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POPULATION STRUCTURE OF THE EUROPEAN ANCHOVY (*Engraulis encrasicolus*) IN ICES DIVISION 9a: SYNOPSIS AND UPDATED INFORMATION

By

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1. ABSTRACT

In the present WD we intend to summarize and present new information on the stock structure of anchovy in the Sub-division 9a, which led the WGHANSA to consider the anchovy populations inhabiting the southern and western Iberian regions as separate stock units for management purposes.

2. INTRODUCTION

The European anchovy, *Engraulis encrasicolus*, is a small pelagic coastal marine fish distributed from the North Sea to SE Africa, including the entire Mediterranean basin. This species supports an important fisheries and economic activity for the countries bordering the Iberian Peninsula and Mediterranean Sea (Uriarte *et al*., 1996; Lleonart and Maynou, 2002). Due to its market value, production, and wide distribution in several E Atlantic and Mediterranean countries, anchovy is a major shared resource in the region.

For management purposes, the European anchovy that occurs in the Atlantic was separated in two distinct stock units, one distributed in the Bay of Biscay (ICES Sub-Area VIII) and the other distributed in ICES Division 9a (Portuguese coast and Spanish waters of the Gulf of Cadiz). However, these stock limits were essentially based on administrative considerations.

A review on the sub-stock structure of the European anchovy in the Bay of Biscay and Iberian-Atlantic waters was provided by Ramos (2015) to the ICES Stock Identification Methods Working Group (SIMWG) 2015. The evidences presented in that document suggested the existence of an anchovy stable population in the Gulf of Cadiz that seemed to be relatively independent of the remaining populations in Division 9a. At that time, the ICES SIMWG (ICES, 2015a) considered that there was evidence to support a self-sustained population of anchovy located in the Gulf of Cadiz (ICES Subdivision 9a South), but there was a lack of information regarding the origin of European anchovy in ICES Subdivisions 9a North, 9a Central-North and 9a Central-South (Fig. 1).

In the present WD we intend to summarize the information presented in Ramos (2015), update the analysis of the historical dynamics of landings and surveys, describing the new evidences that point to a discontinuity of the distribution of anchovy in the Sub-division 9a Central-South, both in years of high and low abundance. The evidences shown in the current WD on anchovy stock ID led to the decision of considering the anchovy populations inhabiting the southern and western Iberian regions as separate stock units for management purposes.

2. SPATIAL DISTRIBUTION OF ANCHOVY IN DIVISION 9a

The distribution of anchovy in division 9a (Fig. 1) was investigated by using all the available information of the scientific cruises carried out regularly in the area, and covering several life-stages (eggs, juveniles and adults) and seasons of the year (spring, summer, fall). In what follows, the historical data of the distribution of the species will be shown for the indices derived from those cruises and also those covering the major part of the division 9a (PELAGO, PT-DEPM, Portuguese Trawl Surveys).

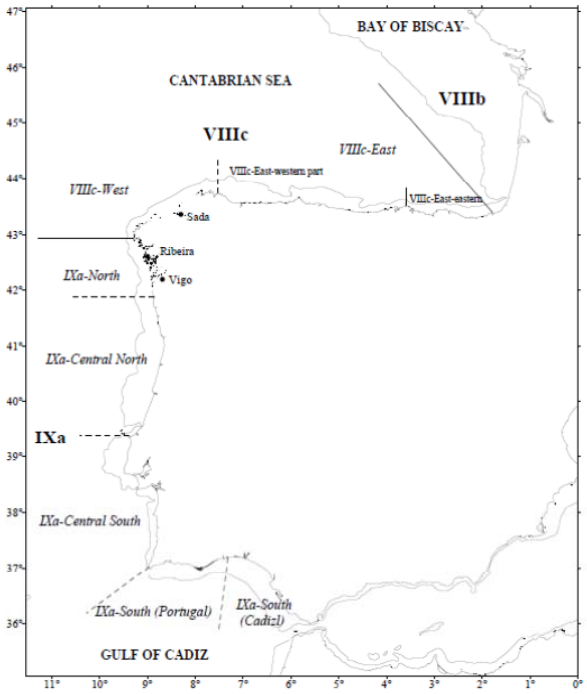

Figure 1. ICES Statistical Divisions and Subdivisions in Southern Europe. Note that Subdivision 9a South (which includes the European waters of the Gulf of Cadiz) is also differentiated between Portuguese (Algarve coasts) and Spanish waters.

2.1. HISTORIC DYNAMICS OF SURVEY DATA

2.1.1. SPRING ACOUSTIC SURVEYS

According to the estimates provided by the spring acoustic surveys carried out in the Iberian Atlantic waters (PELAGO, PELACUS and PELGAS surveys, Fig. 2), from 2013 to 2017, adult anchovy core distribution areas in springtime were, by decreasing order of importance: coastal areas in Southern Bay of Biscay (Gironde and Landes coast, ~46°N), the Gulf of Cadiz (~37°N), and in a small area North of Cape Mondego on the Western coast of Portugal (~40°N). There is a gap in the distribution of adult anchovy in the western side of the Cantabrian Sea and in the southwestern Portuguese coast.

