 1999; Relvas and Barton, 2002; Sánchez and Relvas, 2003; Criado-Aldeanueva *et al.*, 2006; García-Lafuente *et al.*, 2006; Sánchez *et al.*, 2006; Peliz *et al.*, 2009).

Cape Santa Maria divides the GoC shelf in 2 sectors that support different oceanographic processes (forcings by mass and energy inputs and tidal processes) causing that the eastern shelf is warmer and more productive than the western one, which is subject to a more permanent upwelling (Navarro & Ruiz, 2006; Prieto *et al.*, 2009). In this eastern sector, shallower and with a lower intensity of currents, the Guadalquivir estuary also plays a relevant role (by constant tidal mixing) in the control of the biological activity on the shelf.

The GoC is heavily influenced by the Guadalquivir River, which drains one of the major European catchments areas (650 km, 57 000 km^2) contributing to the area's high productivity. Sediments carried by the Guadalquivir form marshes and wetlands that host a rich diversity of wildlife and are relied upon by commercially valuable species. The estuary of the Guadalquivir

River comprises the lower course of the river, a 90 km stretch from its mouth to the first dam at Alcalá del Río, and covers an area of 1800 km^2 (Llope, 2017).

The presence of the Guadalquivir estuary and marshes together with the tidal forcing generate a pool of warm water off the river mouth during spring and summer (García-Lafuente *et al*., 2006; García-Lafuente & Ruiz, 2007). This feature systematically appears in satellite imagery analyses (Vargas *et al*., 2003; Navarro & Ruiz, 2006). The tidal forcing and the river flow also contribute to maintaining high nutrient and chlorophyll levels all year round, which is particularly important in the summer, when the rest of the basin is stratified and oligotrophic. These particular conditions make the area off the Guadalquivir the most productive of the GoC (Navarro & Ruiz, 2006). Traditionally, the local cyclonic surface circulation pattern described during spring-summer has been put forward as a favorable meso-scale feature with regard to the maintenance of this warm and productive cell (García-Lafuente *et al*., 2006; Criado-Aldeanueva *et al*., 2006, 2009; Garel *et al*., 2016).

Estuaries are known for their role as nursery areas for many marine species and the Guadalquivir is no exception (Drake *et al*., 2002; Baldó *et al*., 2006; Ruiz *et al*., 2006; Drake *et al*., 2007). Studies arising from a Guadalquivir estuarine monitoring program since 1997 have described long term changes in anchovy early life stages and other nekton components in relation to salinity and turbidity conditions (Drake *et al.* 2007, González-Ortegón *et al*. 2010, 2012). This nursery function is the main regulating service the region provides in relation to the GoC fisheries. It is this estuarine factor, where terrestrial and marine processes converge, that makes the GoC a unique case study (Ruiz *et al*., 2015; Llope, 2017).

For these reasons, these shelf waters of the NE GoC, mainly those ones in the inner shelf surrounding the Guadalquivir River mouth, offer a favourable environment for the development of anchovy eggs and larvae in spring-summer and become in the main GoC anchovy spawning area (Baldó *et al*., 2006). The outer stretch of the Guadalquivir estuary is used almost synchronously by anchovy post-larvae and juveniles as a nursery area. Recruitment to the estuary occurs when water temperature and salinity are relatively high, but turbidity and rainfall are relatively low. Some studies (Baldó & Drake, 2002; Drake *et al*., 2007; Fernández-Delgado *et al*., 2007; González-Ortegón *et al*., 2010) point out that, within this optimal window, the main factor regulating the nursery function of the estuary is the food availability of key-prey species (copepods for post-larvae, the mysid *Mesopodopsis slabberi* for juveniles).

