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Contents

1 Introduction and Executive summary

The Workshop on Atlantic Sardine (WKSAR), chaired by Alexandra Silva (Portugal) and Lionel Pawlowski (France), met in Lisbon, 26–30 September to (i) review information on stock identification, connectivity and migrations of sardine within European Atlantic waters (Area 7 to Subdivision 9.a)and, (ii) collate, standardize and analyse survey, fishery and biological data collected in the region, (iii) propose scenarios of stock structure and dynamics and (iv) methods/models for stock assessment (ToRs, Annex 5).

There were 18 participants from the UK, France, Portugal and Spain, including one representative from PONG-PESCA (NGO, Portugal) and two chair-invited experts on genetics (Annex 1). A WebEx meeting was organized with stakeholders to facilitate their effective involvement in the benchmark process, clarifying what their role is, and to promote their contribution. To that purpose a questionnaire was written, translated into French, Spanish and Portuguese, and sent to stakeholders with questions regarding their perception of the various aspects of the Northern and Southern stocks, the fisheries, the monitoring and their management (Annex 2).

Information on stock identification, connectivity and migrations has been compiled in Section 3 to be reviewed by SIMWG.

The group agreed to set the deadline to compile final datasets (all) at 5th December in order for people to start running assessment in preparation for the ICES benchmark meeting in February 2017.

2 Current definition of sardine stocks in ICES Division 7, 8 and 9

Sardine is distributed in the Northeast Atlantic Ocean and Mediterranean Sea. In the Atlantic, sardine extends along the continental shelf from the Celtic Sea and the North Sea to Senegal, with residual populations off the Azores, Madeira, and the Canary Islands (Parrish *et al.*, 1989) (Figure 2.1).

Figure 2.1. Geographical distribution of European sardine.

Two stocks are considered in EU Atlantic waters: Northern stock (ICES Subareas 7 and 8.a,b,d) fished mainly by France and Spain, and Southern stock (ICES Subarea 8.c and Division 9.a) fished by Spain and Portugal (Figure 2.2).

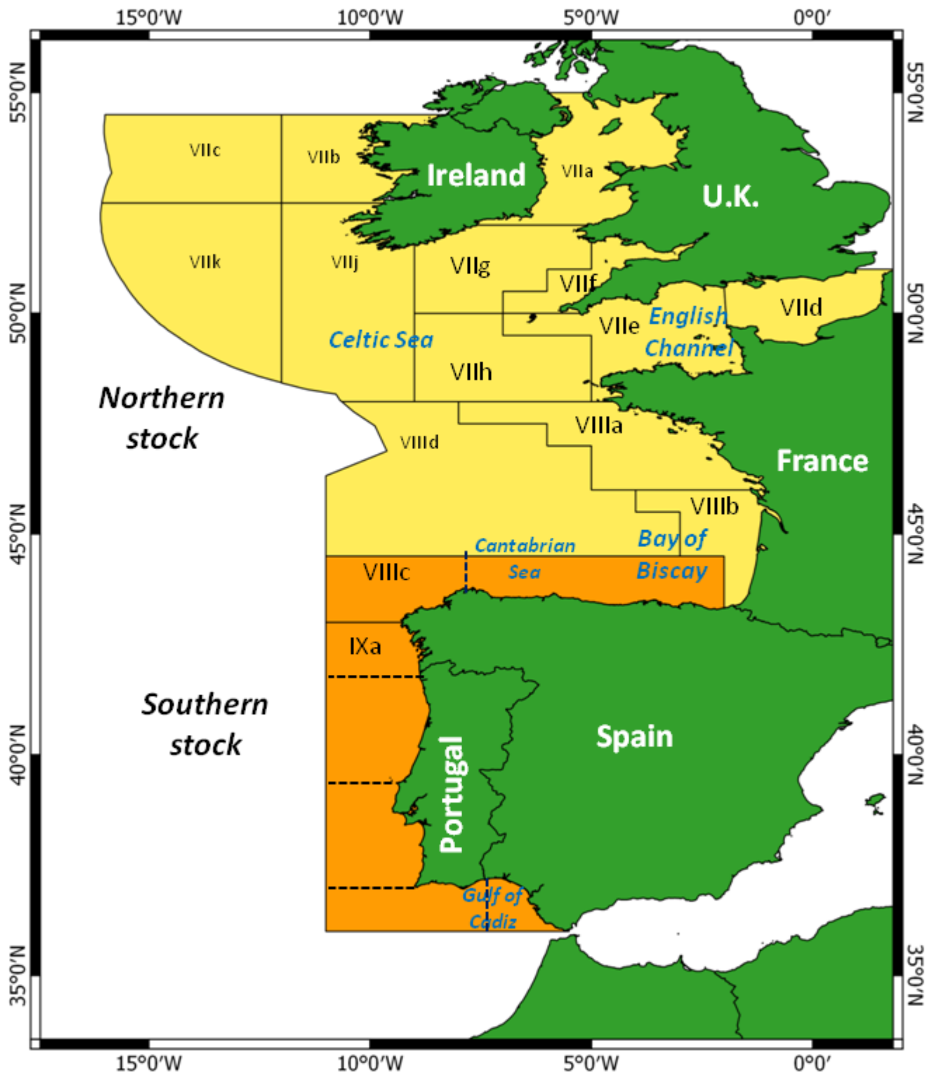


Figure 2.2. Delimitation of the Northern and Southern sardine stocks.

3 Review of the available information on sardine stock identification, connectivity and migrations

3.1 Presentations

3.1.1 Update of stock structure from SARDYN project based on literature review (Presentation 21)

The SARDYN project (2002–2006) aimed to describe sardine stock structure in the Northeast Atlantic and Mediterranean Sea using a holistic approach that integrates genetic, morphometric and otolith microchemistry studies (Anon., 2006). Together with knowledge of spawning and nursery grounds and geographic variation of biological traits, the results from stock-structure studies were interpreted in the context of oceanographic features and processes which could favour or else restrict mixing among populations.

3.1.1.1 Genetic studies conducted within SARDYN and afterwards were reviewed in Kasapidis (2014)

The main conclusions indicate:

- studies using different molecular markers are not fully consistent; earlier studies using allozymes and studies using mtDNA indicated a higher degree of differentiation than recent studies using allozymes and studies using microsatellite DNA;
- in general, no genetic structure is evident in most of the distribution range for neutral markers;
- several studies point to a pattern of isolation by distance i.e. genetic differentiation among individuals increases as geographical distance increases;
- certain loci (allozymic and microsatellite; possibly under selection), exhibit abrupt changes in allele frequency related to oceanographic features (fronts and filaments) which appear to constitute barriers to gene flow.

Areas of discontinuity were used as guidelines to define and delineate four genetic stocks (genetically differentiated populations), i.e. units that are more or less reproductively isolated from each other, and thus may react independently to exploitation) (Kasapidis, 2014; Kasapidis *et al.*, 2012):

1) an African stock (south of 30ºN);
2) a Northeastern Atlantic stock (north of 30ºN to the North Sea and the Alboran Sea);
3) a Mediterranean stock (east of Almeria-Oran front); and
4) Azores and Madeira stock, which may actually consists of two different stocks.

The genetic stocks identified above are generally consistent with areas of phenotypic change in sardine, but they are not in concordance with morphological subspecies recognized by some authors: *Sardina pilchardus*, distributed in European Atlantic waters until the Gibraltar Straight and *Sardina pilchardus sardina* distributed in the Mediterranean Sea and Northwest African Atlantic waters.

The WG noted that possible genetic boundaries are outside the current boundaries of European Atlantic sardine stocks.

3.1.1.2 Body and otolith morphometry

The analysis of body morphometric variation among sardine populations from the Northeastern Atlantic (Brittany to Casablanca) and the western Mediterranean (Alboran Sea and Gulf of Lyons) carried out within SARDYN indicated (Silva, 2003):

- existence of two sardine morphotypes, one distributed in southern Iberia and northern Morocco and the other distributed across the remaining Atlantic areas and in the Mediterranean Sea;
- the two morphotypes are distinguished by head size, eye diameter and head-to-body ratio; these dimensions are larger in sardine from southern Iberia and northern Morocco;
- a shallower differentiation between sardine from the northern Atlantic and from the Mediterranean Sea, mainly on the basis of the position of the dorsal fin.

A subsequent study with additional samples (2003–2004) spanning the Atlantic area from the North Sea and English Channel to Mauritania and the western Mediterranean Sea (Silva *et al*., 2012) indicated:

- clear segregation of sardine from Mauritania mainly due to the combination of a larger head and smaller eyes;
- a shallow segregation of sardine from the North Sea due to smaller eyes than expected for Northeast Atlantic areas;
- differentiation between Atlantic and Mediterranean sardine at the Gibraltar Strait;
- no significant differentiation of the remaining Northeast Atlantic areas, clinal variation in body shape (north–south increase in head dimensions and anterior-ward shift in the insertion of dorsal fin) and two broad groups with extensive overlap; a northern group, from the English Channel to southern Galicia and a southern group from northern Portugal to northern Morocco.

Morphometric data support the current southern limit of the Iberian stock at Gibraltar Strait, points to the continuity between Iberian and northern Morocco and suggests some differentiation of North Sea sardine. The existence of a morphometric break in the southwestern corner of the Iberian Peninsula shown in the analysis of 2000 data (Silva, 2003) was not corroborated in the subsequent study that analysed 2003 samples (Silva *et al*., 2012); the latter instead suggested some differentiation between sardine distributed north and south of Cape Finisterra (across the northwestern corner of the Iberian Peninsula). The reasons for this discrepancy were not fully explored but revealed that morphometric population structure may change over time.

Jemaa *et al*. (2015) combined shape indices and elliptic Fourier descriptors to investigate the geographic variability of sardine otolith shape using samples collected in 15 locations in the Northeast Atlantic, from the English Channel to north Morocco, and across the Mediterranean Sea. The results indicate three distinct groups of sardine: one group distributed in the northern Mediterranean Sea and Gulf of Gabès, another group distributed from the northern Atlantic Morocco to south Alboran–Algero-provençal coasts and the third groups distributed in the European Atlantic coast. The groups are broadly consistent with the hypothesis of two subspecies of sardine mentioned before; moreover, they disagree with the hypothesis of a break between Mediterranean and Atlantic populations of sardine. The jackknife classification matrix of a discriminant analysis between sampling areas showed reasonable percentages of classification for Atlantic areas (>=60%) apart from the Gulf of Cadiz and Casablanca samples, which were misclassified almost evenly in several areas off the southern Mediterranean Sea. Interestingly, as suggested by genetic and body morphometry, sardine from the English Channel showed some similarity with sardine from the Gulf of Lyon in the Mediterranean.

3.1.1.3 Otolith microchemistry

The chemical elemental composition of sardine otoliths was investigated by Castro (2007) using samples collected under SARDYN from the inner Bay of Biscay, northern Portugal and the Gulf of Cadiz. Individuals from each area were grouped into three size classes, ≤15 cm (small), 16–18 cm (medium) and ≥21cm (large). Differences in otolith composition between areas decreased with size, i.e. differences were smaller for big sardines (≥21 cm) than for smaller fish (up to 18 cm). Nevertheless, the percentage of correct sample classification by area was still high for >21 cm individuals (>70%) except for the Gulf of Cadiz. In addition, differences in otolith composition between size classes were larger for the Bay of Biscay and Gulf of Cadiz than for northern Portugal. The author conclude that a migratory pattern where net balance movement for big sardines is from northern Portugal to the other two areas could explain these results.

The WG notes that samples used by Castro (2007) pool individuals from different years and cohorts. Other studies, such as the one described below, suggest there may be temporal and year-class effects on otolith microchemistry.

In a study carried out after SARDYN, Correia *et al*. (2014) studied the elemental composition of sardine otoliths along the Portuguese waters and Gulf of Cadiz and focused on the dispersal of a strong cohort (2004) recruited mainly off northern Portugal. Cohort dispersal was investigated comparing the elemental composition of the otolith core of recruits sampled at recruitment areas (in 2004, at age 0 or early age 1) with that of 3-year old individuals (adults) of the same cohort sampled in 2007 at various places. Laser-ablation ICPMS was the technique used to analyse the otolith core area. The integrated composition of adult otoliths (3 years-old) was analysed by Solution-Based ICPMS.

The results indicated that the northern recruitment area supplied over 80% of the adults of the 2004 cohort collected in the Portuguese-Cadiz waters (i.e. collected as age 3+ in 2007) and suggested this cohort experienced a broad geographical expansion. Intra-cohort differences in otolith elemental composition were observed possibly associated with individuals being born at different times of the year throughout the extended spawning season. On the other hand, the core and whole otolith of adults showed moderate and strong differentiation, respectively. The authors conclude that while adult life stages may be derived from common juvenile nursery area(s) they seem to form regionally distinct adult populations with limited mixing.

The WG notes that samples from the northern areas of the stock, to where recruits could also disperse, were not included in the above study. The influence of intra-cohort variability of otolith composition in regional differentiation deserves further investigation.

3.1.2 Connectivity through eggs, larvae, adults: clues from oceanographic features (Presentation 14)

To date, the most comprehensive description of the main oceanographic features in the area of distribution of sardine is the work by Mason *et al*. (2005). Other studies provide detailed knowledge of the temporal and/or spatial variability of the oceanographic conditions of particular areas that are important to sardine populations. Few recent studies have used modelling approaches to study the dispersal and survival of sardine larvae (Oliveira and Stratoudakis, 2008; Garcia-Garcia *et al*., 2016), with promising results.

Over the Atlantic distribution of sardines, three areas are identified in terms of prevailing winds; 1) windstress is predominantly equatorward and upwelling-favourable over the subtropical African coasts, 2) off the Iberian Peninsula this equatorward wind-forcing reverses seasonally to become poleward in autumn and winter and 3) further to the north the windstress is stronger, prevails for most of the year and has a more westerly component. Main large-scale currents are North Atlantic Current (NAC, north of the Iberia), the Azores Current (AC, south of the Iberia) and the Canary Current (CaC). Two major oceanic water masses are found in this area: North Atlantic Central Water (NACW, salty) and South Central Atlantic Water (SACW, nutrient-rich, African upwelling). Local Currents such as the poleward flows (e.g. Iberian Poleward Current, IPC) are below the depths (<50 m) at which the early life stages of pelagic fish generally occur and will, therefore, have little direct effect on structuring the population. However, this influence must be clarified, as Garcia-Garcia (2016) modelling exercise in Northwestern Iberia found a relationship between the intensity of the IPC and the faster growth of sardine larvae.

The relationship between Oceanography and Dispersal/Connectivity should be studied in relation to the ontogeny of the fish. Four stages can be considered during the life of sardines with respect to the influence of oceanographic features on dispersal and connectivity, related to the ontogeny of the fish:

1) **Eggs and early larvae** have no migration abilities and therefore the main factor determining their retention or dispersal are the oceanographic features at the location at which the eggs are spawned. This, coupled with intrinsic (e.g. egg quality) and extrinsic (e.g. predation) factors will determine the potential survival at this stage. In all the distributional range of sardines, production is discontinuous (to a lesser extent off Africa at the permanent upwelling system). Given that eggs and larvae are carried passively, the success of reproduction is, to a great extent, dependent of how stable and productive is the nursery ground chosen by adult sardines. Spawning sites of sardine populations will depend, upon other factors, of the population size. High density populations will occupy a broader area that will promote connectivity namely through higher dispersal of the early life stages.

   Buoyancy-driven coastal currents are generated by less saline waters from rivers, and when combined to relatively large costal currents, remain trapped to the coast and flow poleward due to geostrophic forces. These can be an important mechanism for egg and larval dispersal to other areas. Santos *et al.* (2004) demonstrated a retention mechanism for sardine larvae produced by the interaction of a strong winter upwelling event, the IPC and the buoyant (Western Iberian Buoyant Plume, WIBP) river plume off western Iberia in February 2000. The WIBP is a particularly important feature owing to the maximum regional rainfalls that characterize winter months.

2) **Larvae after the flexion of the notochord** (ca. 20 dph) start to have limited locomotory abilities (Silva *et al.*, 2014). They perform vertical migrations (Santos *et al.*, 2004) and can resist moderate currents for limited periods of time (Silva *et al.*, 2014; Garrido *et al.*, 2016). It is likely that they remain, however, in retention nutrient-rich areas, as growth at this stage implies high energy demands and consequently the need for high food availability.

3) **Juveniles** have migration abilities but are still very vulnerable to predators when compared to adults and depend upon high concentrations of food to grow. Preferred recruitment areas are known for the species. Tolerance for higher temperatures increases with ontogeny since eggs and early larvae will perish in temperatures that are suitable for juvenile and adult fish (Garrido *et al.*, 2016). Migration to areas with higher temperatures would be beneficial for juveniles that would grow faster but their needs for food availability would also increase.

4) **Adults** have migration abilities but their movements are most likely influenced by prevailing currents and fronts. Currents and fronts are considered **barriers** for adult fish, despite their locomotory abilities because water is a fluid environment that is much more resistant to movement than the air, and has much less oxygen. Generally, fish horizontal migration, when occurring, is annual and separates the spawning and feeding seasons. In the Adriatic, sardines are described to migrate at the end of the spawning season from the spawning grounds to shallower, high productive regions (Škrivanić and Zavodnik, 1973). There is no evidence that such migration of adult sardines during the resting season (May to October) for Atlantic populations. However, food concentrations at the main recruitment areas off the Iberia are generally higher than off the Mediterranean Sea, so the need to migrate to find suitable food concentrations is potentially lower. The most important prey for sardine larvae are very similar to those of the adults (Garrido and van der Lingen, 2014), which means that preferred feeding grounds can match those of the spawning grounds.

In Conclusion:

- Several studies describe large- and small-scale oceanographic features of the region (both spatial and temporal variability) and the knowledge of the oceanographic processes occurring at Iberian waters are now properly described in 3D hydrodynamic models (e.g. ROMS).
- Recent studies have provided a large number of vital rates of sardine eggs and larvae in relation to prevailing water temperature and food availability conditions. These can be used as species-specific parameters of individual based models.
- However, studies addressing the influence of the major oceanographic features on sardine ELS dispersal and connectivity are missing. The study by Garcia-Garcia *et al.*, 2016 mainly focuses on the temporal variability of sardine recruitment but shows some results on larval connectivity; models of the type used in this study would be very useful to fill this knowledge gap.
- In order to understand the potential dispersal and migration of juveniles and adults, other methodologies should be adopted, such as following strong cohorts and using stable isotopic composition analysis.

3.1.3 Temperature and food-mediated variability of sardine recruitment (Presentation 9)

The influence of the environmental conditions during larval development on the resulting recruitment strength was investigated for European sardine (*Sardina pilchardus*) at Atlanto-Iberian waters (WK Presentation of Garrido *et al.*, 2016). Satellite-derived Sea Surface Temperature (SST) and Chlorophyll-a concentration (Chl-a) data from the previous spawning seasons (January to March and October to December of the previous year) were related to recruitment success data in the main recruitment hot spots taken from yearly acoustic scientific cruises and from the ICES recruitment index estimated by an age-structured model for the entire stock. Mean SST and Chla, as well as the abundance of spawners during the spawning season, were able to identify years of high and low recruitment for all the recruitment hot spots with an accuracy of ≥79% using linear discriminant analysis. In general, high recruitment years were associated to high food availability and to low SST, although there were differences of the most important variables according to the areas under study. High recruitment years in the West coast and in the Gulf of Cadiz were mostly related to high food availability (Chla), particularly during the last quarter of the previous year. In the Bay of Biscay, Chla was also important to separate years of high and low recruitment but higher temperatures were associated to higher recruitment strength given that mean SST was below the optimal range (≈11–12ºC) for sardine larval development. In the case of ICES data of the southern stock, lower SST and higher Chla during the last quarter of the previous year were associated to high recruitment years and temperature alone was able to discriminate between the two recruitment groups with 73% accuracy. Although the time-series of available data are still small, these significant relationships confirm what was observed in field and laboratory studies regarding the environmental drivers of larval growth and mortality. These relationships should be further investigated in the following years to evaluate if they can be used to construct reliable indicators to predict the level of recruitment and abundance with sufficient advance to help in the management of this important fishing resource.

3.1.4 Microchemistry of otolith and calorimetry in Biscay and Channel (Presentations 4 and 15)

The microchemistry study of sardine and anchovy otoliths from the Bay of Biscay carried out in the last three years by Ifremer using models and otoliths microchemistry, the main objectives were:

- Identify Essential habitats and migrations diagrams / connectivity
- Compare strategies of life history.

Samples were collected during the PELGAS13 survey on board Thalassa, in five particular stations to "maximise" coastal/offshore and North/South gradients, in a selection of 3-year old fish, for more "life history".

Microchemistry on different elements was studied (Sr, Ba, Mn, Mg and Li) with continuous laser transects from the nucleus to the edge of the otolith.

A method of classification was developed, which allows to group individuals with similar patterns, but the whole signal not easy to use. Elements are not really discriminant and heavy metals (Cd, Cu, Pb) were tested but nothing was really conclusive.

A biological comparison between Bay of Biscay and English Channel sardines is conducted by Ifremer, with the help of calorimetry. Samples come from three surveys (Figure 3.1.4):

- PELGAS (Bay of Biscay, spring) : white;
- CGFS (Channel, September/October): grey;
- IBTS (BoB, October): dark.

Globally, the growth (in length, and in weight as well seems to be much more important in the Channel. Calorymetry shows the same thing, with an energy density really high for sardine coming from the CGFS survey, in the Channel.

This work is still preliminary, more samples will be included in the near future (particularly 2015 samples).