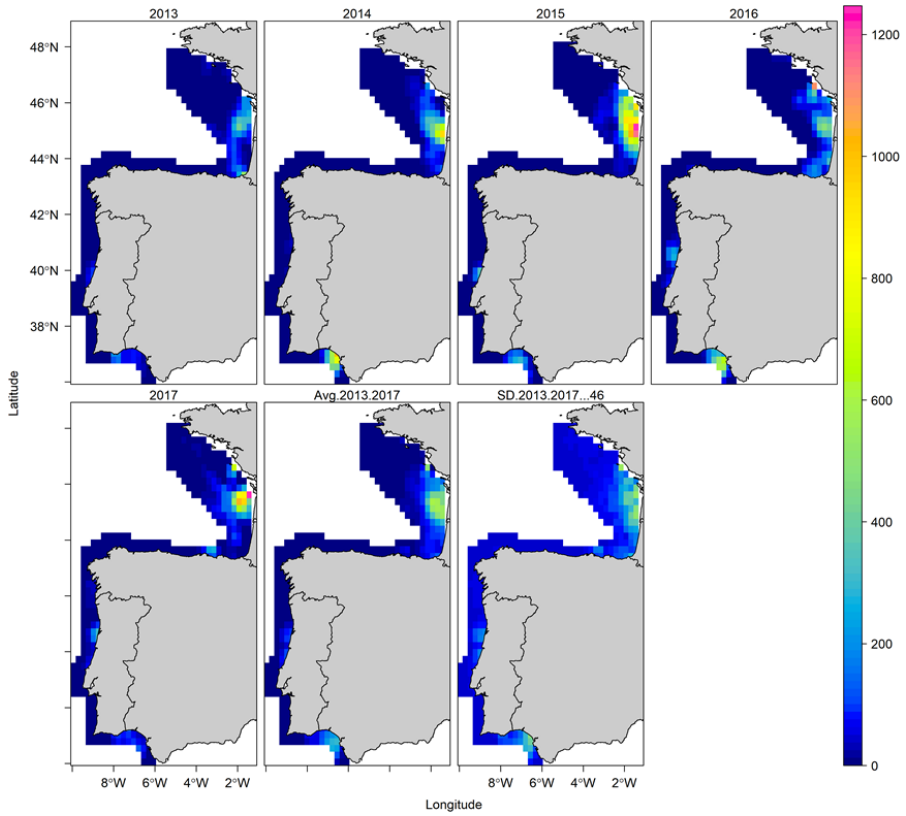

Figure 2 Adult anchovy mean acoustic density (NASC, $m^2.nm^{-2}$) maps derived from the PELAGO, PELACUS and PELGAS surveys, 2013-2017, 0.25° map cell. "Avg.2013-2017 panel": map of anchovy NASC values averaged over the series. "SD.2013-2017 panel": map of anchovy NASC standard deviation over the series. Source: ICES WGACEGG 2017 Report.

Anchovy egg distribution estimated during the spring acoustic surveys is similar to that of the adults, being higher in the Bay of Biscay, followed by the Gulf of Cadiz and a small area Western coast of Portugal (Fig. 3). Note however that peak spawning for anchovies is generally two months after these surveys.

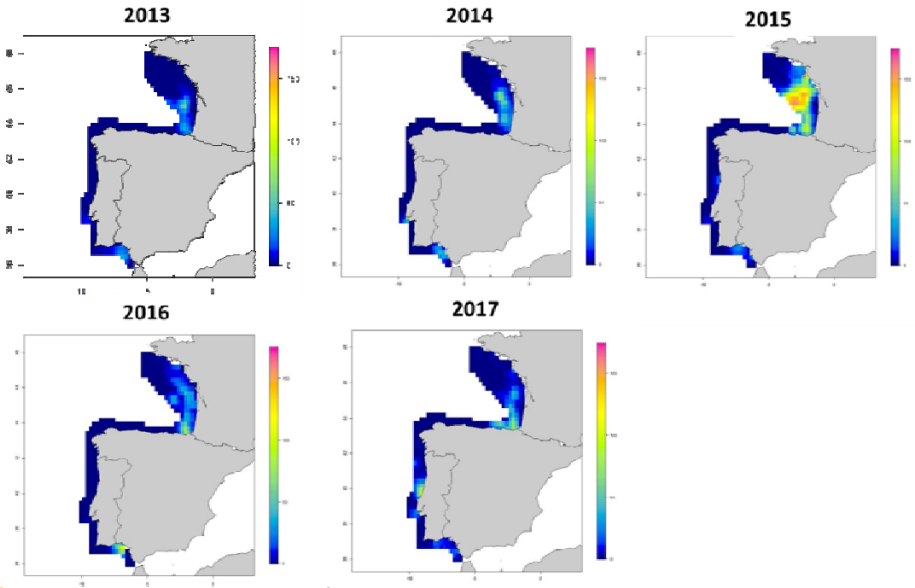

Figure 3. Anchovy egg density (eggs m^{-3}) distribution derived from CUFES sampling during the spring acoustic surveys, PELGAS (Ifremer), PELACUS (IEO) and PELAGO (IPMA) for the period 2013-2017. Source: ICES WGACEGG 2017 Report.

2.1.1.1. PELAGO survey series

The PELAGO survey covers the majority of the 9a Division, from sub-areas 9aCN to the Gulf of Cadiz, only excluding the 9a-N sub-division, that accounts, on average, of <0.01% of anchovy abundance in Division 9a and less than 5% of anchovy in the western component. Acoustic surveying is undertaken along 71 transects perpendicular to the coast, covering the whole platform, and separated approximately 6 (south) or 8 nm (west). Fishing hauls are carried out for species ground-truthing and fish size composition. The zooplankton samples are collected underway every 3 nmiles, with the CUFES system (water pumped from 3m from the surface, system fitted with a 335 µm mesh size net), concurrently to the acoustic surveying along the trajectory of the acoustic transects.