There is a local upwelling regime to the west of Cape Santa Maria, which is independent of that of the Canary Current and considered a coastal process with a short time response to changes in the wind regime (Criado-Aldeanueva *et al*., 2006). Westerlies are the winds responsible for upwellings while easterlies have the opposite effect leading to a remarkable increase in temperatures (Prieto *et al*., 2009). Furthermore, the westerlies/easterlies regime plays a central role in the continental shelf dynamics of the area, affecting retention within the warm cell. Under westerlies conditions, local upwellings enhance productivity and plankton is confined inside the cyclonic cell. In contrast, easterlies would favor oligotrophy and the westward advection of plankton and larvae (Relvas & Barton, 2002; Catalán *et al*., 2006). Thus, persistent easterlies bursts (preceded and followed by intervals of a lower frequency of this wind) may generate significant modifications in the oceanographic regime in the GoC (*i.e*., decrease of SST, oligotrophy, offshore advection of early stages away from favourable conditions), which can influence markedly the reproductive success of the species. These detrimental conditions were evident during the period 1990-1997 and they seemed to affect to the development conditions of eggs and larvae, which could result in failed recruitments in those years as evidenced by the severe drop of landings in 1995-1996 (Ruiz *et al*., 2006, 2009;

Figure 8.3). According to the authors, this drop of landings resembled more the easterly signal than the NAO index or precipitation. Conversely, the 1996 rain fall peak (and associated river discharges) –clearly reflecting the dramatic change in the NAO index– may have played a role in the recovery of 1997 anchovy landings.

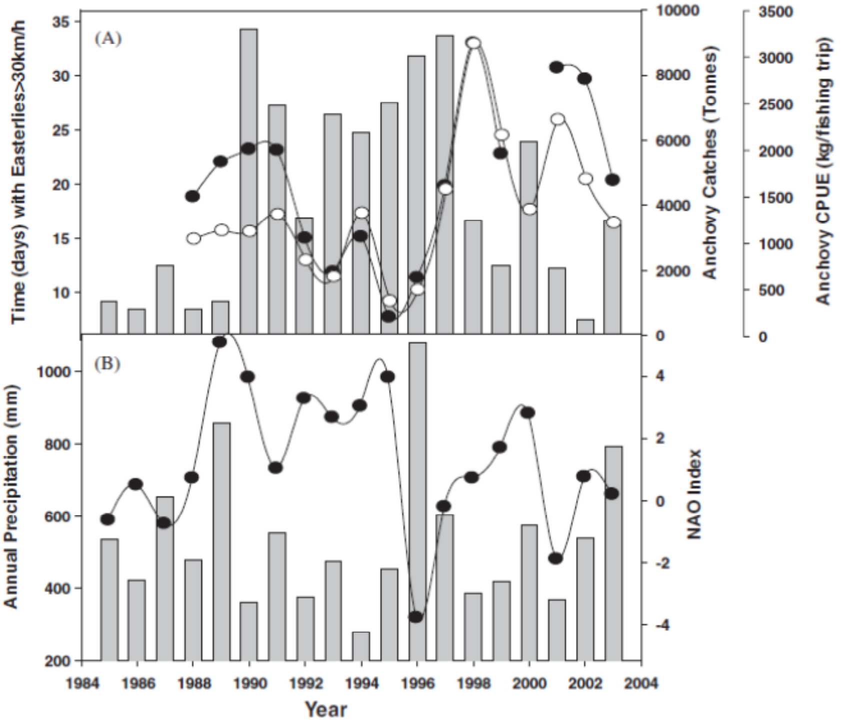


Figure 8.3. A. GoC anchovy landings (ICES Subdivision 9a South; black circles) and Barbate's single-purpose purse-seine fleet CPUE (white circles, in kg/fishing trip). Barbate is considered as a reference fleet in the GoC anchovy harvesting. Landing data for 2000 is not included in the graph as catches were not representative due to social conflicts in the fleet. Bars accumulate the time when easterlies stronger than 30 km/h hit Cádiz over the period from March to September. B. Circles and bars indicate North Atlantic Oscillation index and annual precipitation, respectively. Source: Ruiz *et al.* (2006).