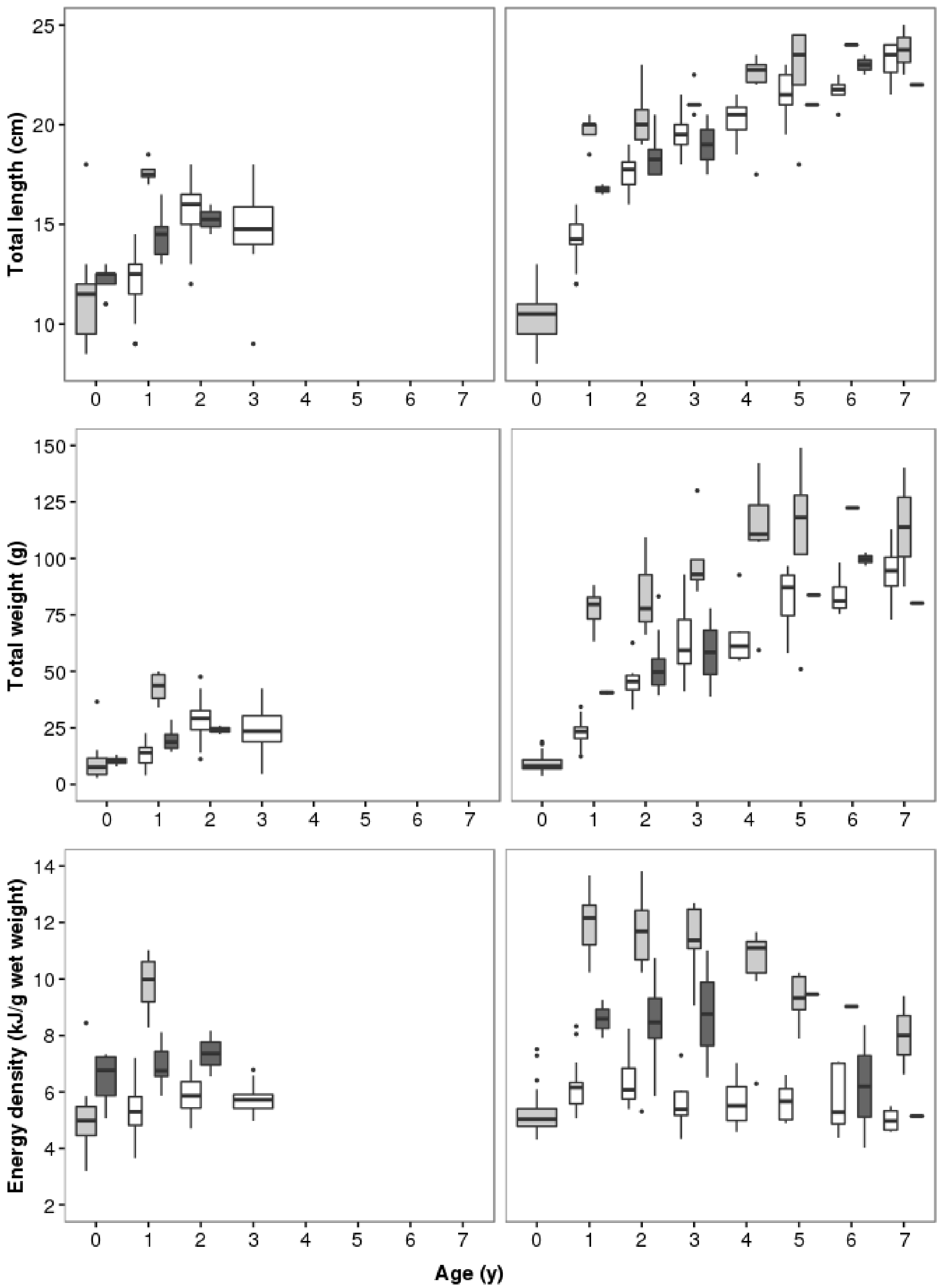


Figure 3.1.4. Biological comparison of Bay of Biscay and Channel sardines, in spring and autumn. Bay of Biscay, spring: white; CGFS (Channel, September/October): grey; IBTS (BoB, October): dark.

3.1.5 Demographic connectivity of sardine populations (Presentation 6)

Earlier studies suggest that sardine has multiple regional populations connected by dispersal/advection of early life stages and migration/straying of juveniles and adults (Garcia-García *et al.*, 2016; ICES, 2016-Sardine stock annex and references therein). Core regional populations of sardine appear to be linked to three hot spots of recruitment located in high productivity retention areas: northern and central Bay of Biscay, northwest Iberia and Gulf of Cadiz. Areas in-between, typically with lower abundance and predominance of older individuals, southern Portugal and northern Spain (Cantabrian Sea and North Galicia), appear to be sustained by straying from core areas.

In the past 15 years, the Bay of Biscay population showed several strong recruitments whereas the population off northwest Iberia decreased severely due to prolonged low recruitment. The results of an ongoing study of temporal and regional distribution of sardine cohorts suggest that cohorts appearing in northern Spain have stronger connectivity with those recruited off Northwest Iberia (south) than with those recruited in the Bay of Biscay (north) (Silva *et al.*, 2016 WK presentation). Despite the large abundance of recruits in the Bay of Biscay in some recent years (2008, 2012) the data do not suggest massive straying of sardine cohorts towards the south, i.e. to the Cantabrian Sea or south of it. Given the proximity, straying into the Cantabrian Sea would be more plausible from Biscay than from the western areas. However, if influx into the Cantabrian Sea depends mainly on sardine density in "source" areas it seems more likely from the western areas, where density is one order of magnitude larger than in the Bay of Biscay. Environmental factors may also play a role in straying intensity and are being investigated.

The above analysis used data from spring acoustic surveys (carried out between March and May each year) and assumes national survey series (PELGAS, PELACUS and PELAGO) have similar catchability, overall and at-age. It is known that catches of 0-group and 1-year old sardine prior to the spring surveys may not be negligible. The WG discussed the possible impact of catches prior to spring surveys on the perception of recruitment strength, variability and connectivity between areas. This possibility was explored after WKSAR by back-calculating 0-group abundance from age 1 abundance observed in each area in spring surveys (applying Pope's approximation, with catches-at-age 0 and first quarter age 1 and assuming M-at-age to be equal to that in the assessment of the Iberian sardine in all areas). The results suggest that age 1 abundance in surveys may underestimate recruitment for some cohorts and areas (see slides added to presentation) but it doesn't change the overall trends in recruitment. Underestimation is more noticeable in North Galicia, where age 1 is often missing in surveys, and Cantabria. In these areas, local recruitment may be slightly higher than indicated by spring surveys or alternatively, part of 0-group catches may be taken in neighbour recruitment areas, or both.

The WG discussed also the hypothesis that young sardines are less accessible to surveys than to the fishery off northern Spain (due to difficulty to sample nearshore areas <30 m depth in surveys where smaller fish concentrate). This could possibly explain the low abundance of age 1 in surveys but not the low abundance of ages 2 and 3 compared to older fish (year-class curves in these areas are dome-shaped with a maximum at-age 3 or 4) since sardines with two years and older have similar size.

In conclusion, the WG considers the overall perception of interannual variation and trends in recruitment given by surveys is not affected by 0-group catches or low accessibility of small fish to surveys.

3.1.6 Update on genetic study

The announcement of the sardine (*Sardina pilchardus pilchardus*) genome project start was made. Besides the fundamental biological interest, the rationale and usefulness for the scientific community was discussed by the WG. The genome is the scaffold for high throughput genetic methodologies, resulting in large-scale and high resolution genetic studies capable of identifying the structure of genetic subpopulations and respective dynamics. The major deliverable will be the development of a high throughput genetic screening for long-term monitoring that is economically viable. Additionally to the population genomics results other long-term goal is the ability to quantitatively dissect the weight of genetic and environmental effects in the phenotypic traits.

Summary of the discussions

ToR 1) Review information on sardine stock identification, connectivity and migrations within European Atlantic waters (Area 7 to Subdivision 9.a)

Has the perception of the boundary between the current north and south stocks changed?

No. There is no evidence of strong demographic connectivity between the two stocks. There is evidence of some mixing which does not appear to affect the main dynamics of each stock.

The data on cohort dynamics in recent years do not indicate massive straying of cohorts from the Bay of Biscay to the Cantabrian Sea (or south of it) (Section 3.1.5). Furthermore, the recent review of growth by regions suggest some heterogeneity among the northern regions, with larger homogeneity in the periods 2000–2010 than in the years 2011–2016, whereby in Biscay smaller sardine mean growth than in the Cantabrian regions are seen (although both areas have shown a decreasing trend in recent years) (Section 4.1.1).

The continuity of the spawning area, overlap in spawning seasons, similarity of genetic, morphometric and life-history properties (growth and maturation) studied in SARDYN support mixing between the stocks (Anon., 2006). Trial area-based assessments with different models (Bayesian state-space model and AMCI) indicated that migrations, most likely involving a net immigration from Biscay to Cantabria, were plausible.

Further work after SARDYN with the Bayesian state–space model estimated likely emigration from south Biscay (8.b) to east Cantabria (8.c-east) for 1-year-olds and also estimated likely immigration (at a smaller rate) into east Cantabria for 2+ adults (ICES, 2006). However, the total-stock biomass in Iberia resulting from immigration from Biscay was estimated to be low (1–4%). The effect of this immigration was much greater if only the east Cantabria area was considered (19% of the biomass could come from Biscay).

Is there evidence of connectivity between Biscay and Channel/Celtic Sea?

The English Channel sardine is not simply an immigrant component of the Biscay sardine.

The recent PELTIC surveys (abundance of eggs, larvae, recruits and adults in the Channel) and results from the calorimetry/growth analysis suggest that Channel/Celtic Sea can be a self-sustained population.

There is no information on connectivity between the Bay of Biscay and English Channel/Celtic Sea. Bordering catches in 7 (statistical rectangles 25E4, 25E5) to the Bay of

Biscay are generally considered to be taken from sardine populations in the Bay of Biscay. At this point, it is unknown if mixing occurs between Bay of Biscay and English Channel populations.

Is there evidence of connectivity between Cantabrian/North Galicia and western Portugal?

Yes. Both at the larval and adult stages. Marked geographical differences in adult growth patterns places south Galicia in an intermediate region between the high growth levels (in mean sizes) of sardine in the northern regions (North Galicia and Cantabria) and the smaller growth levels observed in the western Portuguese areas.

Using a biophysical model for simulating early life stages of sardine, Garcia-Garcia *et al*. (2016) observed an alongshore transport of larvae spawned in Portugal to the Cantabrian sea and vice-versa. They argue that the transport from Cantabria to north Portugal may be more important as a connectivity process because while larvae transported to the Cantabrian Sea end up in a cold area with limited food, sometimes larvae transported to the northern Portuguese shelf from the Cantabrian Sea end up in a favourable environment.

Data on otolith microchemistry and cohort dynamics (Sections 3.1.1.3 and 3.1.5) support the hypothesis that sardine cohorts stray from western Iberian to North Galicia and the Cantabrian Sea during their first 2–3 years of life. The hypothesis is based on following strong cohorts however, if recruitment levels are generally low in Northern Spain, the pattern may apply to all cohorts.

Growth patterns suggest some partially independent dynamics between the northern areas and the western areas (Section 4.1.1). But higher lengths-at-age in northern areas might also suggest straying of larger fish to the north.

Is there evidence of connectivity between the south Iberian Peninsula and the west Iberian Peninsula?

Some.

Otolith chemistry suggested that a strong cohort (2004) dispersed from northwest Portugal and made up the bulk of the adults of that cohort in the southern areas (Section 3.1.1.3).

However, sardine body and otolith shape, life-history properties and cohort dynamics, all point to some differentiation between the western and the southern areas, mainly with respect to the Gulf of Cadiz (Sections 3.1.1.2 and 4.1.1). In terms of otolith shape, growth and maturation sardine distributed in the Gulf of Cadiz appear to be closer to sardine in southwestern Mediterranean than to those in western Portugal.

In summary

- No definite evidence to support change of current stock boundaries but locally there are signs of regional substructure and potentially different population dynamics.
- Areas in the limits, Gulf of Cadiz and Channel/North Sea, show differentiation in some approaches (Gulf of Cadiz: otolith shape, morphometrics, recruitment dynamics / English Channel: otolith shape, growth) but further information from the area (in the case of Channel/Celtic Sea/ North Sea) or from adjacent areas (Southwestern Mediterranean and northern Morocco) is needed.

- Recruitment synchrony/asynchrony and life-history traits show strong variability between areas that needs to be taken into account when sampling, weighting of biological data that goes into stock assessment and stock assessment modelling.

4 Review of information and data regarding survey, fishery and biological data

4.1 Presentations

4.1.1 Growth by area (Presentations 10 and 11 and WD 3)

In a former study Silva *et al*. (2008), covering data up to 2005, pointed out that higher growth (larger lengths-at-age) occurred typically in the northern Iberia and Biscay waters; whilst smaller lengths-at-age, occurred typically off western Portuguese waters and Cadiz showed the smallest mean length-at-age (except for age 1). A general pattern of increasing growth with latitude was also found.

For this workshop Citores *et al*. (2016 WK presentation and WD) have reviewed all data available on mean weight and length-at-age from surveys and catches from Cadiz to the Bay of Biscay by regions, focusing the analysis on the period 1996–2016.

A stationary analysis of mean weight-at-age (Wages) in both surveys and catches (for ages 1–7) shows a group of lower mean Wages from Cadiz to North Portugal, followed by South Galicia with intermediate values and finally Biscay followed by North Galicia and Cantabria with the highest values (4.1.1). Analysis of length-at-age in catches endorsed those results. Therefore these results basically endorsed the former findings of Silva *et al*. (2008). Statistical analysis with GAMs pointed out that the grouping according to homogenous growth patterns could be made on this basis: Cadiz // NPort +SWPort+Sport // SGal // NGal+Cantabria //Biscay.

Nevertheless it has been shown that significant changes have occurred throughout the time-series (and by cohorts) in mean weights-at-age (and lengths-at-age) distinctly by areas (Figure 4.1.2). Visual inspection of the series (focused on ages 1 to 4) suggest that mean weights of the southern group from South to North Portugal have shown some increasing tendency in the time-series, and that SGal and NorthGal experienced a rather parallel increasing tendency to the southern group (though at higher mean weight levels, particularly in catches for NGal), while Cantabria and Biscay have had a decreasing tendency in their mean weight though more intense in Biscay than in Cantabria. Mean weights in Cadiz (contrary to the southern group) have remained stable in surveys but have had a decreasing tendency in catches.

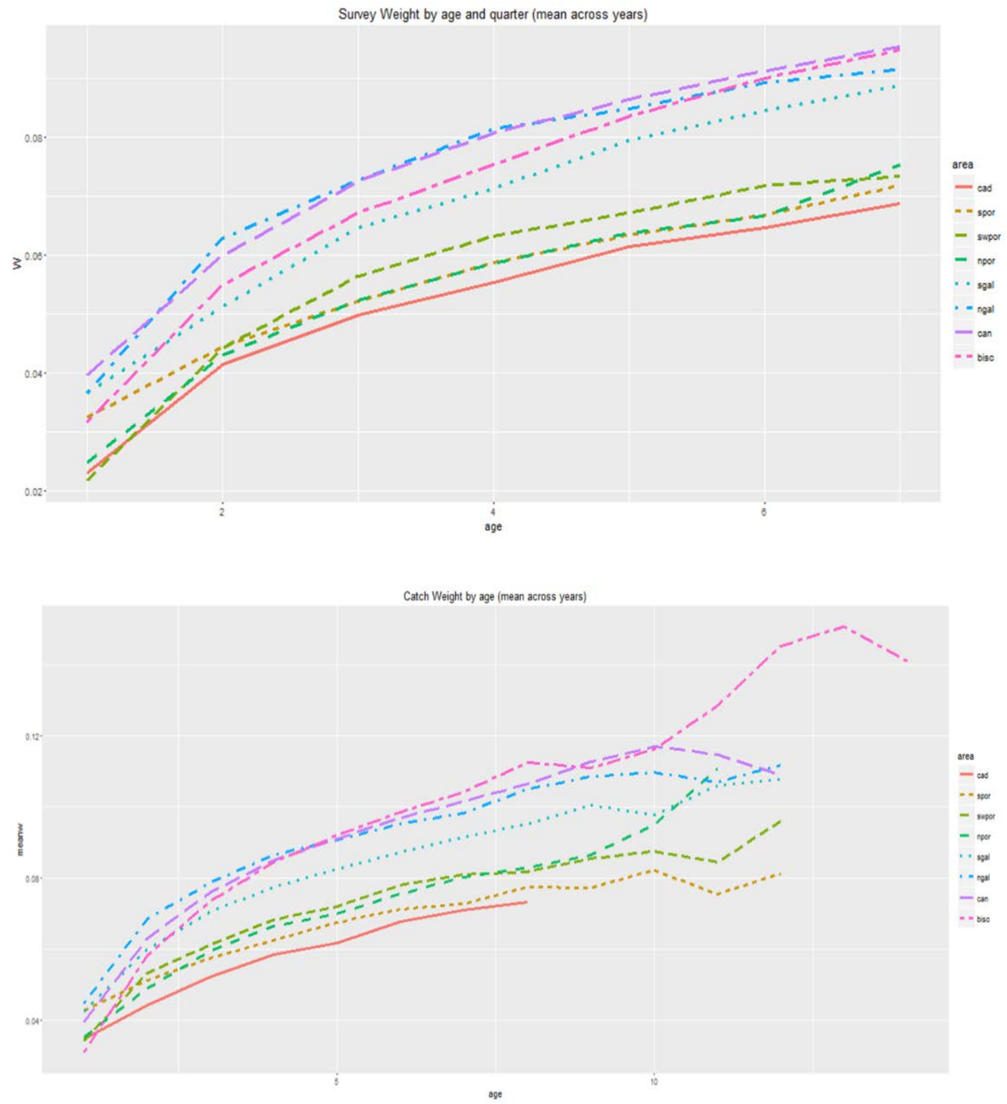


Figure 4.1.1. Mean weight-at-ages in surveys (ages 1–7 period 1996–2016) and in catches (ages 1–12, period 1997–2016).

Therefore a dynamic analysis of mean weights-at-age and length-at-age both in surveys and catches was also implemented restricted to ages 1–4 (the ages showing highest signals) and time period 2000–2016 (i.e. the common period to all surveys by regions). Interactions with time were significant. According to the observed changes in time three time periods have been defined to fit a growth curves across ages for the surveys (Figure 4.1.3). Period 1: 2000–2005, Period 2: 2006–2010, Period 3: 2011–2016. In period 1 Ngal, Can and Bisc show similar growths patterns with similar smooth curves and overlapping confidence intervals. The rest of the areas present lower weight values defining another group with overlapping intervals as well. In the second period the similar shapes are observed although Bisc mean weights decreased, and in the last period there are not distinguishable groups with wide overlapping Confidence intervals. Very similar results were obtained when analysis mean weight or lengths-at-age in catches.

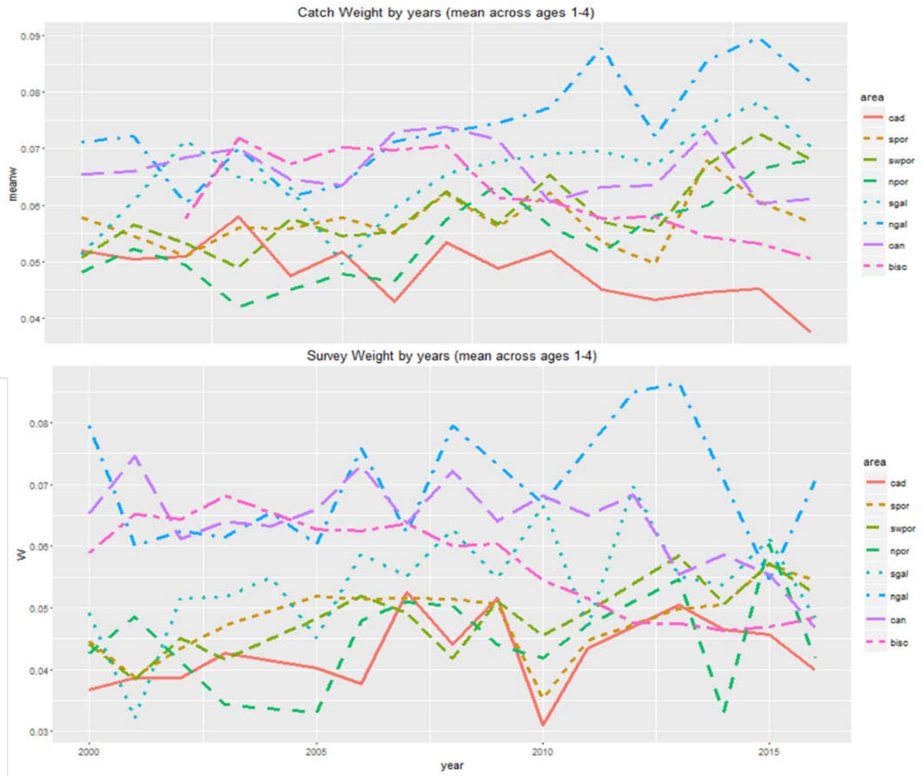


Figure 4.1.2. Raw data stationary analysis of mean weights (pooling ages 1–4) by areas.

In summary two groups have appeared consistently between 2000 and 2010: From Cadiz to NPortugal and from Ngal+ Can to Bisc (with SGal at intermediate level closer southern and northern group in the first and second periods respectively). This was rather consistent with the results of Silva *et al*. (2008). For the last period (2011–2016) no distinct group is clearly distinguishable probably due to the increasing trend in mean weights observed in the former southern group and the decreasing trend in part of the former northern group.

Within the Southern Group Cadiz stands aside as the one showing the lowest mean weights-at-age and shows different growth tendencies (slightly decreasing) from the remainder southern areas (increasing). In any case the southern group from SPortugal to NPortugal has a rather homogeneous growth pattern and consistent tendencies throughout the entire time-series (1996–2016).