A more detailed observation of the PELAGO results (Fig. 4) allows the identification of other more local patterns. Apart from the main centres, in Cadiz and in the northwest, it is recurrent the appearance of eggs in the area from Cape Carvoeiro to Cape Espichel and also, in some years, off River Mira (south of Cape Sines) in the southwestern coast. The major egg densities in the western shores occur more often in the central region off Ria de Aveiro – River Mondego area. The anchovy egg distribution is highly variable between years. During years of high abundances, the southern coast appears almost entirely occupied, with observations from the inner Cadiz Bay to Cape S. Vincente, while during low abundance periods the distribution is retracted to the Spanish waters. Likewise, in the west coast during years of higher abundances the anchovy eggs may be observed almost across the whole platform (eg. in 2017) while during low density periods may only be observed in the core areas. It is worth noting that the spawning period for anchovy in the area of the PELAGO survey is considered to have its peak during summer. Unplanned delays occurred in surveying in the last couple of years, may have contributed to the higher anchovy egg abundances observed since the survey was carried out more into the spawning season for the species. In fact, 2017 was the year with the record of anchovy egg abundances during the PELAGO survey series. The higher egg densities were observed in the northwestern coast and in good agreement with the detection of anchovy schools where high fish abundances were also registered during the previous spring.

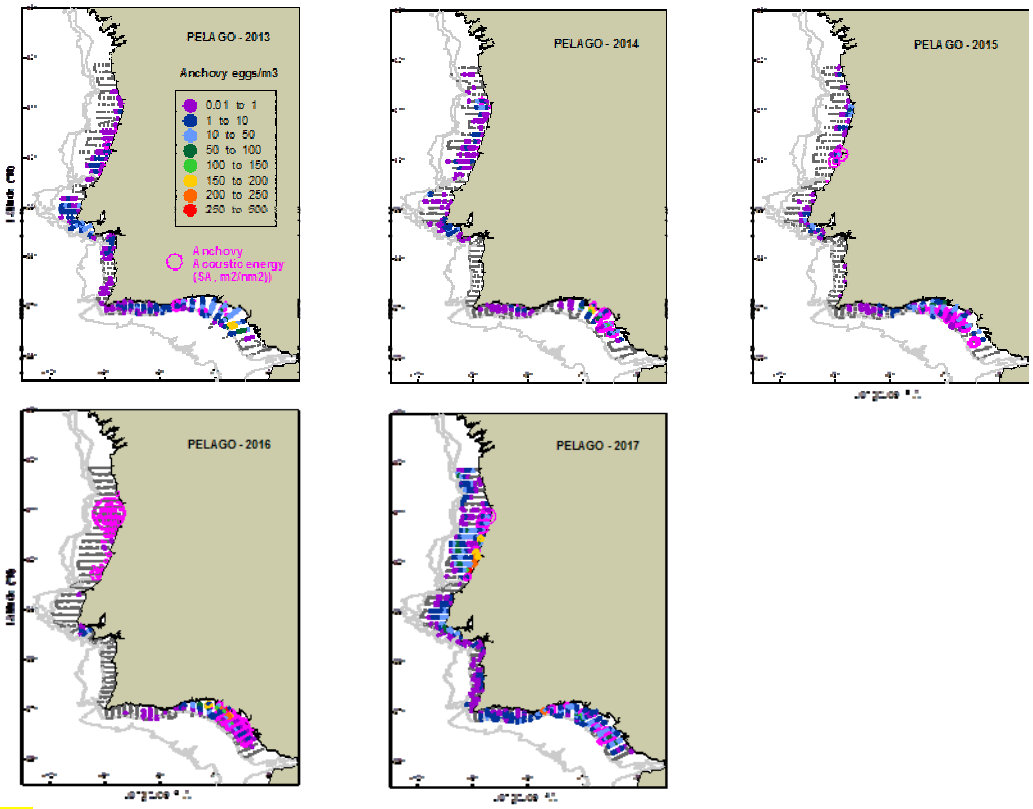

Figure 4 - Anchovy, egg density (eggsm-3), from CUFES sampling, and acoustic energy (SA m2/nm2) distributions, during the acoustic surveys of the PELAGO series (IPMA) for the period 2013-2017. Egg distributions are represented by density classes according to the colour scale depicted and acoustic energies are shown in pink circles with areas proportional to SA. Source: ICES WGACEGG

2.1.2. DEPM surveys

According to the anchovy egg abundances provided by the DEPM surveys carried out in the Atlantic Iberia and Bay of Biscay (PT-DEPM-PIL, SAREVA and BIOMAN , Fig. 4) during 2017, which, in the case of the PT-DEPM-PIL was delayed for technical problems and therefore carried out more into the spawning season of anchovy, it is clear the high abundance of eggs in the western coast of Portugal, revealing this is a spawning site for the species.

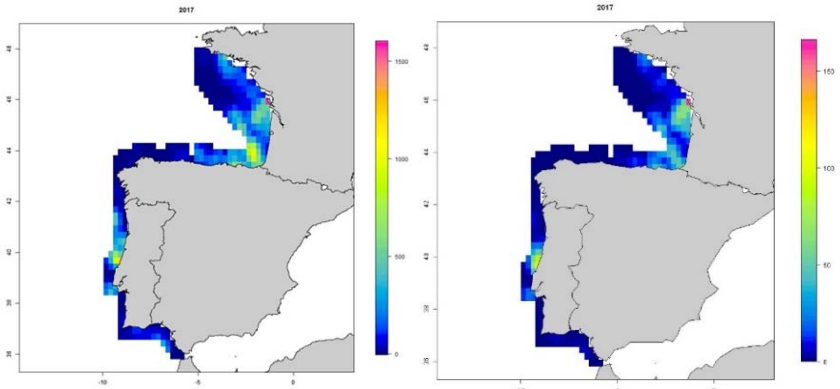

Figure 4. Anchovy egg distributions from PairoVET (left panel; eggs/m^2) and CUFES (right panel; eggs/m^3) observations collected during the DEPM surveys starting from the North: BIOMAN, SAREVA and PT-DEPM 2017-PIL. Note that colour scales do not match between panels. Source: ICES WGACEGG

2.1.3. TRAWL SURVEY SERIES – PORTUGUESE CONTINENTAL COAST

Data on the occurrence of anchovy in the time series of demersal trawl surveys since 1990 until 2017 was analysed in order to investigate the distribution of the species in seasons different from that analysed in the spring acoustic survey series. The surveys follow a fixed grid of 97 sampling stations, spread throughout the shelf between 36 and 710 m. The time series of data (1990–2017) collected by 43 surveys conducted in the fall (26 surveys), summer (10 surveys), spring and winter (5 and 1 survey, respectively). The fishing gear used is a bottom trawl (type Norwegian Campell Trawl 1800/96 NCT) with a 20 mm codend mesh size. The target duration of each tow was 60 min and further details on the methodology of the surveys can be found in Cardador et al. (1997).