The GoC anchovy population has also experienced a noticeable decreasing trend during the period 2008-2010 as a probable consequence of successive fails in the recruitment strength in those years (**Figure 8.4**; ICES, 2011). A man-induced alteration of the nursery function of the Guadalquivir estuary, caused by episodes of highly persistent turbidity events (HPTE; González-Ortegón *et al*., 2010; **Figure 8.1**), during the anchovy recruitment seasons in 2008, 2009 and 2010 could be one plausible explanation. Thus, the control of the Guadalquivir River flow, from the Alcalá del Río dam 110 km upstream, has an immediate effect on the estuarine salinity gradient, displacing it either seaward (reduction) or upstream (enlargement of the estuarine area used as nursery). Also affects to the input of nutrients to the estuary and adjacent coastal areas. The abovementioned HPTEs used to start with strong and sudden freshwater discharges after relatively long periods of very low freshwater inflow and caused significant decreases in abundances of anchovy juveniles and the mysid *Mesopodopsis slabberi*, its main prey (**Figure 8.5**).

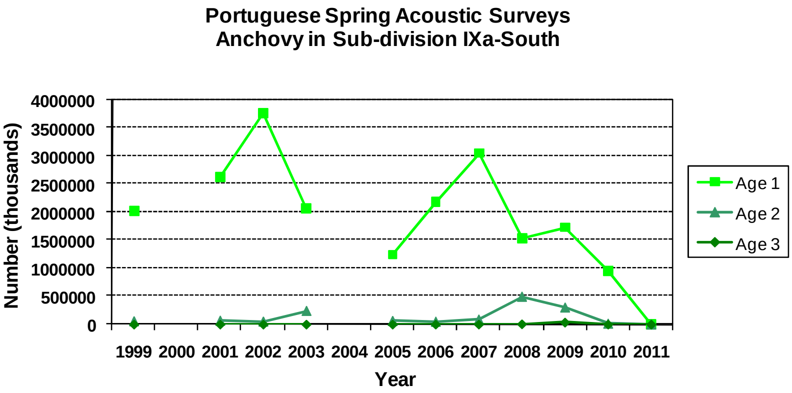


Figure 8.4. Age structured estimates of GoC anchovy abundance from the Portuguese acoustic survey series. The null estimates for the 2011 Portuguese survey should be considered with caution. Source: ICES (2011).

As a short-lived small pelagic species, anchovy population dynamics are strongly affected by year-to-year fluctuations in environmental processes. As described above, temperature, winds and discharges from the Guadalquivir River have been identified as key factors influencing its recruitment (Ruiz *et al*., 2006, 2009; Rincón *et al*., 2016). Discharges have different effects on the nursery role depending on their volume. Low levels of freshwater discharges constrain primary productivity on the shelf limiting the food supply for juveniles (Prieto *et al*., 2009) while very high discharges cause salinity to drop below the threshold forcing juveniles to leave the protective environment of the estuary (Ruiz *et al*., 2009). However, the combination of both natural (weather) and anthropogenic (discharges) effects, plus the timing and volume discharged, results in a broad range of combinations that makes the ecological response of the ecosystem to freshwater inputs be not unequivocal (González-Ortegón & Drake, 2012; González-Ortegón *et al*., 2012, 2015).

In the last years, models including environmental information have been developed by means of Bayesian simulation techniques (Ruiz *et al*. 2009, 2017, Rincón *et al*. 2016, 2018), GAM empirical modeling (Carvalho-Souza *et al*., in prep.), as well as mass-balanced models describing the role of GoC anchovy in the marine food web (Torres *et al*. 2013). An ecosystem approach perspective is presented in Llope (2017) (see also ICES, 2017d).

All of these evidences confirm that the GoC anchovy stock relies on recruits to persist and, therefore, is highly vulnerable to ocean processes and controlled by fluctuations in both environmental and anthropogenic variables.