A northern Group can be setup between NGal+ Cantabria and Biscay showing higher mean weights than the Southern group: The closest and highest mean weights have appeared NGal and Cantabria, with Biscay showing intermediate values. However in terms of tendencies Cantabria and Biscay seems closer as both have shown some decreasing tendency in recent years (more pronounced in Biscay than in Cantabria), whilst NGal has shown some increasing tendency (particularly in catches) more aligned with the one shown in SGal and the southern group. Therefore the dynamics in the northern regions in terms of growth is not as homogenous as it is in the southern region.

South Galicia shows intermediate Wages compared to the northern and southern groups. And in terms of the dynamic approach, South and North Galicia have some slightly increasing tendency contrary to the decreasing tendency observed in Biscay and Cantabria.

Therefore growth seems to be changing differently in Cadiz than in the remaining southern Group (from South to North Portugal); and in Galicia compared to Cantabria + Biscay. So the heterogeneity in the growth patterns and tendencies in time across the Biscay and Iberian regions is high, suggesting partial independent dynamics of sardine among these regions.

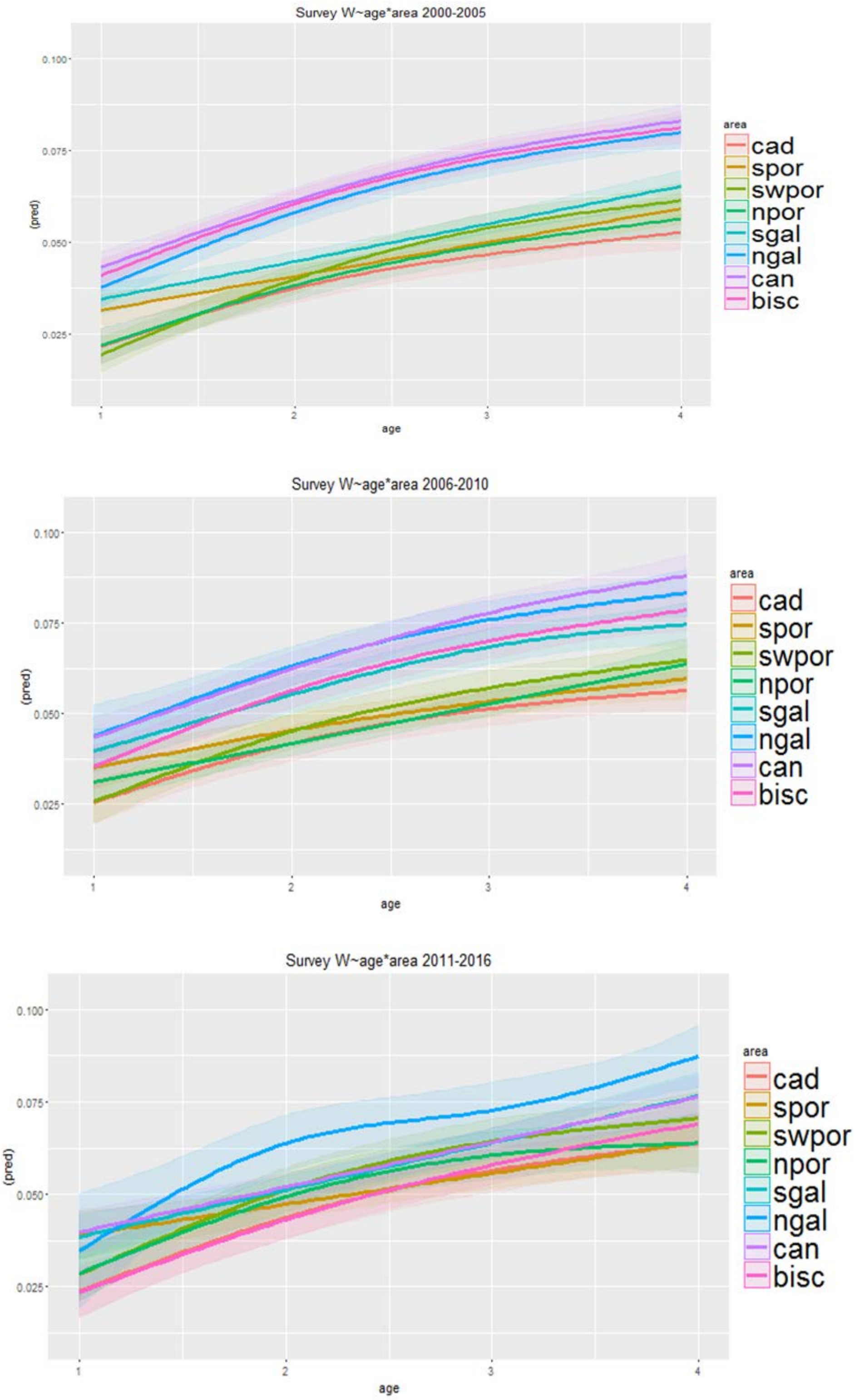


Figure 4.1.3. Modelled growth-at-age 1 to 4 by areas for three time periods, according to a GAM fitting (gam(W~area+s(age,by=area,bs="fs",k=4), data=subset(SURVEYCANa, year<…)).

4.1.2 Catch per statistical rectangle

This study concerns the achievement of an atlas of sardine catches from 2007 to 2015 from Gibraltar to Scotland. For this purpose, concatenation of Spanish, English, Portuguese and French data coming from fishing logbooks are necessary. The latter shall be completed by fisherman after each fishing operation to inform about the fishing sector, the quantity captured, the vessel and gear used during the action. The atlas achievement will provide a monthly cartographic analysis of the exploitation from those European fisheries.

Data from 2007 to 2015 coming from France, Portugal, Spain and England have been cleaned due to errors and missing data identified.

This Atlas was realised with ArcMap from the ArcGIS 10.3.1 software. Few errors are again seen and then eliminated. The different monthly maps are established. There are 108 maps in all, which means twelve maps per year, each countries involved. A slideshow of the different maps and done by the software Windows Movie Maker 2012 has be presented during the meeting, and is still available on the SharePoint of the group.

Unlike France, Spanish country is specially focusing its fisheries along its own coasts, from the Asturias' region to the Basque coast during autumn. The Spanish vessels' activity are decreasing in summer which can be explained by fishermen focusing on tuna fishing. But it is not the case of Portugal country which shows a same level of intensity during all months of the year. Fisheries are located from the Galician coast to the Gulf of Cadiz.

4.1.3 Maturity ogive in the Bay of Biscay (Presentation 20)

The maturity data for the Northern sardine stock were explored by age and semester from 2003 to 2016. Data were collected during the PELGAS survey and also from commercial vessels. The bulk of the datasets is collected during semester 1 and amounts for about $^2/_3$ of the total collected maturity stages. Depending on the year, around 1000 to 2000 samples are collected each year. Data were only available for the Bay of Biscay.

Sardine maturity can be divided into six stages. Stage 1 is made of immature fish. Stage 2 is a maturation stage. 50% of the fish belonging to that stage were considered immature and the other half mature. Stages 3,4,5 are the spawning stages. Stage 6 is post-spawning. This stage is rarely observed during semester 1 but more commonly seen during semester 2. The proportion of individuals belonging to those stage was considered by year and age.

The maturity ogive for semester 1 exhibits a stronger year-to-year stability compared with the data for semester 2. For both semesters, the proportion of mature individuals has been decreasing for age 1. This phenomenon is likely to be related with the decrease of the mean individual size-at-age. With fish of a given age being smaller and smaller, the youngest fish are likely to have their metabolism and physiology impaired to some extent. The cause of the size decrease is currently unknown although density-dependant effects are likely to occur.

The consequence of this decrease of maturity for management has not been explored however it may numerically affect the biomass estimates. Most stock assessment model use a constant maturity ogive. Setting a constant ogive may lead to substantial bias in biomass. The bias will be proportional to the difference of proportion of mature at a given age between constant and variable ogive multiplied for each year by the number and weight-at-age. Therefore it might be useful to consider here a variable ogive rather than a constant one. Maturity stage is currently unknown of the Celtic Sea, English Channel. Given the potential differences of growth, it may be difficult to extend the ogive from the Bay of Biscay to these areas.

4.1.4 Maturity ogive and mean weight-at-age in the southern stock (Presentation 13)

For the Southern sardine, the life-history data currently used as input for the model assessment, mean weight (Wa) and proportion of mature at-age (Ma), are provided by both spring acoustic (period 1996–2016) and DEPM (period 1997–2014) surveys, respectively. Maturity ogives from both sources of data were latest revised for the 2012 benchmark assessment, since then the proportion of mature fish at-age are obtained from DEPM triennial surveys, a single ogive per year for the whole stock area being used for assessment (WKPELA 2012): the maturity ogive obtained in years with DEPM surveys, and a fixed maturity in years with no DEPM survey (0% mature at-age 0, 80% mature at-age 1 and 100% mature at-age 2+). Mean weights-at-age were last revised in 2006 (Silva *et al*., 2006), they are calculated based on data from both Spanish and Portuguese spring acoustic surveys. During the last benchmark assessment, it was suggested to consider that mean weights-at-age be equally estimated from DEPM surveys, for consistency with the maturity information. The revision of these life-history parameters is underway.

Discussions

If age data are sampled randomly in DEPM surveys, the group considers that we have to assume they are representative of the population, no need to raise to any population abundance index.

In Portuguese surveys, age data are missing for males in most surveys; but it is reasonable to assume the same Ma for both sexes, and only use the age data from the females.

In more recent years, the opinion of the group is that age data in DEPM surveys seem to be large enough to provide a representatively good distribution of age among females. Nevertheless, the surveys for which it is necessary to complete age data (or for the earlier surveys, to estimate all age data), regional ALKs should be applied to the length–frequency distribution per haul, and then average age distributions per area would be obtained, that would then be weighted (with the SSB estimates per area) to obtain a whole stock age distribution.

It is reasonable to accept that all auxiliary information is useful and reliable to complement data, and thus ALKs can possibly come from different sources (either from the acoustic, or from the DEPM, or even from the market samples in the Q1), after a preliminary checking.

Age missing data can also be filled in applying multinomial logistic model (Gerritsen *et al*., 2006).

The analysis of the DEPM data should better be made per haul. For Wa, no problems expected, but for Ma, maybe problems will arise from the fact that we are using microscopic maturity data, instead of macro, and we should guarantee that the histological information is representative of both the immature and mature fractions of the population (which is not the case for the earlier years as stage 1 females were not collected for histology).

Wa and Ma could also come directly from age, and not via length distributions and ALKs. In this case, it would still be better to make the estimations first by haul, and then obtain a whole stock estimation, weighing each area's estimation by the abundances per area.

4.1.5 Peltic Survey (Presentation 17 and 18)

A summary of the sardine data from the Peltic survey was presented to the Workshop. The Peltic survey (2012–2016) was a new, annual integrated survey conducted in Q4 which focuses on the distribution, abundance and size and age structure of small pelagic fish species in ICES Divisions 7.e–f, predominantly sprat, sardine, mackerel and anchovy. In addition, it aims to improve the understanding of the role of these mid-trophic species in the pelagic ecosystem by simultaneously sampling the multiple trophic levels and the physical oceanography. The survey is carried out over ~19 days in October on board the RV 'Cefas Endeavour' (ICES, 2015a).

Data from 2013–2015 were presented at the workshop and included the acoustically derived sardine biomass estimates, the numbers-at-length, age–length relationship and sardine spawning activity measured in numbers of eggs. Although the time-series was relatively short, the results showed some general patterns and a largely new insight into sardine dynamics at the northern boundary of its main distribution area. The results suggested that particularly the western Channel holds significant sardine biomass in autumn from 56 kt in 2013 to ~100 kt in 2014–2015. Increasing numbers of sardine were found to reside in the eastern Celtic Sea, peaking at 55 kt in 2015. In 2015, sardine data from Peltic were combined with those extracted from the JUVENA survey conducted a month earlier in the Bay of Biscay, and showed that of the two areas, most sardine biomass in autumn is found in Subarea 7. This may suggest a northwards migration of sardine in autumn. Significant sardine spawning activity was observed in the western Channel and in 2015 sardine eggs were also found in some of the eastern Celtic Sea stations. While a large range of sardine lengths were found in the western Channel (from 7–25 cm), the eastern Celtic Sea appears to be an important recruitment area as a large component of the acoustically derived sardine biomass consisted of specimens <9 cm.

4.1.6 DEPM Biscay 8.ab

Sardine in 8.ab: egg abundance in triennial mackerel and horse mackerel surveys between 1995 and 2016 (Presentation 7 and WD1 and WD2)

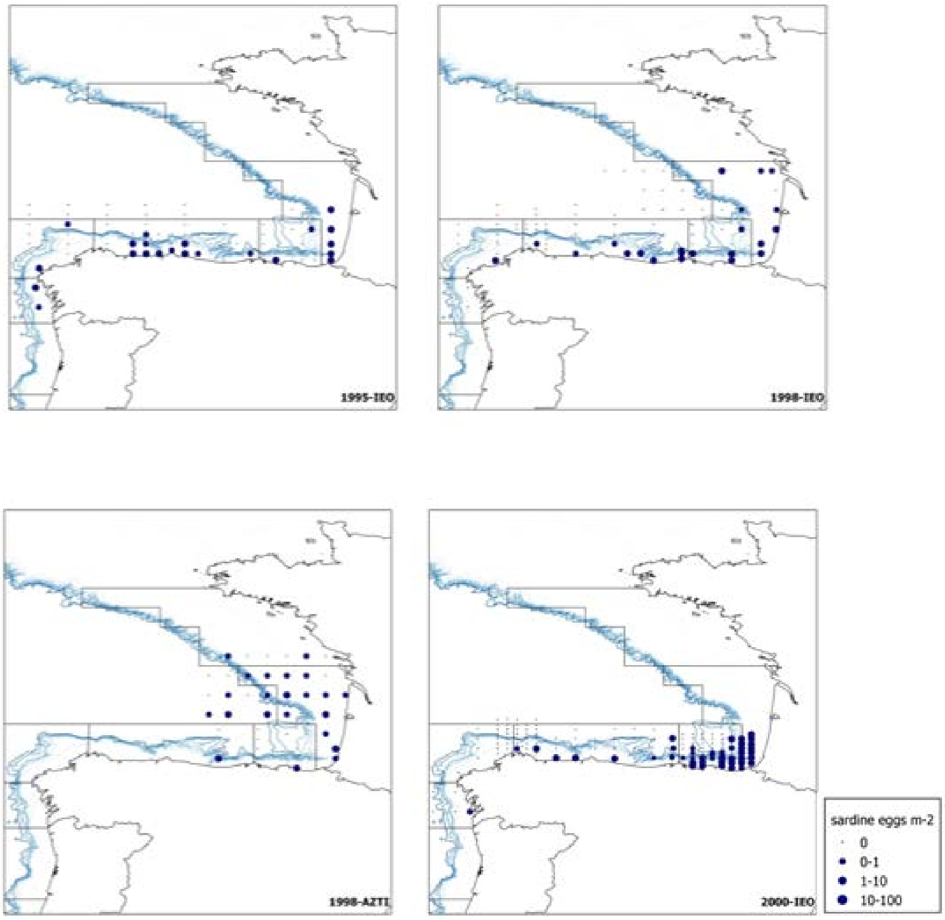
Since 1988, DEPM surveys directed to sardine were performed by IEO (data used in the sardine assessment model since 1997) (mainly in the 8.c–9.a sardine stock area) and AZTI (since 2011)(mainly in 8.abc1), on a triennial basis. Methodology and results are presented and discussed every year in the framework of WGACEGG.

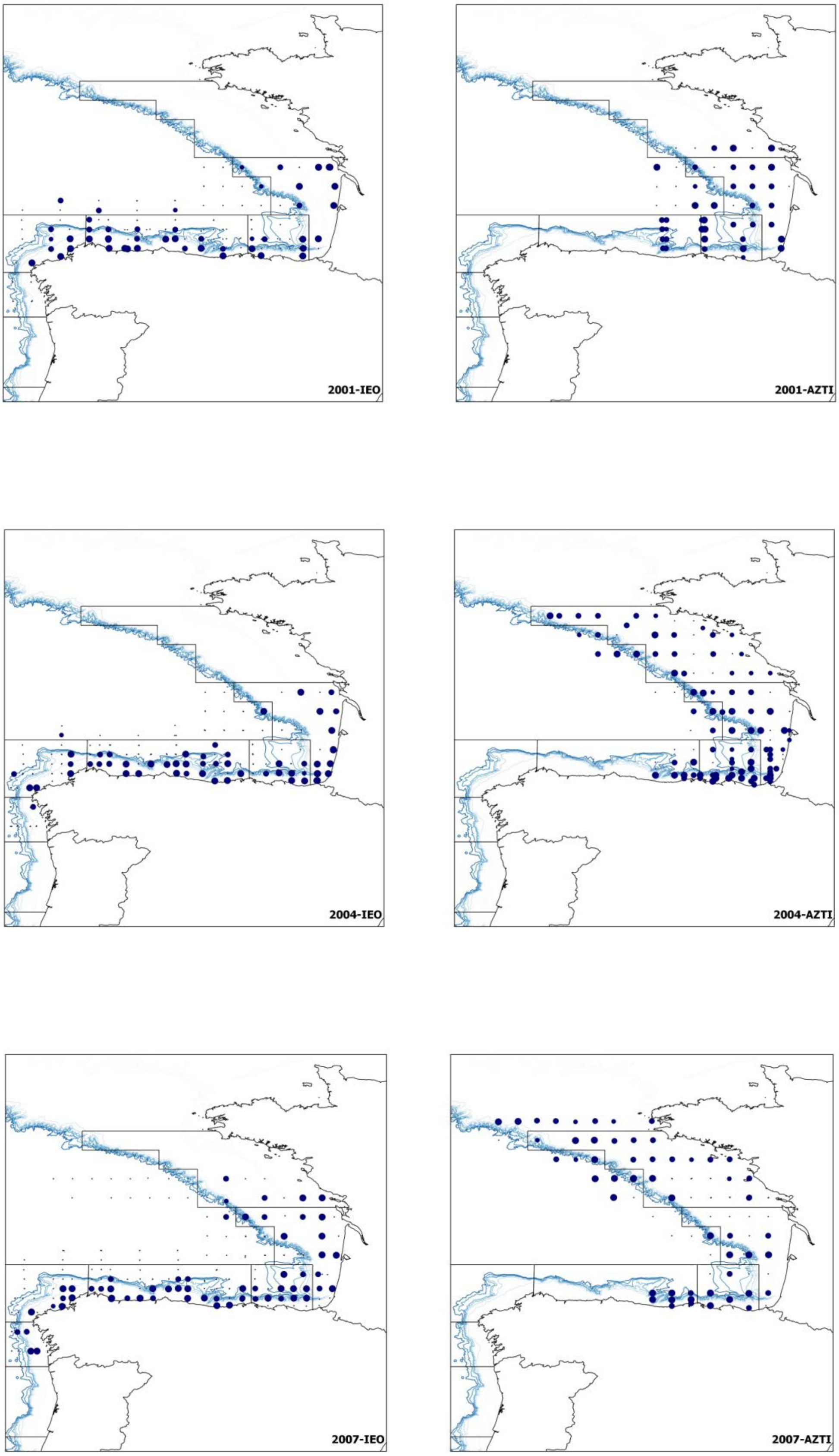
In order to have more information on sardine abundance to include in the assessment model for sardine during the 2017 benchmark (and particularly for the 8.abd–7 sardine stock), sardine egg densities from AEPM surveys (triennial from 1995 to 2006) (IEO and AZTI) directed to mackerel and horse mackerel, were presented during WKSAR.

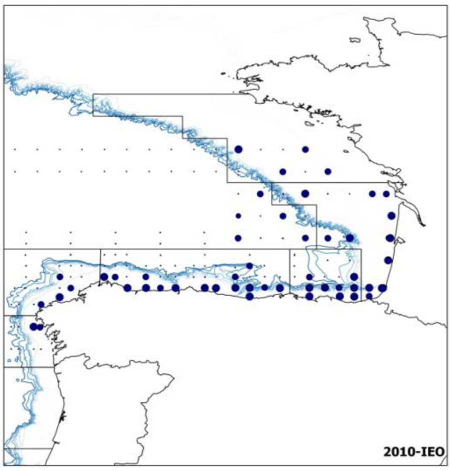
Along the time-series, spring surveys were carried out in 1995, 1998, 2000, 2001, 2004, 2007, 2010, 2013 and 2016 (Figure 4.1.6). In this period, several ships and plankton samplers were used, and depending on the objectives of any given survey, the total area covered was different. Triennial AEPM sardine egg database was uploaded to the WKSAR SharePoint (ices.dk/community/groups/Pages/WKSAR-2016.aspx) in the following format, where **Eggs/m² Sar** are sardine egg densities and **Area,** is the area represented by each sampling station (km²).