Most of fish caught in the Portuguese demersal trawl surveys are distributed in the sub-area 9aCN, particularly near Aveiro - Figueira da Foz and in the Algarve (Fig. 5 and 6). The occurrence of anchovy in sub-area 9a-CS is almost limited to the area around Lisbon, which is a similar trend to that found in the spring acoustic survey series.

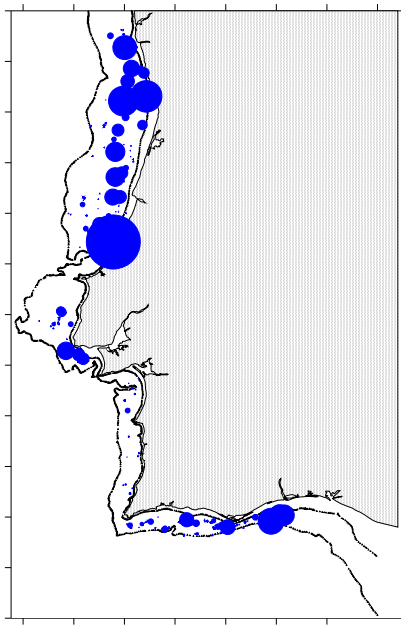

Figure 5. Distribution of the anchovy in demersal research trawl surveys conducted in the Portuguese continental margin since 1990 until 2017 during summer and autumn months. Symbol is proportional to the square root of the catch rate (number of fish caught per hour). Source: IPMA data

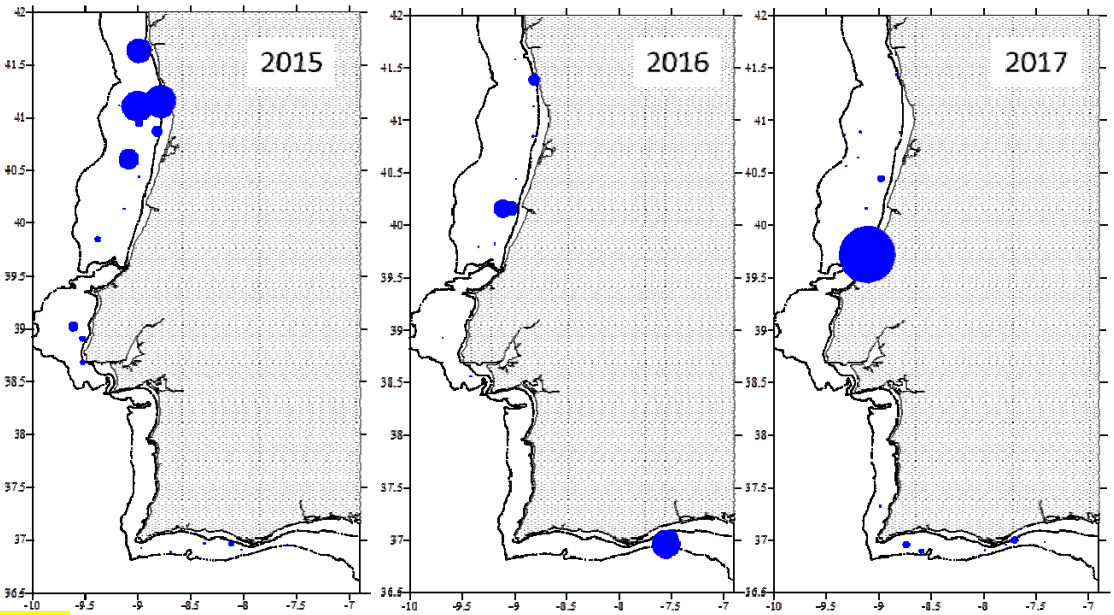

Figure 6. Distribution of the anchovy in demersal research trawl surveys conducted in the Portuguese in 2015, 2016 and 2017 during summer and autumn months. Symbol is proportional to the square root of the catch rate (number of fish caught per hour). Source: IPMA data

3. HISTORIC DYNAMICS OF STOCK BIOMASS SIZE INDICATOR

The series of biomass estimates derived from spring acoustic surveys (PELACUS and PELAGO), and summer acoustic and egg surveys in the GoC (ECOCADIZ and BOCADEVA, respectively), are shown in Fig. 7 and 8.