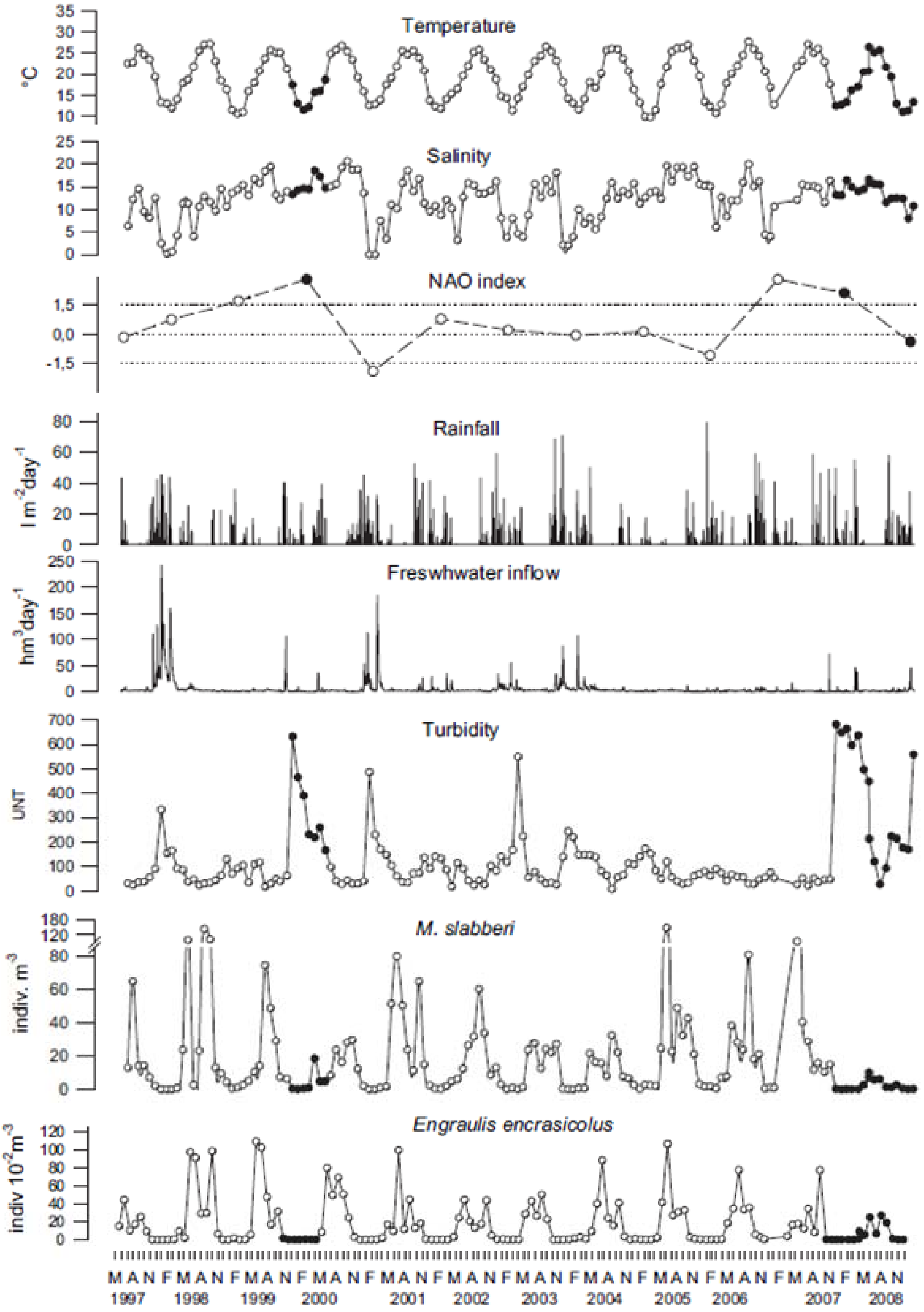


Figure 8.5. Monthly/daily mean values of environmental variables (water temperature, salinity, rainfall, freshwater inflow, and turbidity), mysids and anchovy recruits' densities in the Guadalquivir Estuary from May 1997 to February 2009, and winter NAO index values for the same period. F, February, M, May, A, August, N, November. Shaded symbols, samples collected during HPTEs (composite figure from González-Ortegón *et al*., 2010).

REFERENCES.