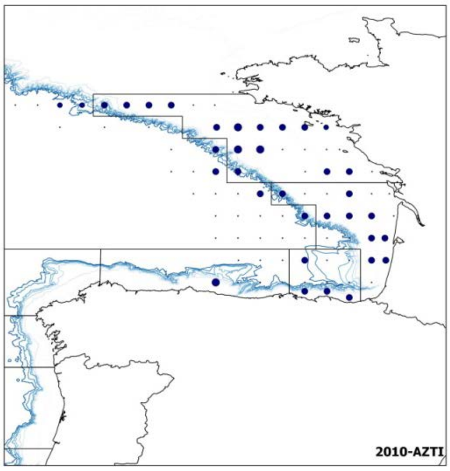
	A	B	C	D	E	F	G	H	I	J	K
1	Year	Survey	Station	Long	Lat	Eggs/m² Sar	Eggs Sar	Date	Sampler	Stratum	Area
2	2013	CAREVA0313	1	-4,745	45,751	0	0	07032013	Bongo 40	VIIIb	1829,42984
3	2013	CAREVA0313	2	-4,251	45,751	0	0	07032013	Bongo 40	VIIIb	1716,75089
4	2013	CAREVA0313	3	-3,741	45,747	0	0	07032013	Bongo 40	VIIIb	1718,58306
5	2013	CAREVA0313	4	-3,243	45,744	0	0	08032013	Bongo 40	VIIIb	1727,74396
6	2013	CAREVA0313	5	-2,739	45,751	0	0	08032013	Bongo 40	VIIIb	1703,00955
7	2013	CAREVA0313	6	-2,248	45,751	0	0	08032013	Bongo 40	VIIIb	1722,24742
8	2013	CAREVA0313	7	-1,744	45,749	15,3999793	13	08032013	Bongo 40	VIIIb	1434,59546
9	2013	CAREVA0313	8	-1,435	45,753	0	0	08032013	Bongo 40	VIIIb	1446,50462
10	2013	CAREVA0313	9	-1,328	45,251	0	0	09032013	Bongo 40	VIIIb	1398,86799
11	2013	CAREVA0313	10	-1,762	45,251	372,934212	305	09032013	Bongo 40	VIIIb	1625,14198
12	2013	CAREVA0313	11	-2,251	45,256	0	0	09032013	Bongo 40	VIIIb	1677,35906
13	2013	CAREVA0313	12	-2,737	45,255	0	0	09032013	Bongo 40	VIIIb	1720,41524
14	2013	CAREVA0313	13	-3,243	45,253	0	0	09032013	Bongo 40	VIIIb	1757,05881
15	2013	CAREVA0313	14	-3,749	45,25	0	0	09032013	Bongo 40	VIIIb	1717,66698
16	2013	CAREVA0313	15	-4,251	45,253	0	0	09032013	Bongo 40	VIIIb	1716,75089
17	2013	CAREVA0313	16	-4,738	45,254	0	0	10032013	Bongo 40	VIIIb	1834,92637
18	2013	CAREVA0313	17	-4,754	44,751	0	0	10032013	Bongo 40	IXa N + VIIIc	1841,339
19	2013	CAREVA0313	18	-4,246	44,751	0	0	10032013	Bongo 40	IXa N + VIIIc	1746,06574
20	2013	CAREVA0313	19	-3,743	44,747	0	0	10032013	Bongo 40	VIIIb	1681,9395
21	2013	CAREVA0313	20	-3,244	44,748	0	0	10032013	Bongo 40	VIIIb	1732,3244
22	2013	CAREVA0313	21	-2,744	44,748	0	0	11032013	Bongo 40	VIIIb	1737,82093
23	2013	CAREVA0313	22	-2,243	44,755	0	0	11032013	Bongo 40	VIIIb	1703,00955
24	2013	CAREVA0313	23	-1,767	44,748	174,891979	162	11032013	Bongo 40	VIIIb	1593,99495
25	2013	CAREVA0313	24	-1,35	44,749	0	0	11032013	Bongo 40	VIIIb	1364,0566

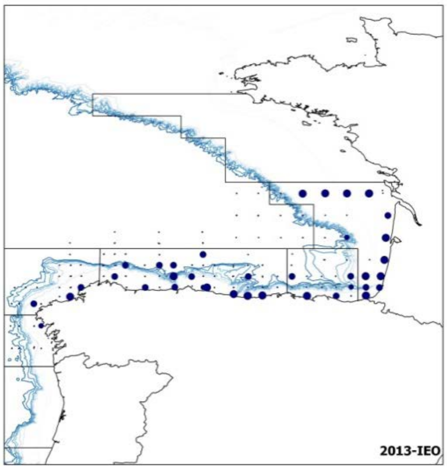
Figure 4.1.6. Sardine egg densities during the different AEPM mackerel and horse mackerel surveys from 1995 to 2016.

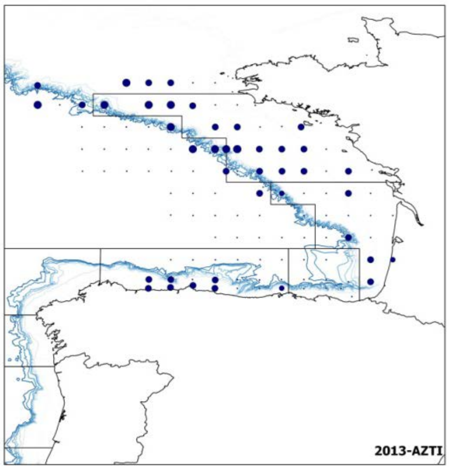

1995-IEO
1998-IEO
1998-AZTI
2000-IEO
sardine eggs m-2
0
0-1
1-10
10-100

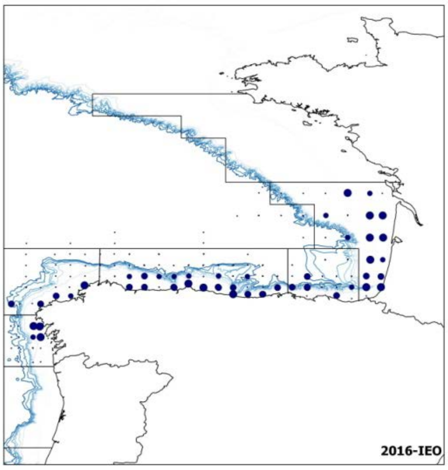

2001-IEO
2001-AZTI
2004-IEO
2004-AZTI
2007-IEO
2007-AZTI

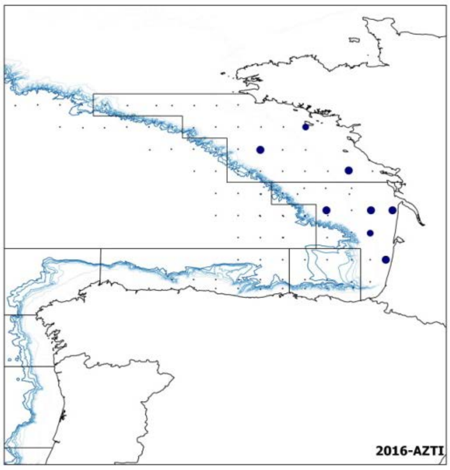

2010-IEO


2010-AZTI


2013-IEO


2013-AZTI


2016-IEO


2016-AZTI

4.1.7 DEPM survey Sardine Egg Production Estimation using data from EPM surveys directed at mackerel and horse mackerel (Presentation 5)

The IEO and IPMA coordinated surveys for sardine spawning–stock biomass estimation through DEPM have been taken place on a triennial basis since the late 1990s. In order to attain higher temporal resolution for the egg production dataseries it was decided within WGACEGG that tests should be run using the egg samples/data available from other egg production surveys taking place in the same geographical areas during a similar period of the year. All the EPM surveys from which it was thought that information for sardine eggs was obtainable were listed (Table 4.1.7) and the sampling spatial grids were assessed. The next step involved revisiting the samples for completing the egg staging (eleven stages) process. For this phase it was also decided to start the re-analyses from the more recent years backwards. In addition to the laboratorial work, issues such as gear capturability vs. area coverage were also addressed. At present, data from three surveys (2007, 2010 and 2013) are available and egg production estimations were calculated. The results appear encouraging and therefore egg production estimations may be available and would assist in filling in some gaps in the dataseries. The results obtained so far will be validated during the next WGACEGG meeting, in November 2016, when a decision on the possible subsequent analyses for other listed surveys will also be reached.

Table 4.1.7. Surveys list by year and type, indicating the egg data availability and/or processing phase, per strata: 1- South, 2- West Pt, 3- North (WGalicia+Cantabric)

Year	Survey type	Egg data (11 stages)	P0 estimates
1988	regular PIL survey	1 inc, 2, 3	available (1, 2, 3) regular survey
1990	other	3	na
1995	MAC/HOM EPM	?,?, 3	na
1997	regular PIL survey	1, 2, 3	available (1, 2, 3) regular survey
1998	MAC/HOM EPM	?, ?, 3	na
1999	regular PIL survey	1, 2, 3	available (1, 2, 3) regular survey
2001	MAC/HOM EPM	1, ?, 3	na
2002	regular PIL survey	1, 2, 3	available (1, 2, 3) regular survey
2004	MAC/HOM EPM	1, 2, 3 (no stgs)	na
2005	regular PIL survey	1, 2, 3	available (1, 2, 3) regular survey
2007	MAC/HOM EPM	1, 2, 3	1, 2, 3
2008	regular PIL survey	1, 2, 3	available (1, 2, 3) regular survey
2010	MAC/HOM EPM	1, 2, 3	1, 2, 3
2011	regular PIL survey	1, 2, 3	available (1, 2, 3) regular survey
2013	MAC/HOM EPM	1 inc, 2, 3	1, 2, 3
2014	regular PIL survey	1, 2, 3	available (1, 2, 3) regular survey
2016	MAC/HOM EPM	1, 2, 3	1, 2

4.1.8 Comparison of DEPM and acoustics (Presentation 2)

Several causes have been addressed during WGACEGG related with the differences between sardine DEPM and acoustic estimates. Among them:

Effect of time-lag between surveys on population structure and behaviour

The surveys are not entirely carried out simultaneously, especially in the Portuguese area. Differences in fish distribution, reproductive phase and interval from recruitment may play a significant role. The phase of the reproductive cycle affects the spatial distribution and aggregation pattern of the fish, and may vary along the surveyed area.

In addition, fish distribution and behaviour are notably modified by the weather conditions (that can vary between surveys); it is not uncommon to observe an appreciable decrease in the fish availability during events of stormy seas.

This may affect both the availability and accessibility of the surveying methods (both acoustics and DEPM) and may lead to results of difficult interpretation.

Allocation of acoustic energy to pelagic species

While the DEPM results derive from direct observations on fish eggs and ovaries, acoustic needs a post-processing phase aiming at to scrutinize the echograms and them to allocate echo-integrated energy to target species. Several methods are described to perform this task (ICES, 2015b), but in most of them, an expertise judgement is needed. The use of multifrequency equipment and post-processing programs such as Echoview, LSSS or Movies among others, highly improved the quality of the scrutinization and allowed automated or semi-automated methods to allocate echotraces to fish species be implemented. When this new tools are not available, ground-truth fish samples are used (McClatchie *et al.*, 2000). In this case the total echointegrated energy is split among the different fish species accounting both the abundance and the specific target strength. This may result in a bias if the fishing gear has different accessibility and catchability to the different fish species and sizes (lengths), giving, thus, a biased representation of the pelagic fish community both in terms of species composition and proportions but also in length structure. However, during a normal acoustic survey, several fishing stations are routinely performed on the same echo-types (i.e. similar echotraces corresponding to a group or single fish species with a given length distribution) in order to ensure the best representation of the pelagic fish community.

Estimation of reproductive parameters

Some DEPM parameters such as spawning fraction, relative fecundity and egg mortality may be more complex to estimate for some particular surveys when sampling is not as comprehensive as desirable due to patchiness of the fish and eggs distribution. Problems related to sardine availability and catchability as described before, may result in a biased sample of sardine and therefore of the adult parameters. Sometimes the samples are not randomly taken, and samples could be only obtained from the high egg density areas, or from particular areas (i.e. offshore or inshore), where there are not restrictions for the fishing operations (i.e. bottom roughness or the presence of other static fishing gears). This is particularly relevant when the data available do not allow estimations stratified by geographical area or population length (age) composition.

Differences on age catchability in acoustic surveys

As explained previously, either because the fishing stations are not randomly or due to a fishing selectivity issues, the length or age structure from the acoustic estimate would result biased in relation to the DEPM one. Moreover, if for both methods the adult sampling intensity is placed accounting, respectively, the egg and the echotrace abundances and if there is a mismatch between both areas, the resulted length or age structure could be different if there is a spatial age or length distribution pattern (i.e. both along the coast or length–depth dependent gradient).

Nevertheless, as can be observed in Figure 4.1.8, trends for both time-series indices a relatively similar, with a high correlation (0.59), and especially after the revision of the mortality estimation method for the DEPM series (WGACEGG 2016).

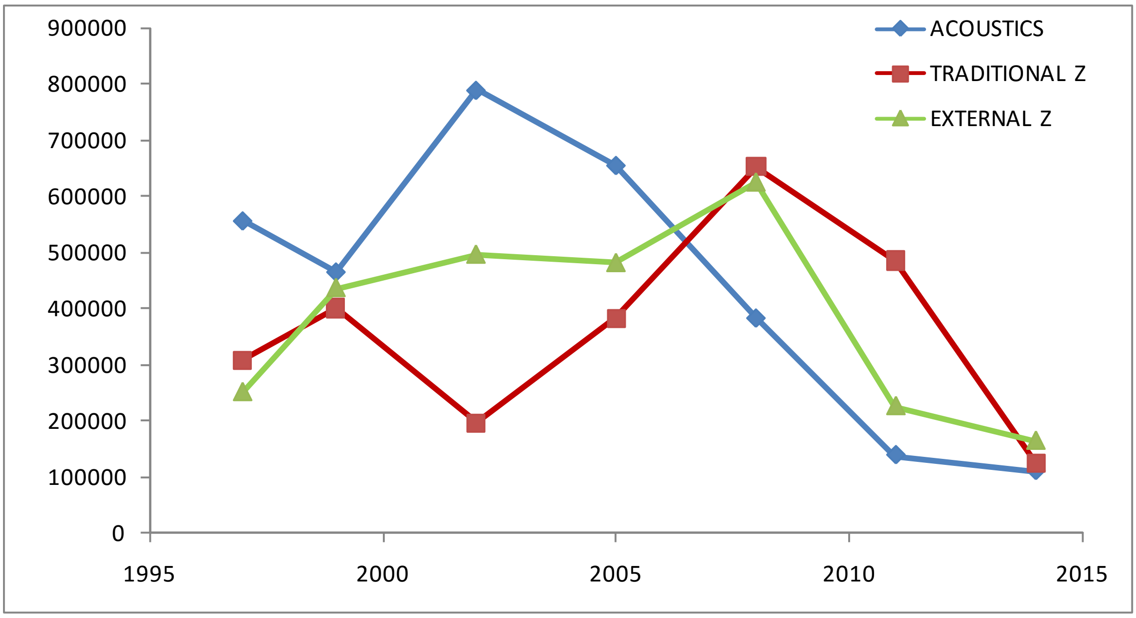


Figure 4.1.8. Tendencies of acoustic and DEPM (traditional and new mortality estimates) sardine estimation.

Major disagreement is due to the differences between indices in 1997. Excluding this particular year, correlation improves from 0.59 to 0.71.

4.1.9 Ecocadiz summer and reclutas surveys/autumn surveys (Presentations 1 and 8)

A summary of acoustic surveys carried out in the 4th quarter of the year was presented to the WG. The set includes several different series of surveys with variable objectives, designs, spatial and temporal coverage, namely the Portuguese SAR series started in the 1980s and discontinued in 2008, the ECOCADIZ-RECLUTAS series started in 2012 and the JUVESAR series started in 2011. All series cover the main recruitment areas of the southern sardine stock, northwest Portugal and Gulf of Cadiz. A preliminary exercise showed 0-group abundance in autumn surveys significantly correlates with 1-group abundance of corresponding cohorts in spring surveys the following year. Further datapoints for the ECOCADIZ and JUVESAR series are desirable to support this indication. The group also recommends to verify the consistency of methods used in the two surveys and evaluate the possibility of adding the regional estimates of recruitment (to be addressed by WGACEGG).

4.1.10 Estimates of CVs for PELAGO surveys (Presentation 19)

For some Portuguese PELAGO surveys, the classic CV associated to the NASC acoustic energies was calculated, with the aim to compare the estimated biomass of these surveys with the spawning biomass estimated by the DEPM method.

From Table 4.1.10.1 we can see that, usually, lower sardine biomass surveys have a higher CV associated, probably due to a patchier sardine distribution.

From previous work, we compare the classic CV's with those calculated by means of geostatistics, in the Portuguese Occidental North area and we found that the later ones have a slight higher CV, due to the spatial correlation between samples (Table 4.1.10.2).

Table 4.1.10.1. CV (classic) calculated for the sardine acoustic density (NASC – Nautical Area Scattering Coefficient), for some PELAGO surveys.

SURVEY	BIOM. ALL AREA	CV. ALL AREA
PEL02	615	0.11
PEL05	587	0.14
PEL08	244	0.17
PEL11	127	0.29
PEL14	101	0.16
PEL15	78	0.35
PEL16	172	0.22

Table 4.1.10.2. Acoustic (NASC) CV% - classic and CV_{geo} - geostatistic, estimated for the Portuguese Occidental North area, for some acoustic surveys.

survey	N	m	σ^2(data)	σ_E^2	nugget	sill	range	CV%	CV_{geo}%
Mar97	351	348	2463874	9290	1300000	2560000	3.0	24.0	27.7
Nov97	327	232	359169	1297	290000	385000	3.0	14.3	15.5
Mar98	360	445	3626542	10958	3150000	3800000	6.6	22.6	23.5
Nov98	349	332	1044197	3206	800000	1050000	2.7	16.5	17.0
Mar99	248	418	2692315	11081	2400000	2860000	6.6	24.9	25.2
Ago99	327	132	349559	1248	280000	365000	3.9	24.7	26.7
Nov99	349	195	362016	1218	300000	400000	7.2	16.5	18.0
Mar00	318	215.4	1165913	4053	870000	1210000	5.7	28.1	29.0
Nov00	318	1542	20348120	69178	13800000	22800000	7.8	16.4	17.0
Mar01	339	767	10833000	34110	8400000	11400000	4.2	23.3	24.0
Nov01	302	610	4996046	17958	4550000	5360000	7.2	21.1	22.0
Mar02	349	497	3875075	13074	3200000	4132000	4.2	21.2	23.0
Fev03	349	340	940399	2787	650000	1050000	9.0	15.2	15.5

4.1.11 Age of very small sardines in spring acoustic surveys (Presentation 3)

In the 2016 WGHANSA meeting (see ICES, 2016, Section 7.3.2.1), the group discussed the need to review the age classification of very small sardines (<9 cm total length) in spring acoustic surveys for the southern stock. The problem mainly affects recruitment areas. It was raised by the occurrence of a large number of such individuals in the Gulf of Cadiz in PELAGO16. According to the birth criteria for the stock, these small individuals are classified as age 1 and are likely to be classified again as age 1 in the next survey.

The topic was revisited in WKSAR to have the input of participants that are involved in otolith age readings. The group identified specific surveys which show a large percentage of very small individuals and recommended national institutes to review age readings (check the otolith pattern and the length distribution) and recalculate survey age compositions. The group also recommended WGACEGG to check the assignment of hauls to acoustic energy in these cases.

After the meeting, WKSAR IEO informed that this problem didn't occur in South Galicia in PELACUS surveys. IPMA is carrying out the revision of otoliths from PELAGO surveys that had more than 7% of sardines below 9 cm length.

4.1.12 Catch-at age data and sampling issues for the southern sardine stock (Presentation 12)

Annual catch-at-age data used to assess the southern sardine stock starts in 1978. Catch age composition is the single data used in the assessment to estimate the stock up to the early 1990s given surveys start in 1996.

It has been acknowledged in the past (see e.g. WKPELA, 2012) that in earlier years sampling of catches did not cover the whole stock area. In the Cantabrian Sea, length sampling started in 1986 and age sampling started in 1990, in north Portugal length sampling started in 1980 and in the Gulf of Cadiz neither catch length nor age were sampled until 1997. Up to 1990, length and age samples were pooled for North and South Galicia and for Northwest and Southwest Portugal without weighing and used to transform catch biomass to catch-at-age in numbers. Cadiz catch-at-age was obtained raising the age composition of south Portugal to catch biomass in Cadiz.

As a result, the same age composition of catches is seen in Areas 9.an and 8.c, in Areas 9.acn and 9.acs and in Areas 9.asa and 9.asc from 1978 to 1990 and this pattern changes abruptly in 1991. Currently we know that catches in 9.an, 9.acn and 9.asc are dominated by young sardine whereas catches in the remaining areas are dominated by older sardine. In general, catch age composition is consistent with population age composition at the local level. Survey data from the 1980s suggests that catch compositions prior to 1991 are biased. The impact of Cadiz is possibly small given catch biomass is around 6% of total stock. On the other hand, bias related to 8.c and 9.acs is possibly not negligible since corresponding catches made on average 19% and 17% of the total. In summary, the use of pooled length and age samples to estimate the age composition of catches jointly in recruitment and non-recruitment areas is biasing the assessment in 1978–1990.

The group considered the direction and magnitude of bias is uncertain. To have a better perception of bias the group recommended to prepare a table with the number of length samples and number of age readings by region and year. This table was submitted to the group after the meeting. The group recommended to keep the start of the assessment in 1978 until we have a better perception of the amount of bias there is in the earlier data.

It should be emphasized that back in the 1980s the knowledge of the spatial distribution of sardine by size and age classes was much scarcer than it is today; it was not known that sardine has a strong spatial pattern with predominant young/small fish in some areas and predominant old/larger fish in neighbour areas. Thus, assumptions made to estimate the catch age composition of the whole stock were based on the best knowledge and data available at the time.

After the workshop, the issue was further explored and the WG realised that data by Subdivision (8.c, 9.an, 9.acn and 9.a.cs) prior to 1991 was obtained by disaggregating data by ICES division (8.c and 9.a) with some assumptions (ICES, 1999) and therefore did not reflect the real catch age composition by area. In addition, detailed information on sampling in 1978–1992 was provided to the WG for Portuguese catches (Table 4.1.12.1). Consultation with the IEO database managers indicated the two Spanish areas (8.c, 9.an) were sampled since the 1980s and the length composition wasn't pooled for all the Spanish waters, instead, every length composition was used for the catch allocation of the given subdivision (for every sampling, length composition was pooled for each purse-seine, then, all the purse-seiners in the harbour were added and pooled for the total catch in the harbour, all the harbours were added, and pooled for a single ICES subdivision). The only problem is that the basic information of length composition before 1992 is not computerized.

The WG concluded that sampling of length and age composition appears to cover all stock areas since 1978 although documentation of sampling design and intensity and protocols for calculating total catch-at-age composition for the earlier period of the assessment are not readily available. Since (at least) 1997, information on sampling intensity is provided in the ICES "yellow" sheets used to report WG data.