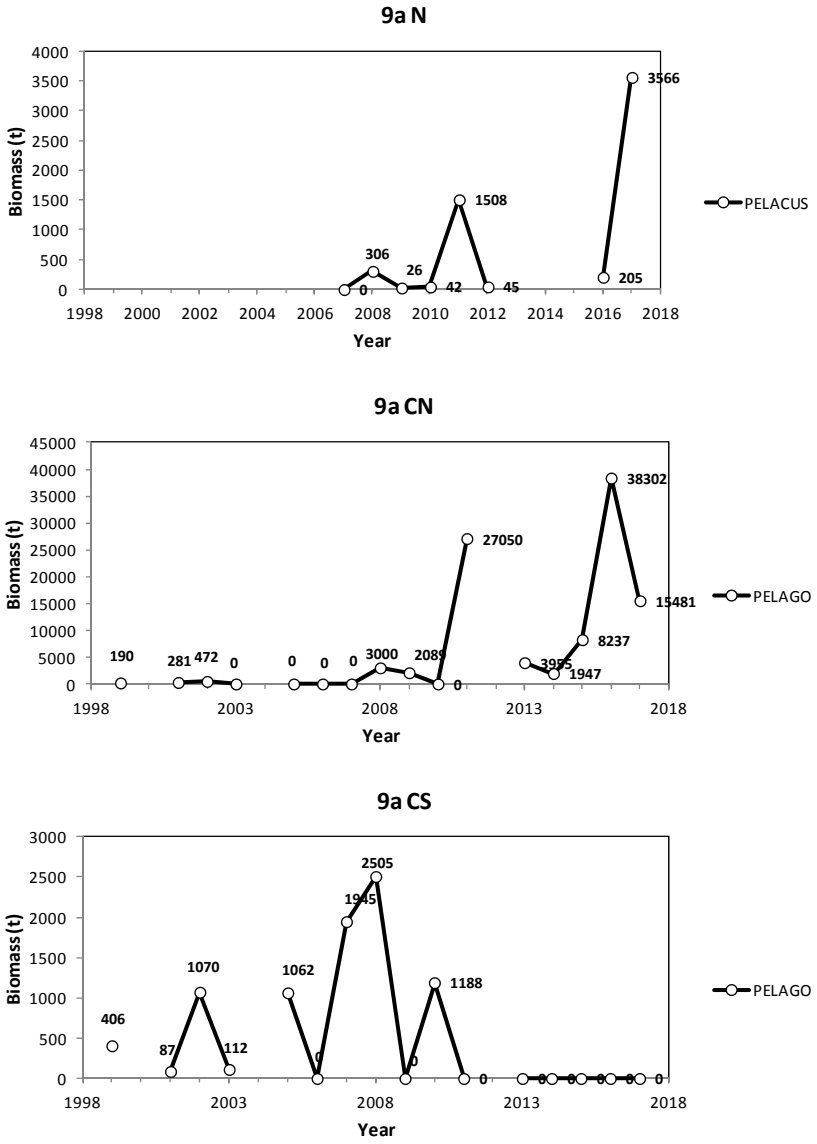

Figure 7. Series of biomass estimates for the western component of the stock or stock unit 9a West from the Spring acoustic surveys series PELACUS (Subdivision 9a N) and PELAGO (Subdivisions 9a CN and 9a CS).

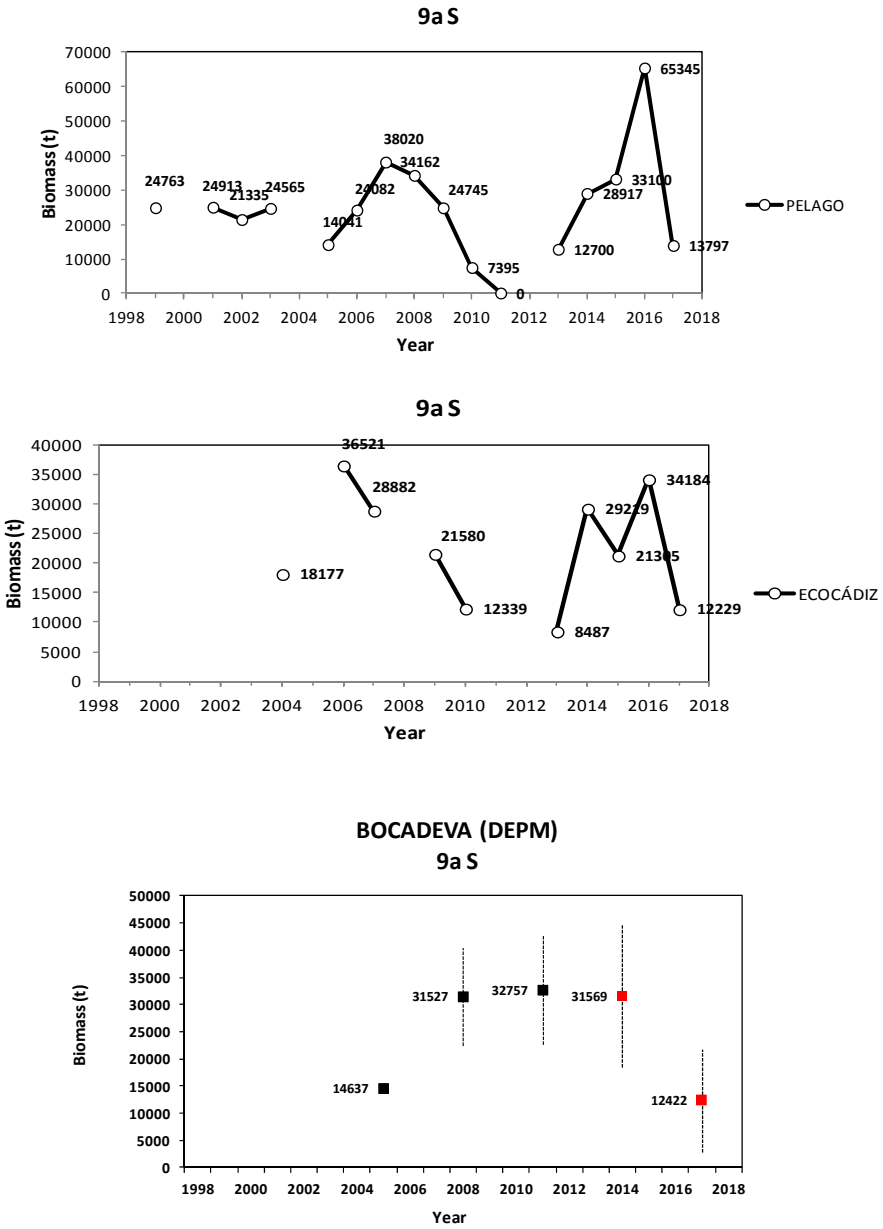

Figure 8. Series of biomass estimates for the southern component of the stock or stock unit 9a South from the spring acoustic surveys series PELAGO and summer acoustic and egg surveys in the GoC, ECOCADIZ and BOCADEVA series, respectively.