Baldó, F., P. Drake, 2002. A multivariate approach to the feeding habits of small fishes in the Guadalquivir Estuary. *Journal of Fish Biology* 61(Suppl. A): 21-32.

Baldó, F., E. García-Isarch, M. P. Jiménez, Z. Romero, A. Sánchez-Lamadrid, I. A. Catalán, 2006. Spatial and temporal distribution of the early life stages of three commercial fish species in the North Eastern shelf of the Gulf of Cádiz. *Deep Sea Research Part II* 53 (11–13): 1391–1401.

Bellido, J. M., G. J. Pierce, J. L. Romero, M. Millán, 2000. Use of frequency analysis methods to estimate growth of anchovy (*Engraulis encrasicolus* L. 1758) in the Gulf of Cádiz (SW Spain). *Fish. Res.* 48:107–115.

Carvalho-Souza, G. F., M. Llope, M., F. Baldó, C. Vilas, P. Drake, E. González-Ortegón, E., *In prep*. Environmental and anthropogenic drivers affect the abundance of anchovy and mysids in the Guadalquivir Estuary (SW Spain).

Catalán, I. A., J. P. Rubín, G. Navarro, L. Prieto, 2006. Larval fish distribution in two different hydrographic situations in the Gulf of Cadiz. *Deep-Sea Research Part II*, 53 (11–13): 1377–1390.

Criado-Aldeanueva, F., J. García-Lafuente, J. M. Vargas, J. Del Rio, A. Vázquez, A. Reul, A. Sánchez, 2006. Distribution and circulation of water masses in the Gulf of Cadiz from in situ observations. *Deep Sea Research Part II*, 53(11–13): 1144–1160.

Criado-Aldeanueva, F., J. García-Lafuente, G. Navarro, J. Ruiz, 2009. Seasonal and interannual variability of the surface circulation in the eastern Gulf of Cadiz (SW Iberia). *Journal of Geophysical Research*, 114:

Drake, P., A. M. Arias, F. Baldó, J. A. Cuesta, A. Rodríguez, , A. Silva-García, I. Sobrino, et al. 2002. Spatial and Temporal Variation of the Nekton and Hyperbenthos from a Temperate European Estuary with Regulated Freshwater Inflow. *Estuaries*, 25: 451–468.

Drake, P., A. Borlán, E. González-Ortegón, F. Baldó, C. Vilas, C. Fernández-Delgado, 2007. Spatio-temporal distribution of early life stages of the European anchovy *Engraulis encrasicolus* L. within a European temperate estuary with regulated freshwater inflow: effects of environmental variables. *Journal of Fish Biology* 70, 1689–1709.

Fernández-Delgado, C., F. Baldó, F., C. Vilas, D. García-González, J. A. Cuesta, E. González-Ortegón, P. Drake, 2007. Effects of the river discharge management on the nursery function of the Guadalquivir river estuary (SW Spain). *Hydrobiologia* 587: 125–136.

Fiúza, A. F. G. 1983. Upwelling patterns off Portugal. In *Coastal Upwelling: Its Sediment Record*, Part A, pp. 85–98. Ed. by E. Suess and J. Thiede. Plenum, New York.

Folkard, A., P. Davies, A. Fiúza, I. Ambar, 1997. Remotely sensed sea surface thermal patterns in the Gulf of Cadiz and the Strait of Gibraltar: Variability, correlations, and relationships with the surface wind field. *J. Geophys. Res.*, 102 (C3): 5669–5683.

García-Lafuente, J., J. Ruiz, 2007. The Gulf of Cadiz pelagic ecosystem: A review. *Prog. Oceanogr.*, 74: 228–251.

García-Lafuente, J., J. Delgado, F. Criado-Aldeanueva, M. Bruno, J. del Rio, J. M. Vargas, 2006. Water mass circulation on the continental shelf of the Gulf of Cadiz. *Deep Sea Research Part II*, 53 (11–13): 1182–197.

Garel, E., I. Laiz, T. Drago, P. Relvas, 2016. Characterization of coastal counter-currents on the inner shelf of the Gulf of Cadiz. *Journal of Marine Systems*, 155: 19–34.