Table 4.1.12.1. Detailed information on sampling for length and age composition by ICES subdivision in Portugal 1978–1992.

	IXa-Cnorth			IXa-Csouth			IXa-South-Algarve		
	Length composition		Biology	Length composition		Biology	Length composition		Biology
year	N samples	N fish sampled	N age readings	N samples	N fish sampled	age readings	N samples	N fish sampled	N age readings
1978				77	6882	*	71	20076	*
1979				205	21782	*	94	21489	*
1980	60	5549	*	227	25155	64	228	30291	*
1981	197	14003	*	67	5118	*	184	16262	103
1982	216	14118	*	269	16030	*	203	18023	*
1983	220	15237	*	255	13953	*	198	19771	*
1984	292	20245	*	264	14492	*	165	17444	*
1985	263	18257	*	279	18486	*	155	18009	*
1986	233	16894	*	250	16844	544	129	14219	324
1987	228	18923	593	212	15151	930	153	16898	595
1988	174	13672	819	195	20380	1329	96	11330	524
1989	106	7668	776	175	16602	958	67	7333	580
1990	121	8365	1003	133	8718	884	69	7389	97
1991	144	10797	1210	150	8899	1055	58	6203	822
1992	198	17123	1126	167	9697	1145	54	5708	911

(*) There are age readings but data are not in central database; not possible to verify number of age readings

4.2 Inventory of the available datasets to be considered for the assessment

Tables 4.2.1 and 4.2.2 summarise data available for the assessment of the Northern and Southern sardine stock, respectively.

Table 4.2.1. Northern sardine stock, data available for stock assessment.

Data set	Catch biomass	Catch age composition	PELGAS acoustic survey	BIOMAN DEPM survey
Time coverage			1996-2016	1997-2014 (triennal)
Spatial coverage	Bay of Biscay, English Channel , Celtic Sea	Bay of Biscay only	Bay of Biscay only	Bay of Biscay only
Quality assurance	considered as well representative in the Bay of Biscay, and estimated as "doubtful" in the English Channel and Celtic Sea.	not described. Age reader shows no significant bias with european colleagues	Coordinated and evaluated in WGACEGG.	Coordinated and evaluated in WGACEGG.
Indicators of bias and precision	not calculated	CV about 14% in the last calculation in 2014 for the bay of Biscay. Nothing available for Channel and Celtic sea	Work in progress to estimate precision. CV assumed to be 0.25 in all years in the assessment.	CVs estimated for each survey. However, in the assessment CVs are assumed to be 0.25 for all surveys, as in the acoustic surveys.
Collection process	since 2002	since 2002	Massé et al (in press), WGACEGG Reports 2010, 2012	Massé et al (in press), WGACEGG Reports 2010, 2012
Used previously	no	no	Yes	Yes
Comments			Abundance and abundance-at-age from the two national surveys summed to obtain a single index of abundance. Spanish surveys started in 1986, data currently not used. Uncertain if surveys have equal catchability; 2 intercalibration exercises (2008 and 2009) were inconclusive (WKPELA, 2012).	Spawning biomass from the two surveys is summed to obtain a single index of abundance. Spanish surveys started in 1988, but data not currently used. DEPM and acoustic surveys show different trends.

Table 4.2.2. Southern sardine stock, data available for stock assessment. Data used previously in blue shaded columns. NA- Not available.

Data set	**Catch biomass**	**Catch age composition**	**Weights-at-age in the catch**	**Weights-at-age in the stock**	**Maturity ogive**	**Spring acoustic survey**	**DEPM survey SSB**	**DEPM/AEPM surveys Egg Production**	**ECOCADIZ summer acoustic survey**	**Autumn recruitment surveys (ECOCADIZ-Reclutas, JUVESAR and SAR-AUT)**
Time coverage	1978 - 2015	1978-2015	1978 - 2015	1978 - 2016	1978 -2016	1996-2016	1997-2014 (triennal)	1997 - 2014 (triennal), only some of these years available/usable	2004 - 2015	1984-2015
Spatial coverage	Whole stock	Whole stock	Whole stock	Whole stock	Whole stock	Whole stock	Whole stock	Whole stock	Southern areas (Algarve+Cadiz)	Main recruitment areas (western Iberia and Gulf of Cadiz)
Quality assurance	By national entities for fisheries statistics.	Within the framework of national (up to 1986) and EU sampling programs.	Within the framework of national (up to 1986) and EU sampling programs.	Within the framework of national (up to 1986) and EU sampling programs.	Within the framework of national (up to 1986) and EU sampling programs.	Coordinated and evaluated in WGACEGG.	Coordinated and evaluated in WGACEGG.	Coordinated and evaluated in WGACEGG.	Coordinated and evaluated in WGACEGG.	Coordinated and evaluated in WGACEGG.
Indicators of bias and precision	NA. Considered unbiased and precise.	Considered unbiased (see comments). Sample sizes and indices of consistency between age readers used to set the precision of age composition in the assessment (Stock Annex.	NA. Considered unbiased and precise (sample sizes are large).	NA. Considered unbiased and precise (sample sizes are large).	NA. Considered unbiased and precise (sample sizes are large).	Work in progress to estimate precision. CV assumed to be 0.25 in all years in the assessment.	CVs estimated for each survey. In the assessment, CVs assumed to be 0.25 for all surveys, as for acoustic surveys.	CVs available.	NA	NA
Collection process	Data collected by national entities responsible for fisheries statistics.	Documented in assessment WG reports and DCR sampling plans (e.g. ICES 2014).	Stock Annex.	Stock Annex.	Stock Annex.	Massé et al (in press), WGACEGG Reports 2010, 2012	Massé et al (in press), WGACEGG Reports 2010, 2012	SISP 6 - MEGS V1.3, Massé et al (in press), WGACEGG Reports 2010, 2012	Massé et al (in press), WGACEGG Reports 2010, 2012	Massé et al (in press), WGACEGG Reports 2010, 2012
Used previously	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**NO**	**NO**	**NO**
Comments	Assumed to correspond to landings. Discards considered to be negligible. Observations in PT bottom trawl fleet confirm very low frequency and volume. Slipping in purse seiners is frequent, survival rates have not been estimated.	Since 1991 sampling design stratified into 8 geographical areas covering the whole stock, quarters or semestres, coverage of main ports, good sampling intensity, considered unbiased and precise. Length and age sampling assumed to cover catches from all stock areas over the whole assessment period. Documentation on	= Mid-year weights-at-age in the assessment. Disaggregated by quarter and sub-division. Weight-at-age fixed from 1978 to 1988; fixed at Age 6+ at 100 g in the whole period	= beggin year weights-at-age in the assessment. Calculated with samples from spring acoustic surveys. Fixed from 1978 to 1988; fixed at Age 6+ at 100 g in the whole period	Calculated with samples from DEPM surveys (triennal). Mean in non-DEPM years.	Abundance and abundance-at-age from the two national surveys summed to obtain a single index of abundance. Spanish surveys started in 1986, data currently not used. Uncertain if surveys have equal catchability; 2 intercalibration exercises (2008 and 2009) were inconclusive (WKPELA, 2012).	Spawning biomass from the two surveys is summed to obtain a single index of abundance. Spanish surveys started in 1993, but data not currently used. DEPM and acoustic surveys show different trends.	Compilation of data from Mackerel/horse mackerel AEPM surveys. Work done for 2007, 2010 and 2013 surveys, to be completed in WGACEGG meeting 2016.	Data available from 8 surveys since 2004. High correlation of age 1+ abundance with spring PELAGO survey in the same area. Maybe useful to confirm PELAGO estimates in the same year.Correlation of 0-group in ECOCADIZ with 1-group in PELAGO the following year not sig in numbers, significant in biomass.	Data on 0-group abundance in autumn (data pooled from all surveys) significantly correlated with 1-group abundance in spring surveys the following year. Requires further data points, verify consistency of methodology and additivity of regional estimates between JUVESAR and ECOCADIZ surveys (to be addressed by WGACEGG).

5 Scenarios of sardine stock structure and dynamics (ToR 3) and candidate method for stock assessment (ToR 4)

5.1 Northern sardine stock

Two scenarios of stock structure will be considered for the benchmark:

Scenario 1: The stock delimitation includes the Bay of Biscay, Celtic sea and English Channel. This is the current area used for the Northern sardine advice. Landings will be compiled and summed for the whole stock area. Catch in numbers-at-age are available for the Bay of Biscay. Survey indices are derived from PELGAS, a stratification index from PELGAS and a new age-structured DEPM index.

Scenario 2: The stock is split into two distinct areas: a portion in the Bay of Biscay which will be a data-rich area and another area in the Celtic Sea/English Channel where data are limited mostly to landings, a few years of data from the PELTIC survey and length composition from the Dutch fishery.

The following candidate methods for the stock assessment were proposed:

For Scenario 1, it is proposed to try two models: 1) an age-structured model based on existing knowledge in the Bay of Biscay and extended to the whole area, 2) a surplus production model based on some of the available index.

For Scenario 2, an age-structured model will be used for the Bay of Biscay. TASACS have previously been used but given the currently available datasets and preliminary work, XSA will be rather considered for this approach. A surplus production model may also be considered. For the English Channel and Celtic Sea, a surplus production might be considered. Catch-at-length data for this area still require to be analysed and fishing effort might be used to derive a cpue. An alternative trend--based assessment depending on the conclusions about data availability might also be considered. Exploration will be carried out using a4a and a Bayesian model. Age-structured scenarios will use a variable maturity ogive.

5.2 Southern sardine stock

Scenarios of stock structure:

Scenario 1: Base case scenario: one stock as currently assumed

> Justification: no definitive evidence of the existence of substocks

Scenario 2: two stocks, one distributed in Southern Iberia (Gulf of Cadiz+South Portugal) and the other distributed in the remaining area (from the Cantabrian Sea to southwest Portugal)

> Justification: differentiation in terms of life-history properties between southern and western sardine; existence of a recruitment hot spot in each putative substock suggests it may host a self-sustained population.

With priority 2 and conditional on time available, the WG agreed to explore a third scenario

Scenario 3: three stocks, Northern (South Galicia + North Galicia + Cantabrian Sea), Western (North + southwest Portugal) and Southern (Gulf of Cadiz+South Portugal)

Justification: differentiation in terms of growth between the three substocks with higher similarity of Galicia with Cantabria than with North Portugal, possible self-sustained population in the Northern substock supplied with recruits from Galicia.

Assessments will be carried out with Stock Synthesis 3 (Methot and Wetzel, 2012), the model currently used in the assessment of the Iberian sardine. A4a (Jardim *et al*., 2015) will also be explored.

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Annex 2: Questionnaire to stakeholders

Stakeholder inputs for Population Assessment for Sardine

Stakeholder input provided by: ……………………………………………

Date: …………………..

Main base and landing ports used by the vessels of your organization

Base ports:………………………………………………………………………………

Landings ports:…………………………………………………………………

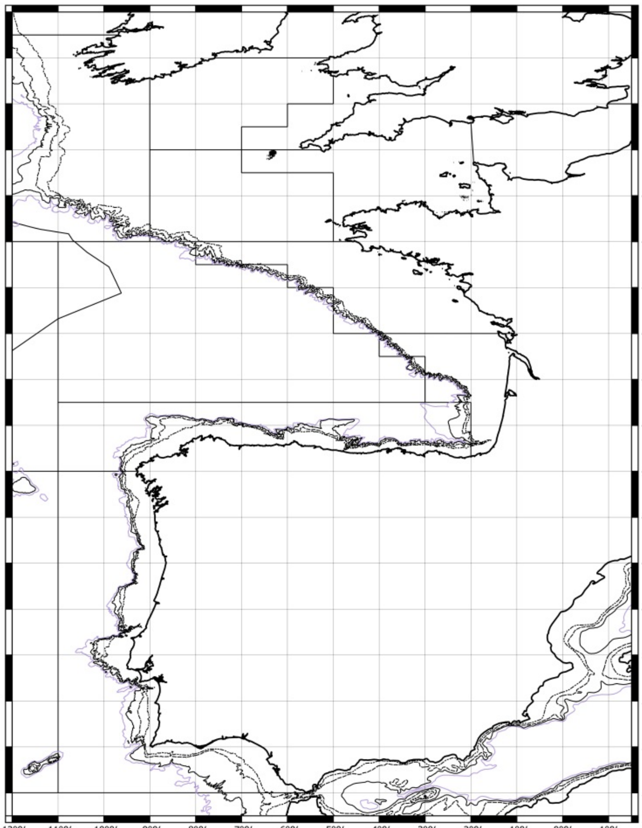
Stock identity and dynamic

1. Do you believe the sardine inhabiting from Gulf of Cadiz to north France belongs to a single population? □ YES □ NO

If answer is YES go to question 8

2. How many populations do you believe are in this area?

3. Can you show these areas in the map?



4. Do you believe the boundaries are fixed (permanent) along time? □ YES □ NO

If answer is YES go to question 6

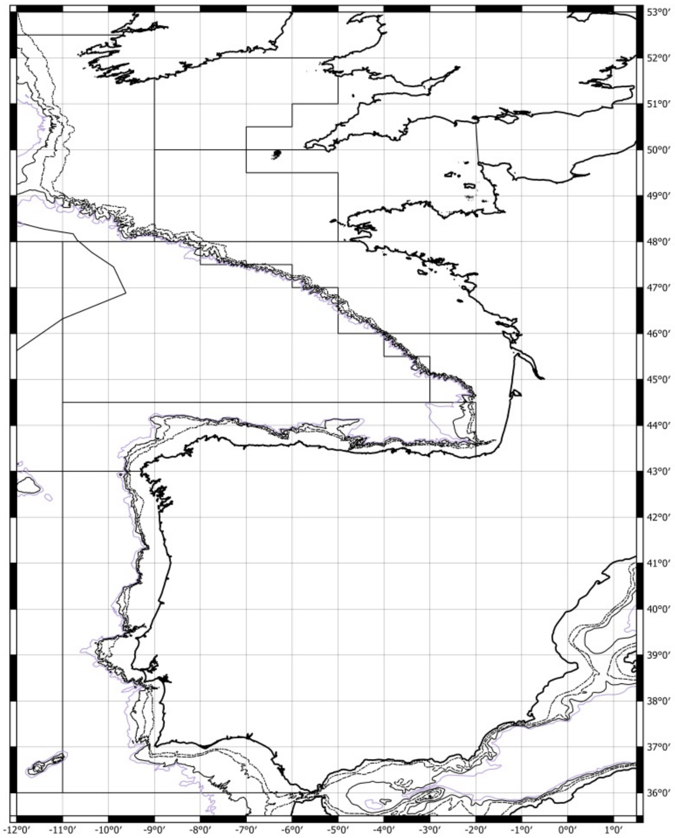
5. Which of the following processes/factors do you believe are driving such changes in boundaries? In case of more than one, please numbering in order of importance	___Temperature ___Winds ___Stock size ___Interaction with other species ___Others
6. Do you believe the populations are interconnected?	□ YES □ NO

If answer is NO go to question 8

7. Could you quantify the degree of such inter-changes	□ Scarce □ Medium □ High
8. Are you able to identify nursery areas?	□ YES □ NO

If answer is NO go to question 10

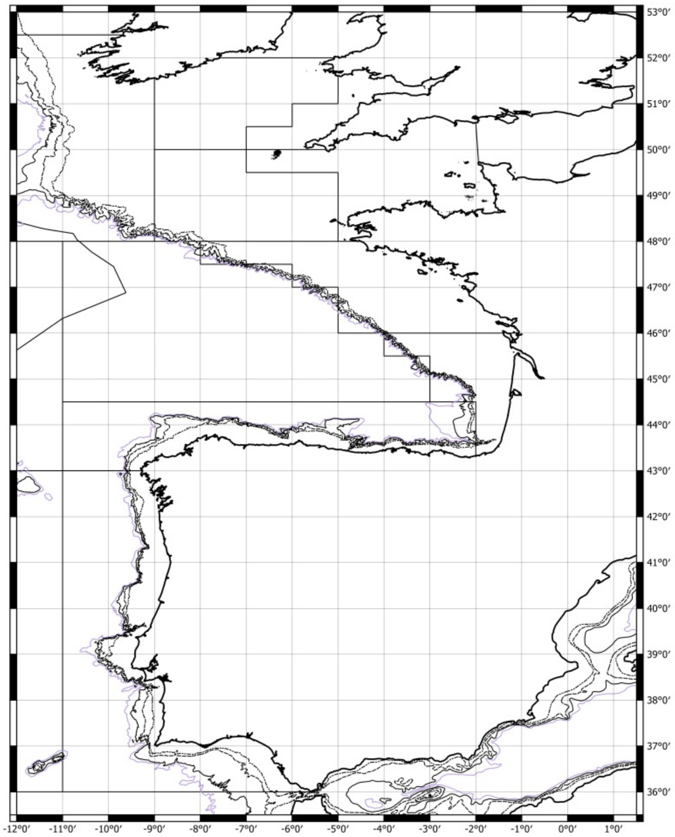
9. Can you show these areas in the map?



10. Are you able to identify the main feeding areas?	□ YES □ NO

If answer is NO go to question 12

11 Can you show these areas in the map?



12. In what quarter(s) do you believe the feeding season takes place?

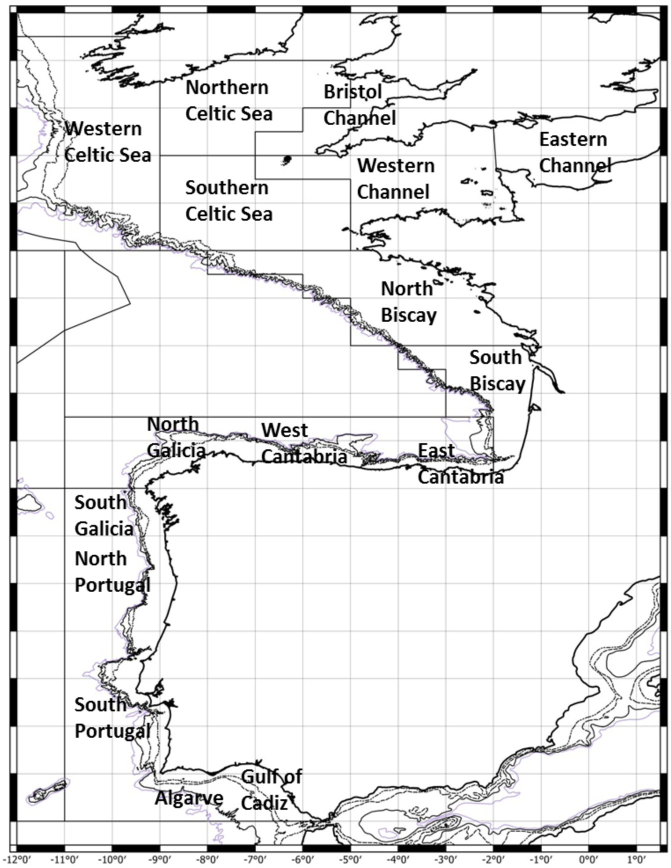
□ Spring
□ Summer
□ Fall
□ Winter

About the fishing activity

13. In which seasons does your main fishing activity take place?	□ Spring □ Summer □ Fall □ Winter

14. In which area(s) does it take place?

□ Western Celtic Sea
□ Northern Celtic Sea
□ Southern Celtic Sea
□ Bristol Channel
□ Western Channel
□ Eastern Channel
□ North Biscay
□ South Biscay
□ Eastern Cant. sea
□ Western Cant.sea
□ North Galicia
□ South Galicia
□ North Portugal
□ South Portugal
□ Algarve
□ Cádiz



If your fishing areas move seasonally from one area to another, How do they move? And why do they move? (market reasons, fish movements, ?)
Explanation:

15. What is the preferred size of sardine for the market and selling?	□ <15 cm / >36/Kg – T4 □ 15–17 cm/ 25–35/Kg-T3 □ 17–20 cm/ 16–24/Kg-T2 □ >20 cm/ 1–15/Kg-T1

Assessment and inputs

16. What is your vision about the current status of the stock?

- □ Good
- □ Normal
- □ Bad with better perspectives in short term
- □ Bad with worse perspectives in short term

17. Do you believe official catch data are good enough?

- □ YES
- □ NO

If answer is yes go to question 19

18. If No, what is the problem, How could catch data be improved?

19. Do you believe surveys indices are good enough?

- □ YES
- □ NO

If answer is YES go to question 21

20. How would survey indices be improved?

- □ Changing the period of the survey
- □ Improving collaboration between fishermen and scientists
- □ Combining vessels (research+fishing vessels)
- □ Others: ______________________________ ______________________________

21 Do you have any input data that you would like to be considered for assessments?

22. Please provide any other relevant information for ICES that you feel should be considered while making the assessment:

Management

23. Do you believe a long-term management plan is needed for this species? □ YES □ NO

If the answer is NO, the questionnaire is finished

24. Rank your preferences for management objectives (from max -1- to min -5-) among the following:
_____Sustainability of the Resource
_____Maximum Sustainable level of catches
_____Stability of catches
_____Maximum economic profitability
_____Social objectives like Maximum number of employs and/or vessels?