The distribution of anchovy biomass between the western and southern components of the 9a stock as shown from the PELACUS and PELAGO survey series (Fig. 9) shows that for the majority of the years, most of the biomass was recorded in the southern component (>80%), except for years of high anchovy biomass in the western coast such as 2011, 2013 and the three last years (2015, 2016, 2017). In fact, 2017 was the first year when the stock abundance was higher in the western component when compared to the southern component.

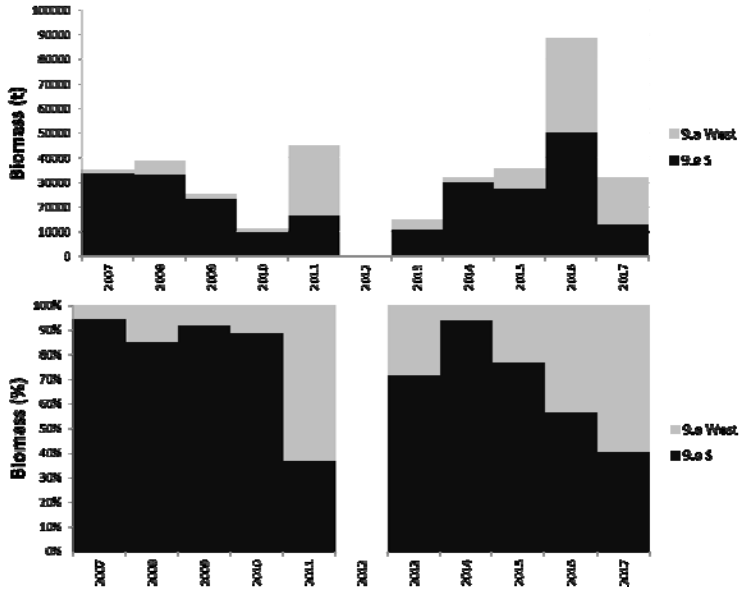

Figure 9. Distribution of anchovy biomass between the western and southern components of the 9a stock. Upper graphs represent total biomass (tons) and lower panel represents proportion between the two components. Note that during 2014 and 2015 there was no estimate for the sub-division 9aN, therefore the biomass and % biomass of the western component shown in the plot is restricted to 9aCN and CS for those years. Source: ICES WGHANSA.

4. HISTORIC DYNAMICS OF LANDINGS

Anchovy in division 9a is mostly harvested by purse-seine fleets (generally 99% of total catches). For the period with complete data for the whole Division (from 1989 to present), landings have ranged between 1,984 t (1993) and 13,740 t (2016) (Fig. 10). Landings have been dominated by those done in the Gulf of Cadiz (sub-division 9a South – Cadiz), which represented >90% of catches in most years, whereas in the remaining area, anchovy is only harvested when its abundance is high. Mean proportion of catches since 1989 have been 84% in the southern coast and 16% in the western coast. As a consequence of the higher abundance in the western Iberia in recent years, catches in that area have been proportionally higher than before, reaching a maximum value of 52% in 2016.

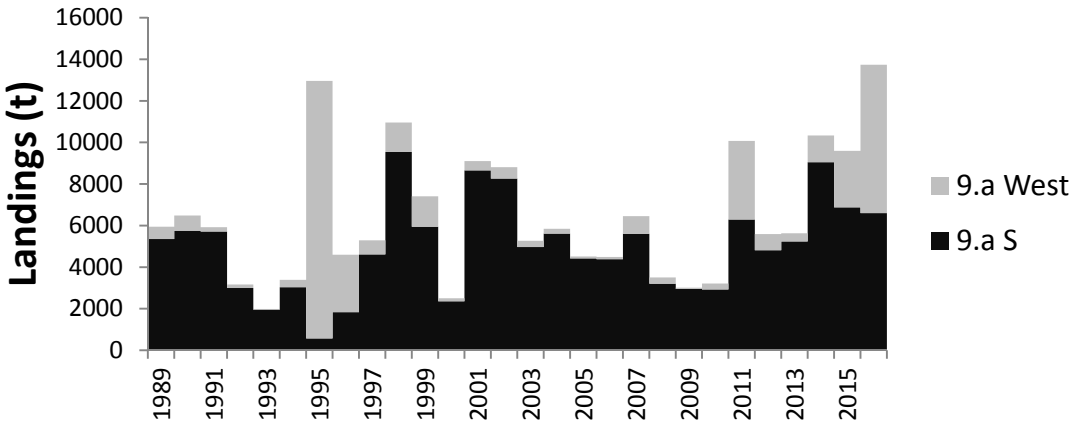

Figure 10. Time series of anchovy landings in Division 9a (1989-2016). Subdivisions are pooled for the western Iberia (ICES Subdivisions 9a North, Central-North and Central-South) and the Gulf of Cadiz (Subdivision 9a South-Alg and 9a South-Cad). Source: ICES WGHANSA.