Giráldez, A., P. Torres, L. F. Quintanilla-Hervás, J. M. Bellido, F. Alemany, M. Iglesias, 2009. Anchovy (*Engraulis encrasicolus*) stock assessment in the GFCM geographical sub-area GSA 01, Northern Alborán Sea. Working Document for the GFCM-SAC-SCSA Working Group on stock assessment of small pelagic species. Centro Oceanográfico de Málaga, Málaga, Spain. 18 pp.

González-Ortegón, E., P. Drake, 2012. Effects of freshwater inputs on the lower trophic levels of a temperate estuary: physical, physiological or trophic forcing? *Aquatic Sciences*, 74: 455–469.

González-Ortegón, E., F. Baldó, A. Arias, J. A. Cuesta, C. Fernández- Delgado, C. Vilas, P. Drake, 2015. Freshwater scarcity effects on the aquatic macrofauna of a European Mediterranean climate estuary. *The Science of the Total Environment*, 503–504: 213–221.

González-Ortegón, E., M. D. Subida, J. A. Cuesta , A. M. Arias, C. Fernández-Delgado, P. Drake. 2010. The impact of extreme turbidity events on the nursery function of a temperate European estuary with regulated freshwater inflow. *Estuarine, Coastal and Shelf Science* 87: 311–324.

González-Ortegón, E., M. D. Subida, A. M. Arias, F. Baldó, J. A. Cuesta, C. Fernández-Delgado, C. Vilas, *et al*., 2012. Nekton response to freshwater inputs in a temperate European Estuary with regulated riverine inflow. *The Science of the Total Environment*, 440: 261–271.

ICES, 1997. Report of the Working Group on the assessment of mackerel, horse-mackerel, sardine and anchovy (WGMHSA), 13-22 August 1996, ICES HQ, Copenhagen, Denmark. ICES CM 2017/Asses: 3. 384 pp.

ICES, 2004a. Workshop on Discard Sampling Methodology and Raising Procedures. Report of the Planning Group on Commercial Catch, Discards and Biological Sampling (PGCDBS). ICES Document CM 2004/ACFM: 13. 60 pp.

ICES, 2004b. Report of the Study Group on Assessment Methods Applicable to Assessment of Norwegian Spring-Spawning Herring and Blue Whiting Stocks (SGAMHBW). 19-22 February 2004, Lisbon, Portugal. ICES CM 2014/ACFM 145. 166 pp.

ICES, 2008a. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG), 24-28 November 2008, Nantes, France. ICES CM 2008/LRC:17. 183 pp.

ICES, 2008b. Report of the Workshop on Small Pelagics (*Sardina pilchardus*, *Engraulis encrasicolus*) maturity stages (WKSPMAT), 10-14 November 2008, Mazara del Vallo, Italy. ICES CM 2008/ACOM:40. 82 pp.

ICES, 2009. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG), 16-20 November 2009, Lisbon, Portugal. ICES CM 2009/LRC:20. 181 pp.

ICES, 2010. Report of the Workshop on Age reading of European anchovy (WKARA), 9-13 November 2009, Sicily, Italy. ICES CM 2009/ACOM:43. 122 pp.

ICES, 2011. Report of the Working Group on Anchovy and Sardine (WGANSA), 24-28 June 2011, Vigo, Spain. ICES CM 2011/ACOM: 16. 462 pp.

ICES, 2012. Report of the Working Group on Small Pelagic Fishes, their Ecosystems and Climate Impact (WGSPEC), 27 February – 2 March 2012, Fuengirola, Spain. ICES CM 2012/SSGEF: 10. 63 pp.

ICES, 2014a. Report of the Planning Group on Commercial Catches, Discards and Biological Sampling (PGCCDBS), 17–21 February 2014, Horta (Azores), Portugal. ICES CM 2014 / ACOM: 34. 103 pp.

ICES, 2014b. Report of the Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA), 20–25 June 2014, Copenhagen, Denmark. ICES CM 2014/ACOM:16. 600 pp.