25. For a management plan, select the basis to establish a TAC or a Maximum allowable level of catches:
- The stock abundance in the most recent year
- The mean stock abundance in a period of years

If you chose the latter option, would you prefer the mean of the last three years, five years, or other
-

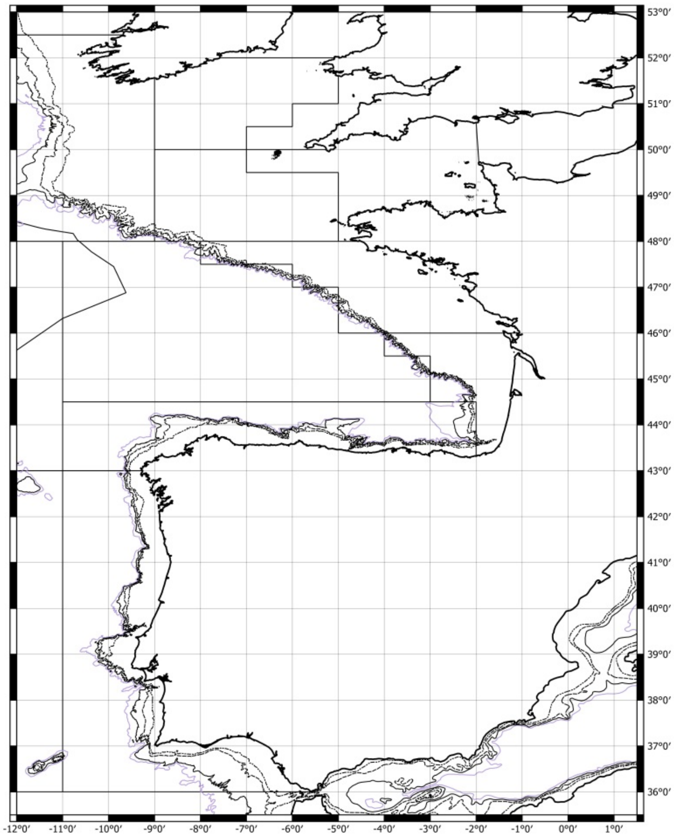
26. For a management plan, Select or propose constrains that you would ask for the definition of Harvest Control Rules
□ Restriction of variability of catches along years
□ Establish a maximum TAC value, independent of the stock size
□ Establish a minimum TAC value, independent of the stock size
□ Others?

27. In order to achieve the goals established in the management plan, which technical measures to regulate the fishing effort, do you believe are suitable
□ Temporal ban during the main spawning period
□ Temporal ban during the main recruitment period
□ Spatial ban in the main spawning grounds during the spawning period
□ Spatial ban in the main recruitment grounds during the recruitment period
□ Establish a daily quota per vessel
□ Increase the minimum landing size

28. Would you be in favor of any spatial explicit management □ YES □ NO

If answer is NO the questionnaire is finished

29 If Yes Can you suggest the geographical boundaries in the map?



Annex 3: Working documents

Three working documents were available to the WKSAR. They are included in full below.

WD1: Preliminary sardine spawning–stock biomass estimates at ICES Divisions 8.ab applying the DEPM in 2011. Paz Díaz, Maria Santos, Ana Lago de Lanzós, Concha Franco and Andrés Uriarte.

WD2: Preliminary sardine spawning–stock biomass estimates at ICES Divisions 8.ab applying the DEPM in 2014. Paz Díaz, Maria Santos, Ana Lago de Lanzós, Concha Franco, Jose Ramón Pérez and Andrés Uriarte.

WD3: Sardine growth data analysis. L. Citores, A. Uriarte, A. Silva, P. Carrera, E. Dduhamel, L. Pawlowski, … *et al*. (Other members of WGHANSA, to be further defined).

Preliminary sardine spawning stock biomass estimates at ICES divisions VIIIab applying the DEPM in 2011

Paz Díaz[1], Maria Santos[2], Ana Lago de Lanzós[1], Concha Franco[1] and Andrés Uriarte[2].

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Introduction

The Daily Egg Production Method (DEPM) for sardine was first used to estimate the spawning stock biomass of the Atlanto-Iberian sardine stock in 1988 (Cunha *et al.,* 1992; García *et al.,* 1992). Afterwards was repeated in 1990, 1997, 1999, 2002, 2005 and 2008 based on coordinated surveys by IPIMAR (Instituto de Investigação das Pescas e do Mar, Portugal) and IEO (Instituto Español de Oceanografía, Spain). Since 1999 surveys have been planned and executed under the auspices of ICES on a triennial basis. DEPM surveys for the Atlantic-Iberian sardine took place covering the area from the Gulf of Cadiz to the Bay of Biscay. The region from the Gulf of Cadiz to the northern Portugal/Spain border (Minho River) was surveyed by IPIMAR, while IEO covered the northwestern and north Iberian Peninsula (IXa N and VIIIc).

Sardine in Divisions VIIIab in the Bay of Biscay, beyond the boundaries of Atlanto-Iberian sardine stock has also been covered by the IEO (and in the inner part of the Bay of Biscay (VIIIb in April of 1997, 1999, 2002 and 2008, up to a maximum of to 45°N) and by AZTI (Divisions VIIIabc in several years from 1999 to 2010 in May, up to a maximum of 48ºN, including the estimates of egg production in 1999, 2002 and 2008). The egg coverage of these areas VIIIab by AZTI and IEO were planned for 2008 within WGACEGG and estimations of Egg production for the areas covered in VIIIab in this year were reported to this WG (ICES CM 2008/LRC:17).

For 2011, a complete coverage of Divisions VIIIab was planned jointly by IEO and AZTI within the framework of WGACEGG (ICES 2010) and the initiative was by the first time funded by the DCF.

This working document provides a brief description of the sampling, laboratory analysis and estimation procedures conducted by AZTI and IEO in the VIIIab ICES divisions to obtain the Spawning Stock Biomass (SSB) estimate for 2011 in this area by the application of the Daily Egg Production Method. The Working Document provides in addition preliminary estimates of all parameters of the DEPM and of SSB. Current estimates are just provided provisionally until definitive estimates are produced before next WGACEGG.

The estimation was based on procedures and software adapted and developed during the WKRESTIM that took place in 2009, as well as the revision of the sardine DEPM historical series (1988-2008) in divisions IXa and VIIIc that was carried out in 2011. As this is the first time that SSB estimates are provided for this area by AZTI and IEO institutes, this estimation must be discussed and validated by the WGACEGG before used for assessment purposes of the sardine in Divisions VIIIabd.

Methodology

Plankton samples, along a grid of parallel transects perpendicular to the coast, were obtained for spawning area delimitation and daily egg production estimation; concurrently, fishing hauls were undertaken for the estimation of adult parameters (sex ratio, female weight, batch fecundity and spawning fraction) within the mature component of the population to obtain the Daily fecundity and finally the Spawning Stock Biomass. All the methodology for the sampling survey and the estimates performance are described in the manual: annex 7 of WGACEGG 2010 report (ICES 2010: ICES CM 2010/SSGESST:24).

Surveying and sample processing

The ICES area VIIIab was surveyed from the French/Spanish border in the Bay of Biscay to 45ºN within the survey Sareva 0411 from the 9th to the 15th of April, while the remainder area of the Bay of Biscay from 45ºN to 48ºN latitude was sampled within the survey Bioman from the 14th to the 26th of May (**Figure 1**).

The protocol for collecting plankton samples, oceanographic parameters and adult fish samples and the differences between institutes are summarized on **table 1** below.

During the survey, part of the sampling area to the North (between 47º and 48ºN) was closed by French authorities to any operation, so it was impossible to sample that area. Moreover during the sampling of the last transect in the North limit the weather was extremely bad and the sampling was finish before to reach 48ºN (last transect was carried out at 47º23' North).

Fishing hauls were obtained with a pelagic trawler following sardine schools detection by the echo-sounder (**Figure 2**). The sampling procedure used for adults is summarized in **table 1**.

All sardine eggs from PairoVET samples were sorted, counted and staged according to the 11 stages of development classification (adapted from Gamulin and Hure, 1955).

The preserved ovaries were weighted in laboratory and the obtained weights corrected by a conversion factor (between fresh and formaldehyde fixed material) established previously. These ovaries were then processed for histology: they were embedded in resin, the histological sections were stained with haematoxylin and eosin, and the slides examined and scored for their maturity state (most advanced oocyte batch) and POF presence and age (Hunter and Macewicz 1985, Pérez et al. 1992a, Ganias et al. 2004, Ganias et al. 2007). Prior to fecundity estimation, hydrated ovaries were also processed histologically in order to check POF presence and thus avoid underestimating fecundity (Pérez et al. 1992b). The individual batch fecundity was then measured, by means of the gravimetric method applied to the hydrated oocytes, on 3 whole mount sub-samples per ovary, weighting on average 50-150 mg (Hunter et al. 1985).

Data analysis

Estimation of the Total Egg Production an area calculation (both surveyed and positive) was carried out using the R packages (*geofun, eggsplore and shachar*) available within the open source project *ichthyoanalysis* (http://sourceforge.net/projects/ichthyoanalysis). Some routines of the R packages used were updated since the 2008 versions. All the procedures are described in the Manual: annex 7 of WGACEGG 2010 report (ICES 2010: ICES CM 2010/SSGESST: 24).

The total surveyed area is calculated as the sum of the area represented by each station and the spawning area is delimited with the outer zero sardine egg stations. To avoid high and low extremes values detected in the area represented by each of the sampled stations, these values of area per station were forced to the minimum and maximum values of 25 and 175 km^2 respectively. The range 25-175 was selected to be a mean interval suitable according to the distance between transect and stations.

The eggs staged in the laboratory were transformed into daily cohort abundances using a multinomial model (Bayesian ageing method, Bernal *et al*. 2008). The Bayesian ageing method requires a probability function of spawning time. Spawning time distribution was assumed with a peak at 21:00 GMT for sardine. and the spawning curve considered in order to be more conservative and allow a longer spawning period that few eggs were excluded from the analyses (how.complete=0.99). The upper age cutting limit was estimated as the maximum age of unhitched eggs (at how. complete=0.99) for the whole strata corresponding with the percentile 95 of the incubation temperature of the eggs sampled in the strata, i.e. a value not dependent on the individual station. The lower age cutting excluded the first cohort of stations in which the sampling time is included within the daily spawning period.

Daily egg production (P0) and mortality (z) rates are estimated by fitting an exponential decay mortality model to the egg abundance by cohorts and corresponding mean age:

$$E[P] = P_0 \, e^{-Z\,age}$$

The model was fitted as a generalized linear model (GLM) with negative binomial distribution and log link. Finally, the total egg production is calculated multiplying the daily egg production by the positive area.

$$P_{tot} = P_0 \cdot A+$$

The adult parameters estimated for each fishing haul considered only the mature fraction of the population (determined by the fish macroscopic maturity data). Before the estimation of the mean female weight per haul (W), the individual total weight of the hydrated females was corrected by a linear regression between the total weight of non-hydrated females and their corresponding gonad-free weight (Wnov). The sex ratio (R) in weight per haul was obtained as the quotient between the total weight of females and the total weight of males and females. The expected individual batch fecundity (F) for all mature females (hydrated and non-hydrated) is estimated by the hydrated egg method (Hunter *et al*., 1985), i.e. by modeling the individual batch fecundity observed (Fobs) in the sample of hydrated females and their gonad free weight (Wnov) by a GLM and applying this subsequently to all mature females. The spawning fraction (S), the fraction of females spawning per day was determined, for each haul, as the average number of females with Day-1 and Day-2 POF, divided by the total number of mature females. The hydrated females are not included due to possible oversampling of active spawning females close to the peak spawning time. In this case, the number of females with Day-0 POF (of the mature females) was corrected by the average number of females with Day-1 or Day-2 POF (Picquelle and Stauffer 1985, Pérez *et al*., 1992a, Motos 1994, Ganias *et al*., 2007).

The mean and variance of the adult parameters for all the samples collected was then obtained using the methodology from Picquelle and Stauffer (1985) for cluster sampling (weighted means and variances). All estimations and statistical analysis were performed using the R software (http://www.R-project.org).

Preliminary results

Total daily egg production

Sea surface temperature and salinity in the area ranged from 12.4 to 17.9ºC and from 33.9 to 35.8 (**Figure 3**). Warmer waters were found between 45º north and 47 ºN, and lower salinities were found in the innermost sector of Bay of Biscay due to the influence of the Gironde River. Notice that the sampling from 45ºN to the North started one month later.

A total of 1026 CUFES samples and 555 CalVET samples were obtained. From those 399 and 250 respectively were positive for sardine eggs (**Table 2** and **Figure 4**). The average of eggs in each station was 3.6 egg/m^3 for CUFES and 135egg/m^2 for PairoVET. The maximum sardine eggs/m^2 in a station was 2,322. Sardine eggs were mostly found within the platform and below 45ºN during the April part of the sampling, a month later from 45ºN to the North few sardine eggs were encountered, part of them were found over the 200m depth isoline (**Figure 4**).

The sampling covered a total area of 68,185 km^2 of which 33,245 km^2 (48.8 %) were considered the spawning area (**Figure 5**). Notice that 54 stations inside positive area were really negative sardine stations. A daily mortality rate of 0.287 and a daily egg production of 138.25 egg/m^2 were estimated (**figure 6**). The total egg production in the area was preliminarily estimated in 4.60 10^{12} egg/day (CV = 19%).

Adult parameters and spawning stock biomass

The linear regression model between gonad-free-weight and total weight fitted to non-hydrated females is given in **Table 3**. The model fitted the data adequately (**Figure 7**, R^2=98.2%, n= 198). The female mean weight was obtained as the weighted mean of the average female weights per sample (Lasker, 1985).

For the batch fecundity 18 hydrated females from 4 samples, ranging from 40 to 84 g gonad free weight were examined. The females until 45ºN ranged from 48.6 to 84 g and those from 45ºN to the North ranged from 40 to 78.8 g gonad free weight. The coefficients of the generalised linear model with negative binomial and identity link are given in **Table 4** and the fitted model is shown in **Figure 8**. The overall batch fecundity estimate was obtained as a weighted sample mean of the batch fecundity per sample (Lasker, 1985).

Estimates of the mean female weight, batch fecundity, sex ratio, spawning frequency and spawning stock biomass with their CVs are given in **Table 5**. The *SSB* estimate from the application of the DEPM was 136.56 t with a CV of 43.2.

Discussion

Current estimates are just provided provisionally until definitive estimates are produced (before next WGACEGG). Despite the preliminary nature of results, this WD presents the first essay of applying the DEPM method to estimate the spawning stock to the North of the Atlanto Ibero stock. The coordinated work of AZTI and IEO allows achieving a complete coverage of the area. However it seems evident that the major problem might come from the lag in time of the southern and northern coverage of the areas. In the current application the lag in time between the SAREVA and BIOMAN surveys was longer than in former years, lasting in total an entire month and this has produced a major change in sea surface temperature in the area. In addition it seems that spawning may have suffered changes during such inner period as to apparently reduce the amount of spawning. All these issues require further analysis in terms of implications for the best estimation procedures, reliability of the results and future planning of the next survey in 2014. Some of this discussion can be carried out within the frame of the estimations of the DEPM adult and egg parameters available from previous years in the same area VIIIab or in the neighborhoods (in VIIIc).

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Table 1. Characteristics of the egg and adult sampling in both surveys

DEPM Surveys	**Spain (IEO)**	**Spain (AZTI)**
Survey	**SAREVA0411**	**BIOMAN 2011**
Survey area	**VIII (until 45ºN)**	**VIII (45ºN-48ºN)**
SURVEY EGGS		
Sampling grid	8 (transect) x 3 (station)	15 or 7 (transect) x 3 (station)
PairofVET Eggs staged (n nets) (stages from Gamulin and Hure, 1955)	All (1 net)	max50 (2 nets)
Sampling maximum depth (m)	100	100
Temperature for egg ageing	10 m	
Peak spawning hour	(PDF 21 ± 2 * 3)	
Upper age cutting	0.99	
Egg ageing	Bayesian (Bernal et al, 2008)	
Egg production	GLM	
CUFES, mesh 335	3 nm (sample unit)	1.5nm(sample unit)
CUFES Eggs counted	All	All
Hydrographic sensor	CTD (SBE 37) CTD SBE 25	CTD(RBR)
Flowmeter	Y	Y
Clinometer	Y	NO
Environmental data	Temperature, and salinity in the water column	Temperature and salinity in the water column
SURVEY ADULTS		
Biological sampling:	On fresh material, on board of the R/V	On formaldehyde and frosen(for otoliths)
Sample size	60 indiv randomly 100 (30 mature female); extra if needed and if hydrated found	60 indiv randomly max 120 (25 mature female); extra if needed for hydrated females
Fixation	Buffered formaldehyde 4% (distilled water)	Buffered formaldehyde 4% (tap water)
Preservation	Formalin	Buffered formaldehyde 4% (tap water)
Histology:		
- Embedding material	Resin	Resin
- Stain	Haematoxilin-Eosin	Haematoxilin-Eosin
S estimation	Day 1 and Day 2 POFs (according to Pérez et al. 1992a and Ganias et al. 2007)	Day 1 and Day 2 POFs (according to Pérez et al. 1992a and Ganias et al. 2007)
R estimation	The observed weight fraction of the females	The observed weight fraction of the females
F estimation	On hydrated females (without POFs), according to Pérez et al. 1992b	On hydrated females (without POFs), according to Pérez et al. 1992b

Table 2. Results from the analysis of icthyoplankton and adult samples

Institute	**IEO**	**AZTI**
Survey area	VIII until 45 ºN	VIII 45-48ºN
ICHTHYOPLANKTON		
R/V	Cornide de Saavedra	Investigador
Date	09/04-15/04	16-26/05/2011
Transects	11	33
PairoVET stations	134	421
Positive stations	114	136
Tot. Eggs (nº nets)	2764 (1 net)	2951(2 nets)
Max eggs/m2	2322	1870
Temp (10m) min/mean/max	13/14/14.7	12/16.3/17.88
SSS	34.7/35.4/35.8	33.5/35.18/35.8
SST		13/16.6/18.6
Max age	54.4	
CUFES stations	83	894
Positive CUFES stations	77	322
Tot. Eggs CUFES	22328	9509
Max eggs/m3	92.12	73.47
Hydrographic stations	134	421
ADULTS		
Number Hauls R/V (total)	12	
- Pelagic Trawls	12	
- Bottom trawls	-	-
Numer Hauls C/V	-	9
Number (+) trawls	3	5
Number (+) trawls used for analysis		
Depth range (m)	63-143	21-1000
Time range	During the hole day	During the hole day
Total sardine individuals	302	305
Length range (mm)	145-243	143-222
Weight range (g)female &male	41.7-101.8	23.1-82.8
Female for histology	129	95
Hydrated females	14	25
Otholites	129	129
Female Ages Range	1-9	1-7

Table 3. Coefficients resulted from the linear regression model between gonad-free-weight and total weight fitted to non-hydrated females with their standard error and the P-Value

Parameter	Estimate	Standard error	P-Value
Intercept	-3.0645	0.5578	0
Slope	1.1071	0.0106	0

Table 4. Coefficients of the generalised linear model with negative binomial distribution and identity link between the number of hydrated oocytes and the female gonad free weight (wgf).

Parameter	estimate	Standard error	Pr(>|t|)
Intercept	-4102	7165	0.567
wgf	570	128	8.8e-06

Table 5. All the parameter to estimate de Spawning Stock Biomass (SSB) using the Daily Egg Production Method (DEPM) for 2011 with correspondent coefficients of variation (CV) in brackets.

Institute	**IEO-AZTI**
Area	**VIIIab**
Eggs 2011	
Survey area (Km^2)	68185
Positive area (Km^2)	33245
P0 ($eggs/m^2/day$)	138.25 (19.1)
Z ($hour^{-1}$)	-0.0141* (41.6)
Daily mortality rate (%)	28.71
P0 tot (eggs/day)	4.60×10^{12} (19.1)
Adults 2011	
Female Weight (g)	54.08 (6.9)
Batch Fecundity	25336 (9.5)
Sex Ratio	0.451(14.8)
Spawning Fraction	0.133 (33.8)
Spawning Biomass – thousand tons	136.56 (43.2)

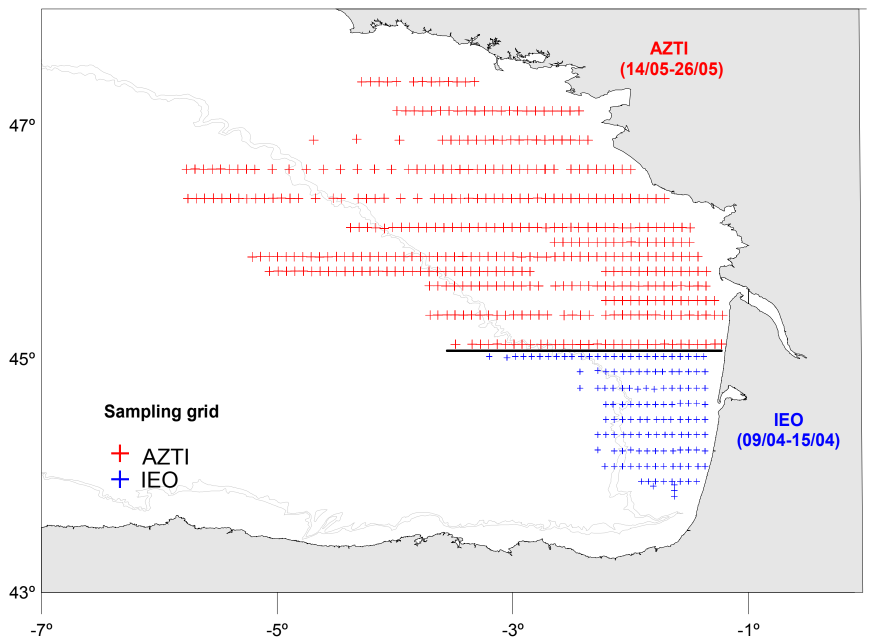


Figure 1. Plankton sampling grid by institute. Black line shows the limits for sampling coverage according to planned and coordinated sardine DEPM survey in VIIIab area.