Correlations analysis between the historical series of catches per Sub-division analysed by Ramos et al. (2001) were updated until present, comparing the western and southern components of the stock. Annual landings per Sub-division (period 1989-2016) were analysed by the spearman correlation test showing no significant correlation between the landings of the two components (correlation =-0.16, 95% confidence interval: -0.50 to 0.21, p=0.39). To test if the fluctuations of catches along the Division were the result of a northward migration (theoretically from Gulf of Cadiz to northern areas), an alternative correlation analysis was carried out. In this second approach, correlations were estimated by comparing catches in the year y from the southern area (Algarve and Gulf of Cadiz) with the ones landed in the year y+1 in the western area (9a-N+9-CN+ 9-CS). No significant correlation (Spearman cor=0.22, 95% confidence interval: -0.55 to 0.17, p=0.26) was found with a one year gap that would be consistent with a northward migration between areas.

On the other hand, the correlation between landings and anchovy abundance in the western coast is highly significant (spearman correlation=0.942, 95% confidence interval: -0.75 to 0.99, p=0.0001).

5. POPULATION DIFFERENCES IN ANCHOVY LIFE HISTORY TRAITS IN DIVISION 9a.

An extensive review of works showing anchovy population asymmetries in division 9a was done by Ramos (2015). In this section, a brief summary of the main results will be presented, as well as new information, and the focus will be given to the differences within the 9a division.

5.1 BIOLOGICAL DATA

Mean length and mean weight of anchovy in spring acoustic surveys is generally lower in the Gulf of Cadiz (Fig. 11) when compared to the other sub-divisions, followed by the 9a-CN sub-division, which may indicate the presence of two different recruitment areas for this species. Mean length in the Algarve (9a_S_alg) and in Galician waters (9a_N) are generally higher. Data of mean length for the 9a_CS sub-division are only available for two years when mean length was also low and comparable to the sub-divisions considered as recruitment areas.

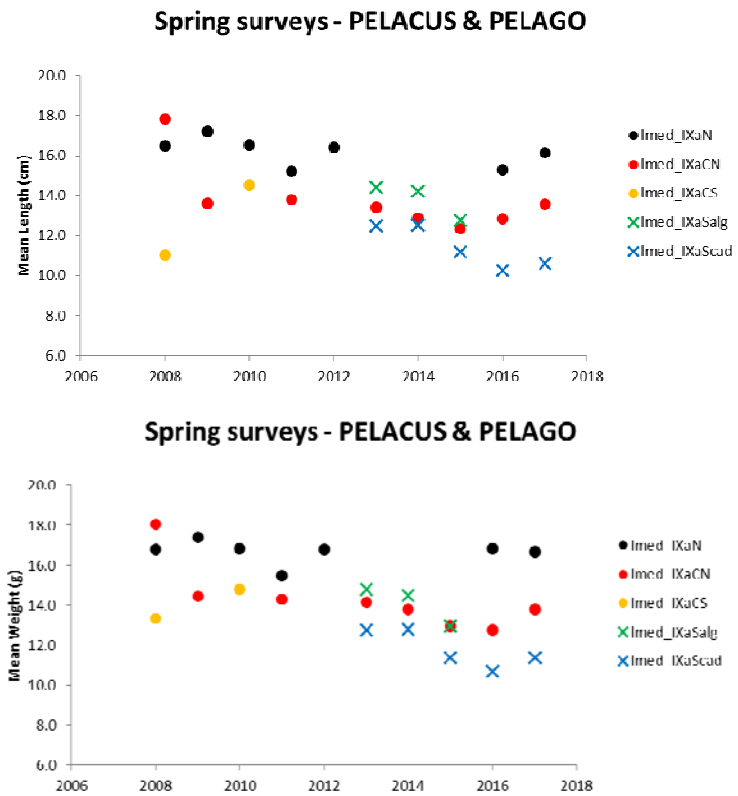

Figure 11. Anchovy mean length (upper panel) and weight (lower panel) estimated for fish captured during the spring acoustic surveys conducted in division 9a (PELACUS and PELAGO) for each sub-division.

There is no available information on mean length and mean weight in catches from the Portuguese fishery, but annual estimates from the Spanish fishery in subdivisions 9a N and 9a S (ES) confirm a lower size and weight of the southern anchovies in comparison with their northern relatives (Fig. 12)

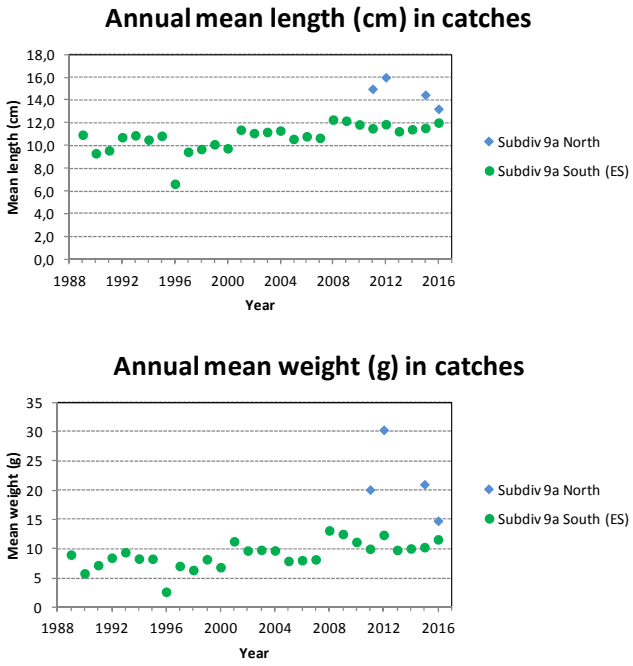

Figure 12. Anchovy mean length (upper panel) and weight (lower panel) in catches from the Spanish fishery in subdivisions 9a N and 9a S.

5.2 SYNOPSIS OF PUBLISHED WORKS ON POPULATION STRUCTURE

Several studies have been conducted on the population structure of the anchovy in Atlantic waters, namely using morphometrics, otolith shape analysis and genetic analysis.