ICES, 2015. First Interim Report of the Working Group on Working Group on Biological Parameters (WGBIOP), 7-11 September 2015, Malaga, Spain. ICES CM 2015/SSGIEOM:08. 67 pp.

ICES, 2017a. Report of the Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA), 24–29 June 2017, Bilbao, Spain. ICES CM 2017/ACOM:17. 547 pp.

ICES, 2017b. Report of the Workshop on Age estimation of European anchovy (*Engraulis encrasicolus*). WKARA2 2016 Report. 28 November - 2 December 2016. Pasaia, Spain. ICES CM 2016/SSGIEOM:17. 223 pp.

ICES, 2017c. Manual of the IBTS North Eastern Atlantic Surveys. Series of ICES Survey Protocols SISP 15. 92 pp. http://doi.org/10.17895/ices.pub.3519

ICES, 2017d. Interim Report of the Working Group on Ecosystem Assessment of Western European Shelf Seas. ICES WGEAWESS REPORT 2017. 24–28 April 2017. Lisbon, Portugal. ICES CM 2017/IEASG:02. 23 pp.

Kimura, D.K., S. Chikuni 1987. Mixtures of empirical distributions: an iterative application of the age-length key. *Biometrics*, 43: 23-35.

Llope, M., 2017. The ecosystem approach in the Gulf of Cadiz. A perspective from the southernmost European Atlantic regional sea. *ICES Journal of Marine Science*, 74(1): 382–390. doi:10.1093/icesjms/fsw165.

Millán, M., 1992. Descripción de la pesquería de cerco en la Región Suratlántica Española y Atlántico-Norte Marroquí. *Informes Técnicos Instituto Español de Oceanografía* 136, 70 pp.

Millán, M., 1999. Reproductive characteristics and condition status of anchovy *Engraulis encrasicolus* L. from the Bay of Cádiz (SW Spain). *Fisheries Research* 41, 73–86.

Millán, M., 2002. A short note on the estimation of catch-at-age data for the Gulf of Cadiz anchovy (Sub-division IXa South) in 1994 and second half in 1995 from an iterated age-at-length key. Working Document presented in the ICES Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy (WGMHSA). 10-19 September 2002. Copenhagen, Denmark.

Navarro, G., J. Ruiz, 2006. Spatial and temporal variability of phytoplankton in the Gulf of Cadiz through remote sensing images. *Deep Sea Research Part II*, 53 (11–13): 1241–1260.

Navarro, G., F. J. Gutiérrez, M. Díez-Minguito, M. A. Losada, J. Ruiz, 2011. Temporal and spatial variability in the Guadalquivir estuary: a challenge for real-time telemetry. *Ocean Dynamics* 61 (6): 753-765.

Payne, M. R., L. W. Clausen, H Mosegaard, 2009. Finding the signal in the noise: objective data-selection criteria improve the assessment of western Baltic spring-spawning herring. *ICES Journal of Marine Science*, 66: 1673‑1680.

Peliz, A., A. Fiúza, 1999. Temporal and spatial variability of CZCS derived phytoplankton pigment concentrations off western Iberian Peninsula. *Int. J. Remote Sens*., 20 (7): 1363–1403.

Peliz, A., P. Marchesiello, A. M. P. Santos, J. Dubert, A. Teles-Machado, M. Marta-Almeida, Le Cann, 2009. Surface circulation in the Gulf of Cadiz: 2. Inflow-outflow coupling and the Gulf of Cadiz slope current. *J. Geophys. Res*., 114, C03011, doi: 10.1029/2008JC004771.

Pestana, G. 1996. Anchovy in Portuguese waters (IXa): landings and length distribution in surveys. Working Document presented in the ICES Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy. ICES, C.M. 1996/Assess:7.

Prieto, L., G. Navarro, S. Rodríguez-Gálvez, I. E. Huertas, J. M. Naranjo, J. Ruiz, 2009. Oceanographic and meteorological forcing of the pelagic ecosystem on the Gulf of Cadiz shelf (SW Iberian Peninsula). *Continental Shelf Research* 29: 2122–2137.