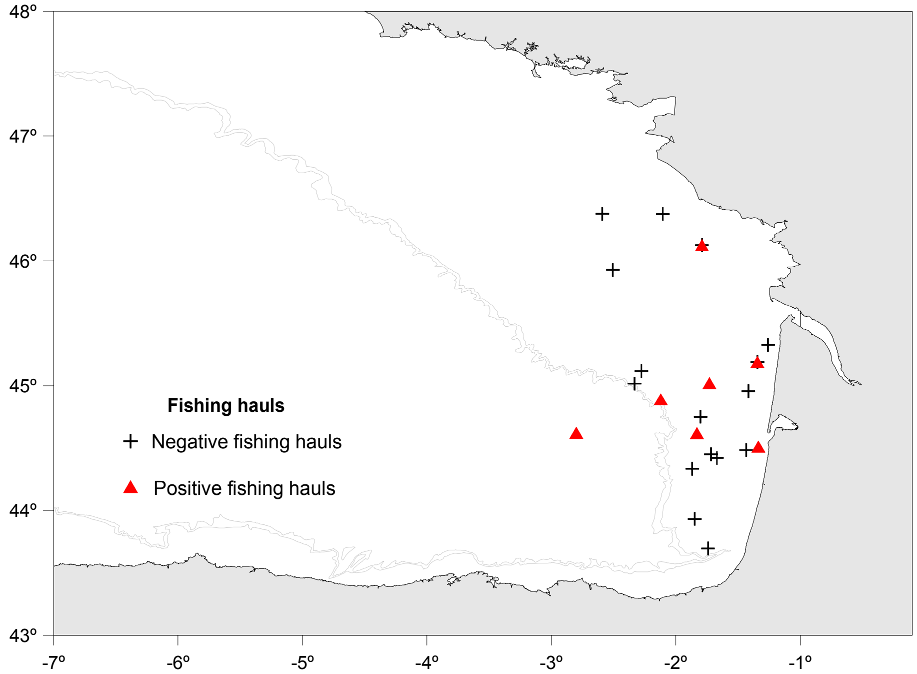
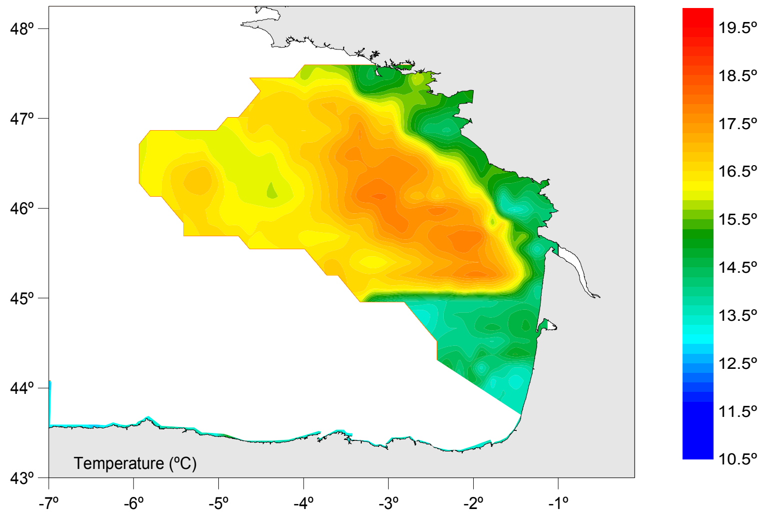


Figure 2. Spatial of sardine hauls (+, hauls without sardine presence or scarce presence).



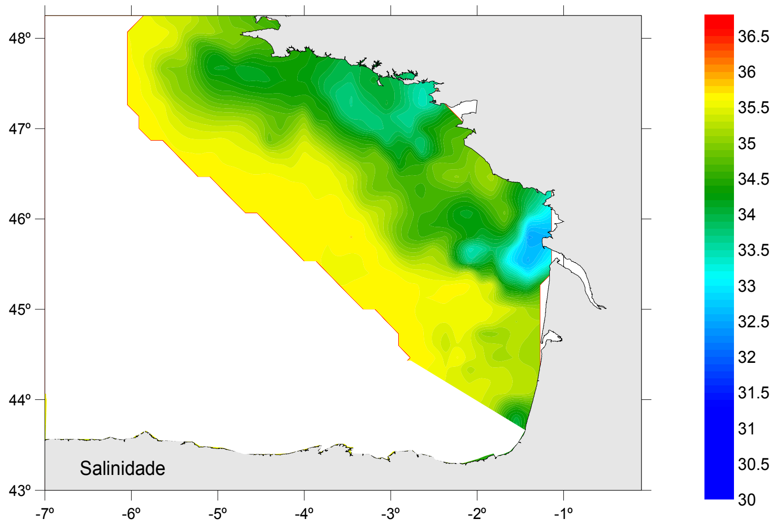


Figure 3. Sea surface temperature in ºC (upper panel) and Sea surface salinity (down panel). Notice that until 45ºN was sampling from 9 to 15 of April and from 45ºN to the North was sampling from 16 to 26 May.

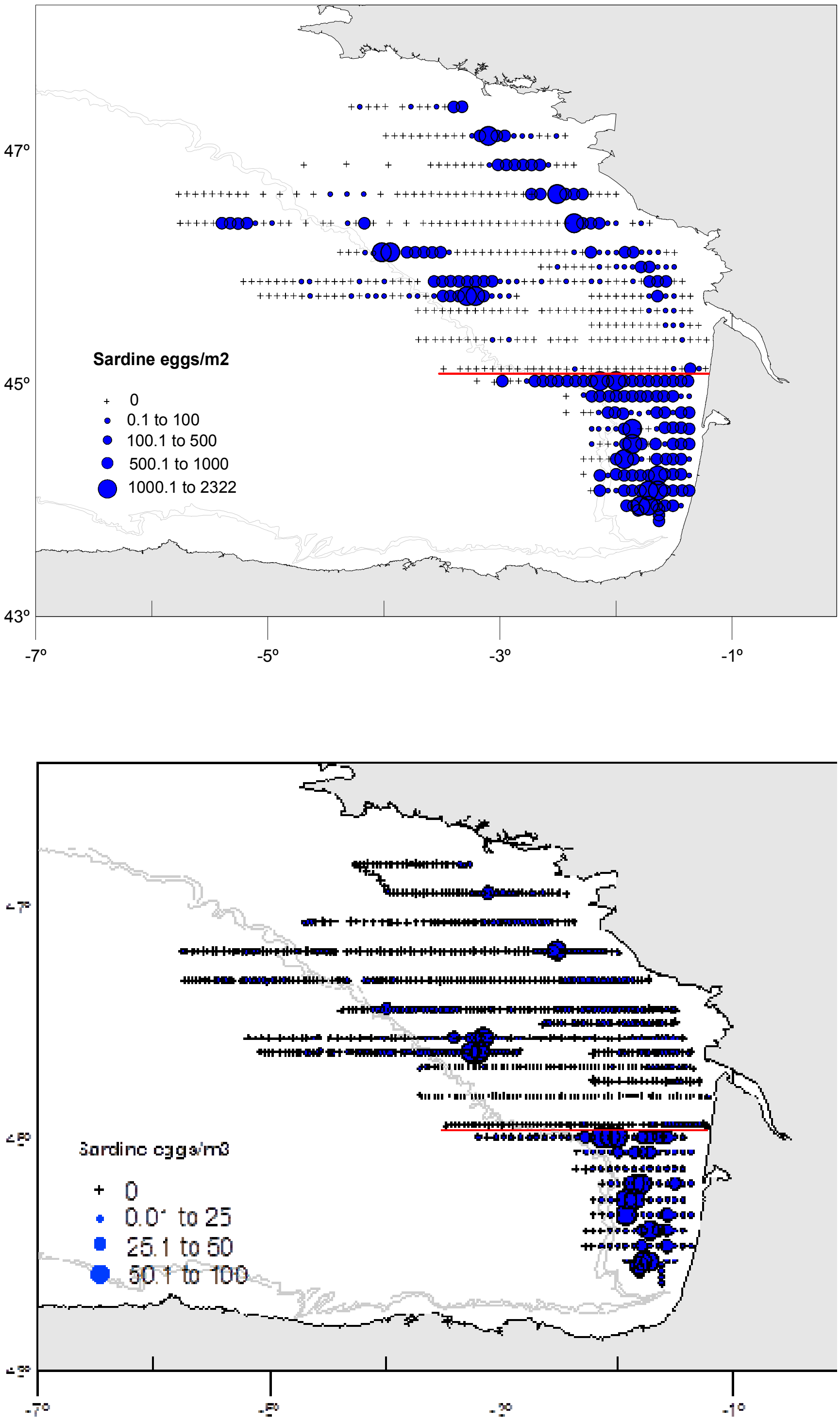


Figure 4. Sardine egg distribution. Egg/m^2 from PairoVET sampling (Upper panel) and egg/m^3 from CUFES sampling (down panel).

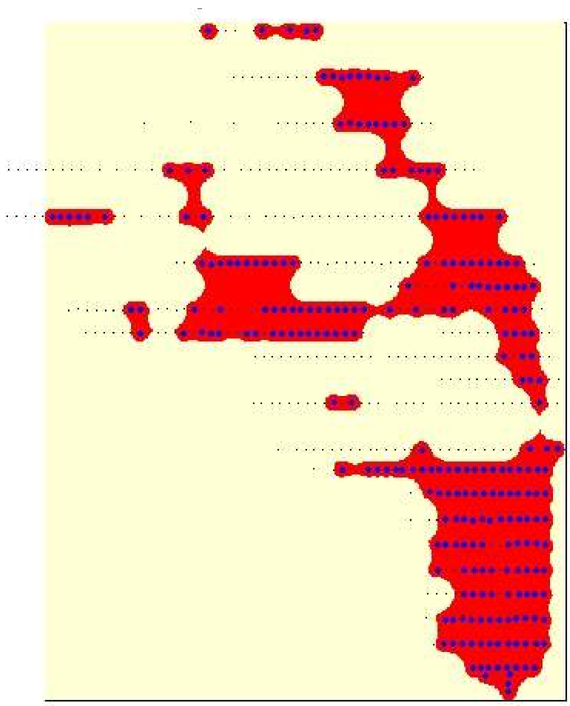


Figure 5. Delimitation of the spawning area for sardine in the region VIIIab.

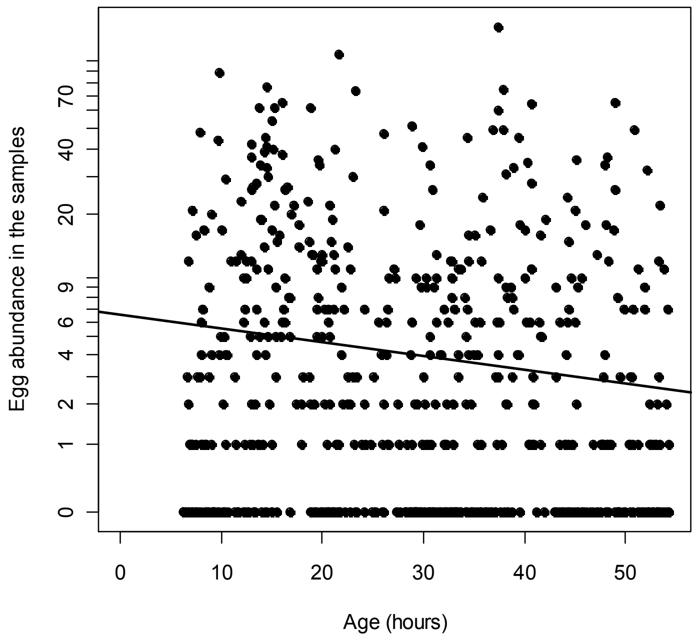


Figure 6. Exponential mortality model adjusted applying a GLM to the data obtained in the ageing following the Bayesian method (spawning peak 21:00h).The black line is the adjusted line. Data in Log scale.

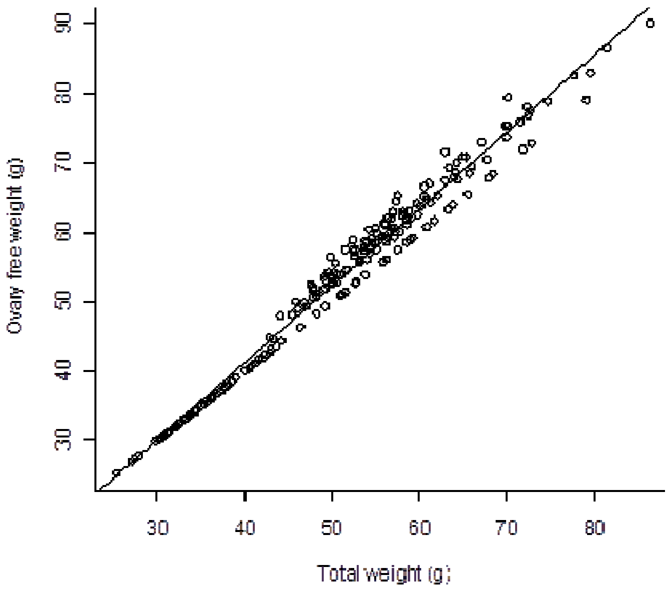


Figure 7. Linear regression model between gonad-free-weight and total weight fitted to non-hydrated females.

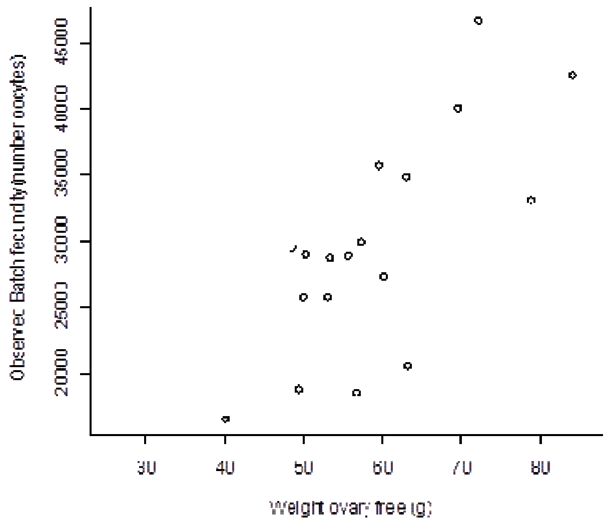


Figure 8. Generalised linear model between gonad-free-weight and hydrated oocyted fitted to hydrated females.

Preliminary sardine spawning stock biomass estimates at ICES divisions VIIIab applying the DEPM in 2014

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Introduction

The Daily Egg Production Method (DEPM) for sardine was first used to estimate the spawning stock biomass of the Atlanto-Iberian sardine stock in 1988 (Cunha *et al.,* 1992; García *et al.,* 1992). Afterwards was repeated in 1990, 1997, 1999, 2002, 2005 and 2008 based on coordinated surveys by IPIMAR (Instituto de Investigação das Pescas e do Mar, Portugal) and IEO (Instituto Español de Oceanografía, Spain). Since 1999 surveys have been planned and executed under the auspices of ICES on a triennial basis. DEPM surveys for the Atlantic-Iberian sardine took place covering the area from the Gulf of Cadiz to the Bay of Biscay. The region from the Gulf of Cadiz to the northern Portugal/Spain border (Minho River) was surveyed by IPIMAR, while IEO covered the northwestern and north Iberian Peninsula (IXa N and VIIIc).

Sardine in Divisions VIIIab in the Bay of Biscay, beyond the boundaries of Atlanto-Iberian sardine stock has also been covered by the IEO in the inner part of the Bay of Biscay (VIIIb in April of 1997, 1999, 2002, 2008 and 2011 up to a maximum of 45°N) (ICES, 2012, Díaz *et al*., 2012), and by AZTI (Divisions VIIIabc in several years from 1999 to 2010 in May, up to a maximum of 48ºN, including the estimates of egg production in 1999, 2002 and 2008). The egg coverage of these areas VIIIab by AZTI and IEO were planned for 2008 within WGACEGG and estimations of Egg production for the areas covered in VIIIab in this year were reported to this WG (ICES CM 2008/LRC:17).

For 2011, a complete coverage of Divisions VIIIab was planned jointly by IEO and AZTI within the framework of WGACEGG (ICES 2010) and the initiative was by the first time funded by the DCF. In 2013 (ICES 2013) a sardine DEPM surveys in region VIIIab was planned and coordinated for 2014.

This working document provides a brief description of the sampling, laboratory analysis and estimation procedures conducted by AZTI and IEO in the VIIIab ICES divisions to obtain the Spawning Stock Biomass (SSB) estimate for 2014 in this area by the application of the Daily Egg Production Method. The Working Document provides in addition preliminary estimates of all parameters of the DEPM and of SSB. Current estimates are just provided provisionally until definitive estimates are produced before next WGACEGG.

The estimation was based on procedures and software adapted and developed during the WKRESTIM that took place in 2009, as well as the revision of the sardine DEPM historical series (1988-2008) in divisions IXa and VIIIc that was carried out in 2011. As this is the second time that SSB estimates are provided for this area by AZTI and IEO institutes, this estimation must be discussed and validated by the WGACEGG before used for assessment purposes of the sardine in Divisions VIIIabd.

Methodology

Plankton samples, along a grid of parallel transects perpendicular to the coast, were obtained for spawning area delimitation and daily egg production estimation; concurrently, fishing hauls were undertaken for the estimation of adult parameters (sex ratio, female weight, batch fecundity and spawning fraction) within the mature component of the population to obtain the

Daily fecundity and finally the Spawning Stock Biomass. All the methodology for the sampling survey and the estimates performance are described in the manual: annex 7 of WGACEGG 2010 report (ICES 2010: ICES CM 2010/SSGESST:24).

Surveying and sample processing

The ICES area VIIIab was surveyed from the French/Spanish border in the Bay of Biscay to 45ºN within the survey Sareva 0414 from the 9th to the 16th of April, while the remainder area of the Bay of Biscay from 45ºN to 48ºN latitude was sampled within the survey Bioman from the 11th to the 23th of May 2014 (**Figure 1**).

The protocol for collecting plankton samples, oceanographic parameters and adult fish samples and the differences between institutes are summarized on **table 1** below.

Fishing hauls were obtained with a pelagic trawler following sardine schools detection by the echo-sounder (**Figure 2**). The sampling procedure used for adults is summarized in **table 1**.

All sardine eggs from PairoVET samples were sorted, counted and staged according to the 11 stages of development classification (adapted from Gamulin and Hure, 1955).

The preserved ovaries were weighted in laboratory and the obtained weights corrected by a conversion factor (between fresh and formaldehyde fixed material) established previously. These ovaries were then processed for histology: they were embedded in resin, the histological sections were stained with haematoxylin and eosin, and the slides examined and scored for their maturity state (most advanced oocyte batch) and POF presence and age (Hunter and Macewicz 1985, Pérez et al. 1992a, Ganias et al. 2004, Ganias et al. 2007). Prior to fecundity estimation, hydrated ovaries were also processed histologically in order to check POF presence and thus avoid underestimating fecundity (Pérez et al. 1992b). The individual batch fecundity was then measured, by means of the gravimetric method applied to the hydrated oocytes, on 3 whole mount sub-samples per ovary, weighting on average 50-150 mg (Hunter et al. 1985).

Data analysis

Estimation of the Total Egg Production and area calculation (both surveyed and positive) was carried out using the R packages (*geofun, eggsplore and shachar*) available within the open source project *ichthyoanalysis* (http://sourceforge.net/projects/ichthyoanalysis). Some routines of the R packages used were updated since the 2008 versions. All the procedures are described in the Manual: annex 7 of WGACEGG 2010 report (ICES 2010: ICES CM 2010/SSGESST: 24).

The total surveyed area is calculated as the sum of the area represented by each station and the spawning area is delimited with the outer zero sardine egg stations. To avoid high and low extremes values detected in the area represented by each of the sampled stations, these values of area per station were forced to the minimum and maximum values of 25 and 175 km^2 respectively. The range 25-175 was selected to be a mean interval suitable according to the distance between transect and stations.

The eggs staged in the laboratory were transformed into daily cohort abundances using a multinomial model (Bayesian ageing method, Bernal *et al*. 2008). The Bayesian ageing method requires a probability function of spawning time. Spawning time distribution was assumed with a peak at 21:00 GMT for sardine. and the spawning curve considered in order to be more conservative and allow a longer spawning period that few eggs were excluded from the analyses (how.complete=0.99). The upper age cutting limit was estimated as the maximum age of unhitched eggs (at how. complete=0.99) for the whole strata corresponding with the percentile 95 of the incubation temperature of the eggs sampled in the strata, i.e. a value not dependent on the individual station. The lower age cutting excluded the first cohort of stations in which the sampling time is included within the daily spawning period.

Daily egg production (P_0) and mortality (z) rates are estimated by fitting an exponential decay mortality model to the egg abundance by cohorts and corresponding mean age:

$$E[P] = P_0 \, e^{-Z \, age}$$

The model was fitted as a generalized linear model (GLM) with negative binomial distribution and log link. Finally, the total egg production is calculated multiplying the daily egg production by the positive area.

$$P_{tot} = P_0 \cdot A+$$

The adult parameters estimated for each fishing haul considered only the mature fraction of the population (determined by the fish macroscopic maturity data). Before the estimation of the mean female weight per haul (W), the individual total weight of the hydrated females was corrected by a linear regression between the total weight of non-hydrated females and their corresponding gonad-free weight (Wnov). The sex ratio (R) in weight per haul was obtained as the quotient between the total weight of females and the total weight of males and females. The expected individual batch fecundity (F) for all mature females (hydrated and non-hydrated) is estimated by the hydrated egg method (Hunter *et al*., 1985), i.e. by modeling the individual batch fecundity observed (Fobs) in the sample of hydrated females and their gonad free weight (Wnov) by a GLM and applying this subsequently to all mature females. The spawning fraction (S), the fraction of females spawning per day was determined, for each haul, as the average number of females with Day-1 and Day-2 POF, divided by the total number of mature females. The hydrated females are not included due to possible oversampling of active spawning females close to the peak spawning time. In this case, the number of females with Day-0 POF (of the mature females) was corrected by the average number of females with Day-1 or Day-2 POF (Picquelle and Stauffer 1985, Pérez *et al*., 1992a, Motos 1994, Ganias *et al*., 2007).

The mean and variance of the adult parameters for all the samples collected was then obtained using the methodology from Picquelle and Stauffer (1985) for cluster sampling (weighted means and variances). All estimations and statistical analysis were performed using the R software (http://www.R-project.org).