MORPHOMETRICS

Morphometric differentiation between anchovies populations from north of Division 9a (Sub-division 9a North) and populations from the Bay of Biscay were obtained by Junquera and Pérez-Gándaras (1993), also suggesting the existence of an intermediate population in the Cantabrian area (west of the VIIIc). Subsequent studies of morphometrics and genetics have failed to sample fish in the western Cantabrian, which is probably related to the low abundance of the species in this area.

Morphometric analysis conducted in fish collected during 2000 and 2001 from the Bay of Biscay to the Gulf of Cadiz (Caneco et al. 2004) point to a clear separation between anchovies from the Bay of Biscay (ICES Sub-areas VIIIb, VIIIc) and those from Division 9a, as well as a north-south cline along the Portuguese and Gulf of Cadiz area, with fish from the Gulf of Cadiz being mostly different from those in northern 9a area. The group of fish from the Algarve (E) was the one whose separation was less robust, given that the classification by cross-validation attributed most of its fish on western Portuguese coast groups than on itself. Results from this study indicate that fish from the Iberian area (i.e. Division 9a) have larger heads and smaller medium-posterior body dimensions than the ones from Bay of Biscay (Sub-areas VIIIb,c). These differences were more pronounced in the Spanish waters of the Gulf of Cadiz (Sub-division 9a-South (Cadiz). Anchovies from the Spanish waters of the Gulf of Cadiz had the greater head-to-body ratios, having shown the greater divergence from the Biscay populations. The Iberian samples had also greater dorsal fin base lengths.

OTOLITH SHAPE AND GENETIC ANALYSIS

Bacha (2014) showed that the Alborán Sea anchovy population is genetically distinct from the Northeast Atlantic populations, including neighbouring populations (e.g. Gulf of Cadiz). Anchovies were analysed from seven locations in the SW Mediterranean Sea and Atlantic Ocean along the northwestern African (Morocco) and Portuguese (Bay of Cadiz) coasts (Bacha et al. 2014). According to this study, three distinct anchovy stocks were identified: the Algero-Provençal Basin, the southern Alborán Sea, and the Atlantic Ocean (Morocco and Gulf of Cadiz). Shape variability of anchovy otoliths was associated with the presence of the Almeria-Oran front (AOF), and the strait of Gibraltar. The Southern Alborán stock was distinct from the Algero-Provençal Basin and from the closest Atlantic stocks (Gulf of Cadiz or Atlantic coast of Morocco).

The European anchovy exhibits a complex population structure which has produced conflicting results in previous (and recent) genetic studies. Geographic surveys of allozymes, microsatellites, nuclear DNA (nDNA) and mitochondrial DNA (mtDNA) have detected several genetic subdivisions among European anchovy populations. However, these studies have been limited in their power to detect some aspects of population structure by the use of a single or a few molecular markers, or by limited geographic sampling (Zarraonaindia et al., 2012 and references therein).

Zarraonaindia et al. (2012) used a multi-marker approach, 47 nDNA and 15 mtDNA single nucleotide polymorphisms (SNPs), analysing anchovies from the whole range of the species distribution. This is the only work which analyses samples from all the different Sub-divisions of Division 9a except from the Algarve (9a S). Nuclear DNA analysis distinguished two groups;

one from North Europe, Bay of Biscay and the Mediterranean Sea and the other including fish from the Atlanto-Iberian waters (9a) and the Alboran Sea. On the other hand, mitochondrial DNA analysis revealed differences between anchovies from the western Iberia (9a N, CN,CS) and those from the Gulf of Cadiz.

Different genetic markers studies (nuclear-DNA, multiple SNP Markers, or allozymes) showed that the anchovy in the Alborán Sea are closely related to populations in the adjacent Gulf of Cadiz (Sanz *et al*., 2008; Zarraonaindia *et al*., 2012, Silva et al. 2014) or Canary archipelago (Bouchenak-Khelladi *et al*., 2008; for samples from Southern Alborán), contradicting studies of otolith shape analysis. Zarraonaindia et al. (2012) and Sanz et al., (2008) showed that anchovies in the Alborán Sea are more closely related to populations in the adjacent Gulf of Cadiz than to what other Mediterranean populations, suggesting that these two stocks represent a meaningful management unit that should be dealt as a single stock. On the other hand, Viñas et al. (2014) indicates that Gulf of Cadiz and Alborán Sea anchovy populations are genetic units clearly separated. Therefore, the stock identity of these two populations is still unclear.

6. Conclusions

Data of the spatial distribution of anchovy in division 9a has clearly shown a discontinuity of the western and south components of the stock, in several life stages (eggs, juveniles and adults) and seasons of the year when research cruises cover the whole 9a subdivision (spring, fall) or the entire Portuguese waters (summer).

No correlation was found between anchovy catches between the two areas, suggesting independent dynamics. The hypothesis that the western stock might come from migration from the southern component was not supported by the current data, since there was no correlation between anchovy landings in the western Iberia with anchovy abundance in the southern Iberia in the following year. On the contrary, anchovy landings in the western coast were significantly related to the abundance of the species in that area, demonstrating the independent dynamics of anchovy fishery from the two components.

The spatial disconnection and the independent dynamics between the western and southern anchovy populations are likely related to the presence of a self-sustained anchovy population in the western Iberia, independent of the southern component.

Morphometric and genetic studies indicate a separation of the Gulf of Cadiz anchovy population from that in the western Iberia (although results from the Algarve are generally absent), while the separation of the population from the Gulf of Cadiz and the Alborán Sea (Spanish SW Mediterranean) is still unclear.

From these reasons, the WGHANSA suggestion is to provide separate advice for the population in Subdivision 9a South and the populations from sub-divisions in the western coast (9a North, Central-North and Central-South), as shown in the WD included in the Benchmark and describing the Short- and mid-term goals that will be pursued in the assessment of the stock.

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