Relvas, P., E. Barton, 2002. Mesoscale patterns in the Cape São Vicente (Iberian Peninsula) upwelling region. *J. Geophys. Res*., 107 (C10): 3164, doi: 10.1029/2000JC000456.

Rincón, M. M., J. D. Mumford, P. Levontin, A. W Leach, J. Ruiz, 2016. The economic value of environmental data: a notional insurance scheme for the European anchovy. *ICES Journal of Marine Sciences*, 73: 1033–1041.

Rincón, M M., F. Ramos, et al., 2018. Gadget for 9a South (WKPELA 2018). Working Document presented to ICES WKPELA 2018 Benchmark Assessment Workshop. 12-16 February 2018, ICES HQ. Copenhagen.

Rincón, M. M., I. A. Catalán, S. Mäntyniemi, D. Macias, J. Ruiz, 2018b. Embedding anchovy survival in the environment with a dual time resolution: A Bayesian state-space size-structured population dynamics model. *Fish. Bull*. 116: 34-49.

Ruiz, J., E. García-Isarch, G. Navarro, L. Prieto, A. Juárez, J. L. Muñoz, A. Sánchez-Lamadrid, S. Rodríguez, J. M. Naranjo, F. Baldó, 2006. Meteorological forcing and ocean dynamics controlling *Engraulis encrasicolus* early life stages and catches in the Gulf of Cadiz. *Deep Sea Research Part II*, 53 (11–13): 1363–1376.

Ruiz, J., R. González-Quirós, L. Prieto, G. Navarro, 2009. A Bayesian model for anchovy (*Engraulis encrasicolus*): the combined forcing of man and environment. *Fish. Oceanogr*. 18(1): 62-76.

Ruiz, J. M. J. Polo, M. Díez-Minguito, G. Navarro, E. P. Morris, E. Huertas, I. Caballero, E. Contreras, M. A. Losada, 2015. The Guadalquivir Estuary: A Hot Spot for Environmental and Human Conflicts. In C. W. Finkl & C. Makowski (Eds.), *Environmental Management and Governance* (pp. 199-232). Cham: Springer International Publishing. DOI: 10.1007/978-3-319-06305-8_8.

Ruiz, J., M.M. Rincón, D. Castilla, F. Ramos, J. J. G. del Hoyo, 2017. Biological and economic vulnerabilities of fixed TACs in small pelagics: An analysis of the European anchovy (*Engraulis encrasicolus*) in the Gulf of Cadiz. *Marine Policy*, 78: 171-180.

Sánchez, R., P. Relvas. 2003. Spring-summer climatological circulation in the upper layer in the region of Cape St. Vincent, Southwest Portugal, *ICES Journal of Marine Science*, 60: 1232–1250, doi:10.1016/S1054–3139(03)00137-1.

Sánchez, R., E. Mason, P. Relvas, A. da Silva, A. Peliz, 2006. On the inshore circulation in the northern Gulf of Cadiz, southern Portuguese shelf, *Deep Sea Research Part II*, 53 (11–13): 1198–1218.

Stratoudakis, Y., A. Marçalo, 2002. Sardine slipping during purse-seining off northern Portugal. *ICES Journal of Marine Science*, 59 (6): 1256-1262.

Torres, M. A., M. Coll, J. J Heymans,. V. Christensen, I. Sobrino, 2013. Food-web structure of and fishing impacts on the Gulf of Cadiz ecosystem (South-western Spain). *Ecological Modelling*, 265: 26–44.

Vargas, J. M., J. García-Lafuente, J. Delgado, F. Criado, 2003. Seasonal and wind-induced variability of Sea Surface Temperature patterns in the Gulf of Cadiz. *Journal of Marine System*s, 38: 205–219.

Villamor, B., A. Uriarte, 2015. Otolith Exchange Results of European Anchovy (*Engraulis encrasicolus*), 2014. Working Document presented in the ICES Working Group on biological parameters. 7-11 September, Málaga, Spain. 79 pp.