Preliminary results

Total egg production

Sea surface temperature and salinity in the area ranged from 11.8 to 15.5ºC and from 29.9 to 35.6 (**Figure 3**). Warmer waters were found between 45ºN and 47 ºN, and lower salinities were found in the innermost sector of Bay of Biscay due to the influence of the Gironde River. Notice that the sampling from 45ºN to the North started one month later.

A total of 1305 CUFES samples and 648 CalVET samples were obtained. From those 740 and 387 respectively were positive for sardine eggs (**Table 2** and **Figure 4**). The maximum sardine eggs/m^2 in a station was 4220. Sardine eggs were mostly found within the platform and below 45ºN during the April part of the sampling, a month later from 45ºN to the North, part of them were found over the 100m depth isoline and part over the 200m depth isoline from the Gironde area to the North.(**Figures 4 and 5**).

Surveyed, spawning area, mortality (hours^{-1}), daily egg production (egg/m^2/day) and total egg production (eggs/day) were estimated for the area covered by each institute (Table 6). The sampling covered a total area of 83424 km^2 of which 54426 km^2 (65.2 %) were considered the spawning area (**Figure 5**). Exponential mortality model adjusted applying a GLM to the data obtained in the ageing following the Bayesian method (spawning peak 21:00h) is shown in

figure 6. The total egg production in area VIIIab, calculated as the sum of values obtained for the area covered by each institute, was preliminarily estimated in 7.72 x 10^{12} egg/day (CV = 13%).

Adult parameters and spawning stock biomass

The linear regression model between gonad-free-weight and total weight fitted to non-hydrated females for areas VIIIb up to 45ºN and VIIIab 45-48ºN is given in **Table 3**. The model fitted the data adequately (**Figure 7**, R^2=99.6%, n= 98 VIIIb up to 45ºN, and R^2=98.8%, n= 199 VIIIab 45-48ºN).

For the batch fecundity 51 and 21 hydrated females from area VIIIb up to 45ºN and VIIIab 45-48ºN respectively, ranging from 25 to 96.5 g gonad free weight were examined. The females until 45ºN ranged from 31.6 to 96.5 g and those from 45ºN to the North ranged from 25 to 86.7 g gonad free weight. The coefficients of the generalised linear models with negative binomial and identity link are given in **Table 4** and the fitted models are shown in **Figure 8**.

Estimates of the mean female weight, batch fecundity, sex ratio, spawning frequency and spawning stock biomass with their CVs are given in **Table 5** for each of the areas sampled by IEO and AZTI. The *SSB* estimate from the application of the DEPM was 409598 tons with a CV of 30.

Discussion

Current estimates are just provided provisionally until definitive estimates are produced (before next WGACEGG). Despite the preliminary nature of results, this WD presents an essay of applying the DEPM method to estimate the spawning stock to the North of the Atlanto Ibero stock adding the estimations for area VIIIb up to 45ºN (area covered by IEO) and VIIIab 45-48ºN (area covered by AZTI). The coordinated work of AZTI and IEO allows achieving a complete coverage of the area. However it seems evident that the major problem might come from the lag in time of the southern and northern coverage of the areas. In the current application the lag in time between the SAREVA and BIOMAN surveys was longer than in former years, lasting in total an entire month and this has produced a major change in sea surface temperature in the area. In addition it seems that spawning may have suffered changes during such inner period as to apparently increase the amount of spawning, opposite to 2011, where a reduction on the amount of spawning was observed between both surveys (SAREVA and BIOMAN). A remarkable increase in the sardine SSB estimate from the 2011 to 2014 DEPM application in VIIIab area is highlighted (136560 tons to 409598 tons respectively). All these issues require further analysis in terms of implications for the best estimation procedures, reliability of the results and future planning of the next survey in 2017. Some of this discussion can be carried out within the frame of the estimations of the DEPM adult and egg parameters available from previous years in the same area VIIIab or in the neighborhoods (in VIIIc).

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Table 1. Characteristics of the egg and adult sampling in both surveys

DEPM Surveys	Spain (IEO)	Spain (AZTI)
Survey	**SAREVA0414**	**BIOMAN 2014**
Survey area	**VIIIb (until 45ºN)**	**VIIIab (45ºN-48ºN)**
SURVEY EGGS		
Sampling grid	8 (transect) x 3 (station)	15 or 7.5 (transect) x 3 (station)
PairofVET Eggs staged (n nets) (stages from Gamulin and Hure, 1955)	All (1 net)	max50 (2 nets)
Sampling maximum depth (m)	100	100
Temperature for egg ageing	10 m	
Peak spawning hour	(PDF 21 ± 2 * 3)	
Upper age cutting	0.95	
Egg ageing	Bayesian (Bernal et al, 2008)	
Egg production	GLM	
CUFES, mesh 335	3 nm (sample unit)	1.5nm(sample unit)
CUFES Eggs counted	All	All
Hydrographic sensor	CTD (SBE 37) CTD SBE 25	CTD(RBR)
Flowmeter	Y	Y
Clinometer	Y	NO
Environmental data	Temperature, and salinity in the water column	Temperature and salinity in the water column
SURVEY ADULTS		
Biological sampling:	On fresh material, on board of the R/V	On fresh and on formaldehyde and frosen(for otoliths)
Sample size	60 indiv randomly 100 (30 mature female); extra if needed and if hydrated found	60 indiv randomly max 120 (25 mature female); extra if needed for hydrated females
Fixation	Buffered formaldehyde 4% (distilled water)	Buffered formaldehyde 4% (tap water)
Preservation	Formalin	Buffered formaldehyde 4% (tap water)
Histology:		
- Embedding material	Resin	Resin
- Stain	Haematoxilin-Eosin	Haematoxilin-Eosin
S estimation	Day 1 and Day 2 POFs (according to Pérez et al. 1992a and Ganias et al. 2007)	Day 1 and Day 2 POFs (according to Pérez et al. 1992a and Ganias et al. 2007)
R estimation	The observed weight fraction of the females	The observed weight fraction of the females
F estimation	On hydrated females (without POFs), according to Pérez et al. 1992b	On hydrated females (without POFs), according to Pérez et al. 1992b

Table 2. Results from the analysis of ichthyoplankton and adult samples

Institute	**IEO**	**AZTI**
Survey area	VIIIb up to 45 ºN	VIIIab 45-48ºN
ICHTHYOPLANKTON		
R/V	Vizconde de Eza	Ramón Margalef
Date	09/04-16/04	11/05-23/05
Transects	11	18
PairoVET stations	128	520
Positive stations	77	310
Tot. Eggs (nº nets)	1449 (1 net)	8245 (2 nets)
Max eggs/m2	2619	4220
Temp (10m) min/mean/max	12.3/13.2/14.5	11.8/14.2/15.5
SSS	33.8/34.8/35.6	29.9/34.3/35.6
CUFES stations	122	1183
Positive CUFES stations	98	642
Tot. Eggs CUFES	12067	14812
Max eggs/m^3	90.7	94.8
Hydrographic stations	127	520
ADULTS		
Number Hauls R/V (total)	13	30
- Pelagic Trawls	13	30
Numer Hauls C/V	-	-
Number (+) trawls	3	8
Time range	During daylight hours	24hours
Total sardine individuals	324	623
Length range (mm)	151-247	133-234
Weight range (g)female &male	24-113.5	13.7-97.1
Female for histology	148	218
Hydrated females	51	21
Otholites	146	354

Table 3. Coefficients resulted from the linear regression model between gonad-free-weight and total weight fitted to non-hydrated females with their standard error and the P-Value

Institute	Area	Parameter	Estimate	Standard error	Pr(>|t|)
IEO	VIIIb up to 45ºN	Intercept	-1.468302	0.460827	0.00195**
		Slope	1.095110	0.007166	<2e-16***
AZTI	VIIIab 45-48ºN	Intercept	-1.416080	0.385605	0.00031***
		Slope	1.098898	0.008365	< 2e-16***

Table 4. Coefficients of the generalised linear model with negative binomial distribution and identity link between the number of hydrated oocytes and the female gonad free weight (wgf).

Institute	Area	Parameter	Estimate	Standard error	Pr(>|t|)
IEO	VIIIb up to 45ºN	Intercept	-4574.9	2212.5	0.0387*
		Slope	497.7	59.8	<2e-16***
AZTI	VIIIab 45-48ºN	Intercept	-15415.9	7074	0.0293*
		Slope	796.9	180.2	9.77e-06***

Table 5. All the parameter to estimate de Spawning Stock Biomass (SSB) using the Daily Egg Production Method (DEPM) for 2014 with correspondent coefficients of variation (CV %) in brackets.

Institute	**IEO**	**AZTI**	**IEO-AZTI**
Area	**VIIIb up to 45ºN**	**VIIIab 45-48ºN**	**VIIIab**
Eggs 2014			
Survey area (Km^2)	13480.4	69943.6	83424
Positive area (Km^2)	7913.8	46511.8	54425.6
P0 ($eggs/m^2/day$)	214.2 (27.6)	129.4 (15.2)	
Z ($hour^{-1}$)	-0.021*** (28.7)	-0.013***(29.8)	
P0 tot (eggs/day)	1.70×10^{12} (27.6)	6.02×10^{12} (15.2)	7.72 (13)
Adults 2014			
Female Weight (g)	65.51 (22)	48.46 (5)	
Batch Fecundity	25545 (24)	21056 (12)	
Sex Ratio	0.59 (12)	0.482 (18)	
Spawning Fraction	0.084 (25)	0.089 (23)	
Spawning Biomass (tons)	86624 (51)	322974 (35)	409598 (30)

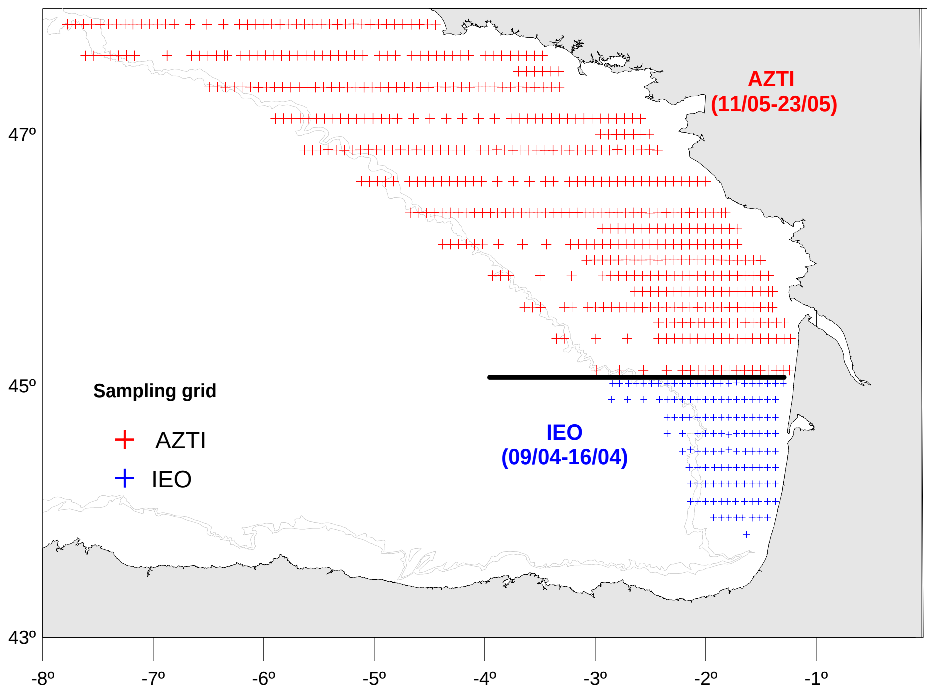


Figure 1. Plankton sampling grid by institute. Black line shows the limits for sampling coverage according to planned and coordinated sardine DEPM survey in VIIIab area.

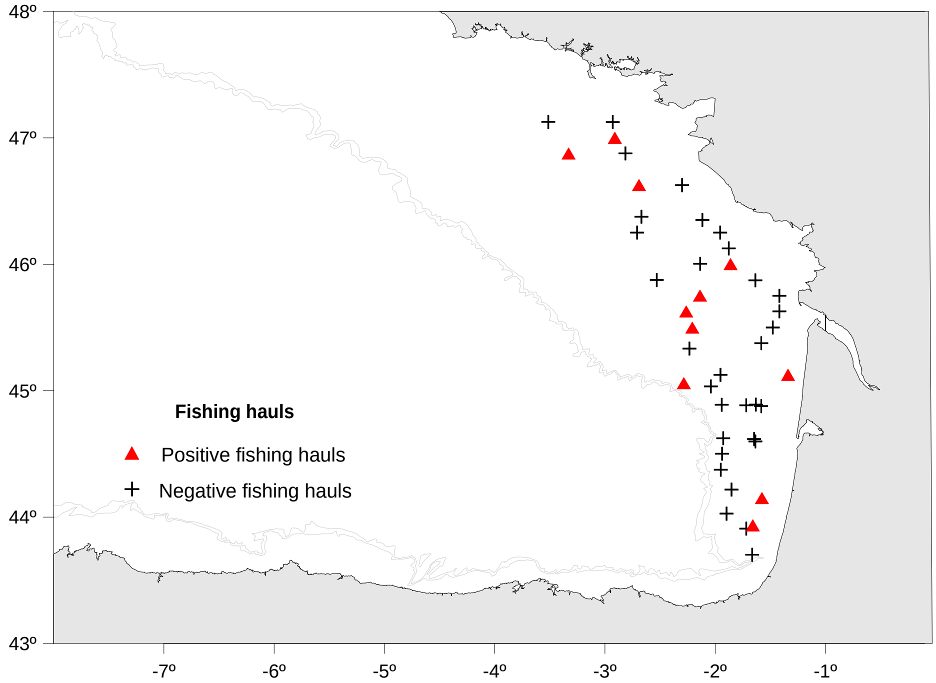


Figure 2. Spatial of sardine hauls (+, hauls without sardine presence or scarce presence).

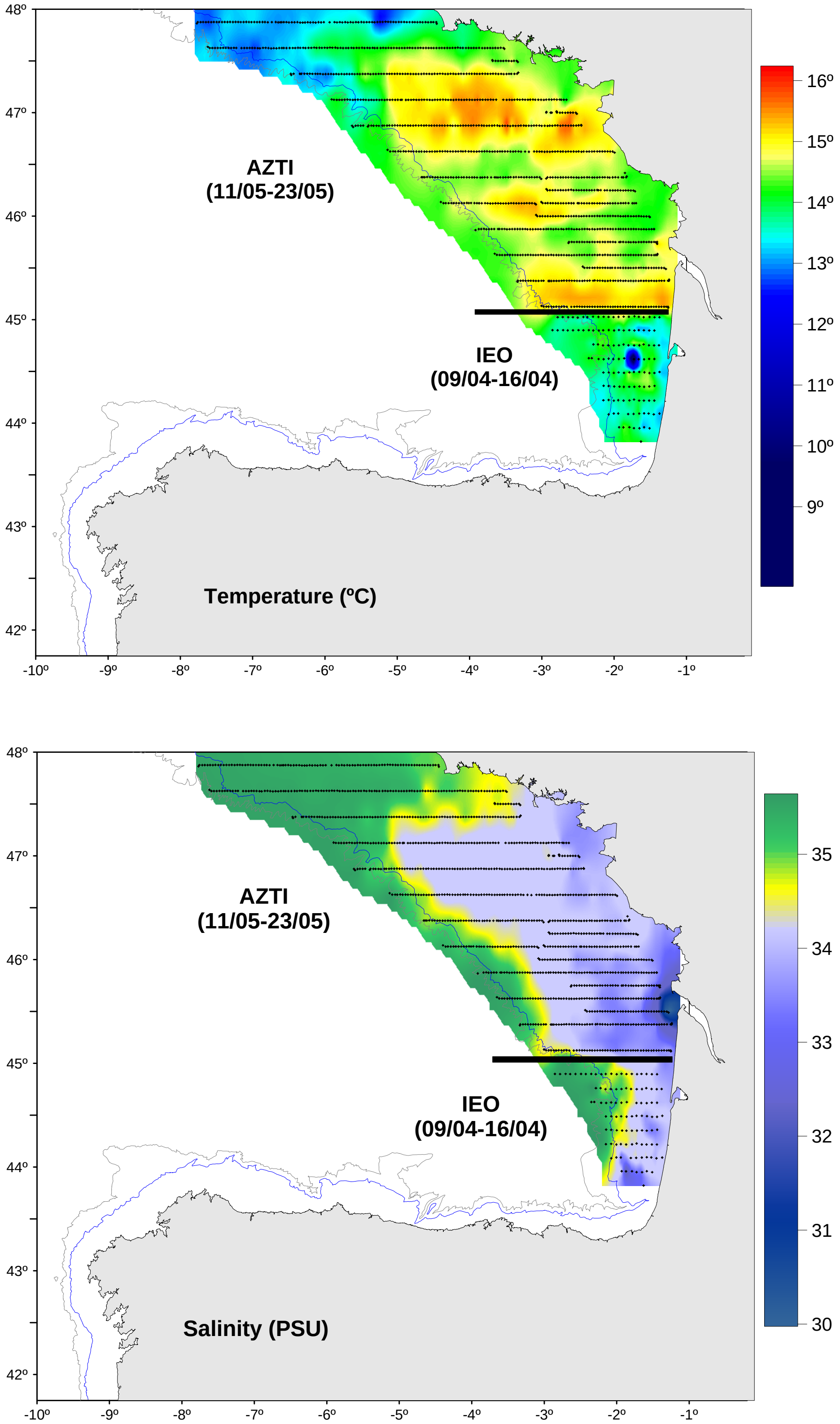
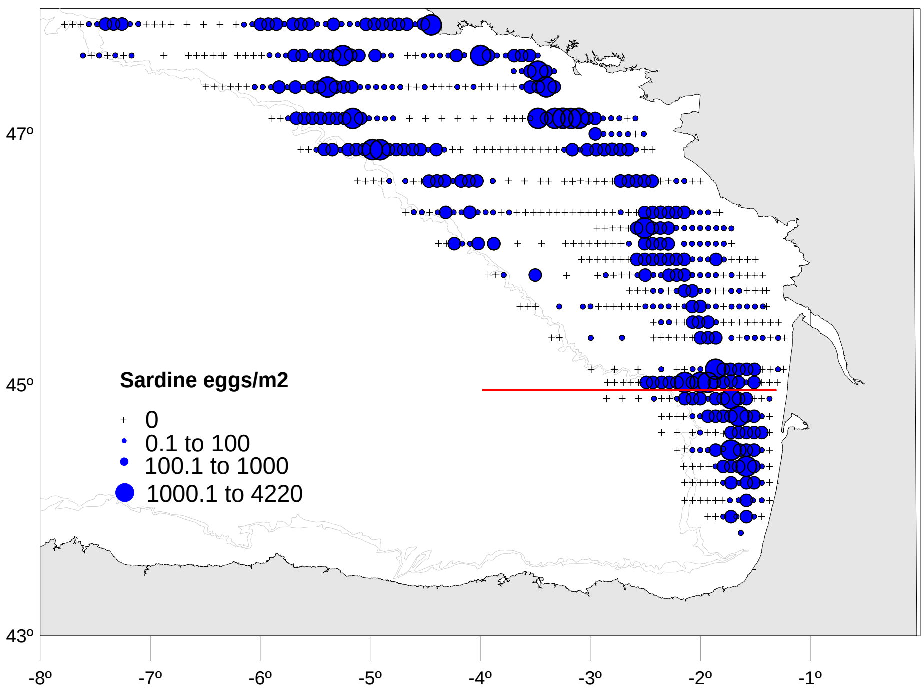


Figure 3. Sea surface temperature in ºC. Notice that until 45ºN was sampling from 9 to 16 of April and from 45ºN to the North was sampling from 11 to 23 May.



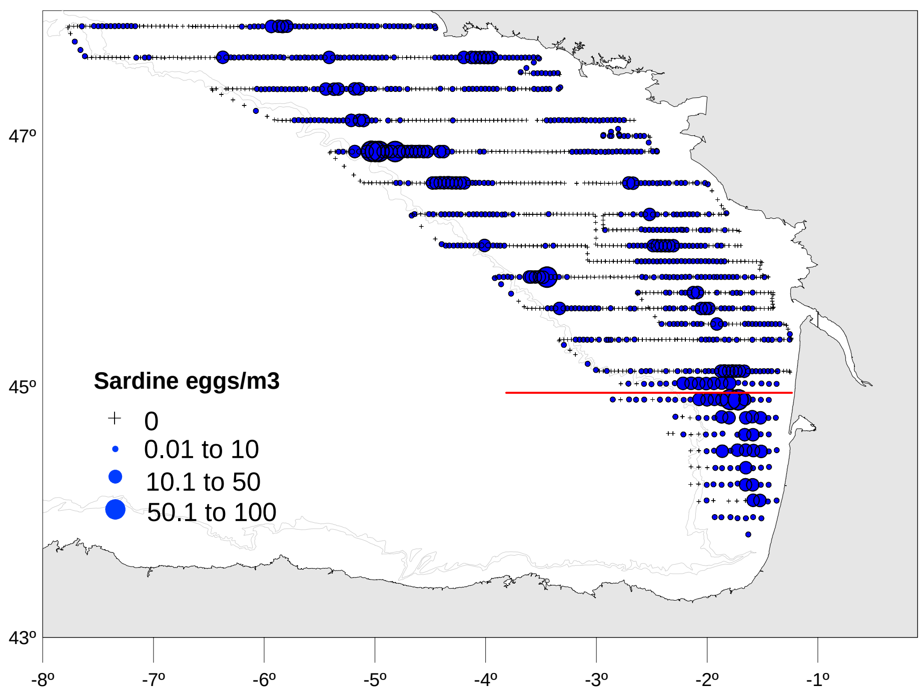


Figure 4. Sardine egg distribution. Egg/m^2 from PairoVET sampling (Upper panel) and egg/m^3 from CUFES sampling (down panel).

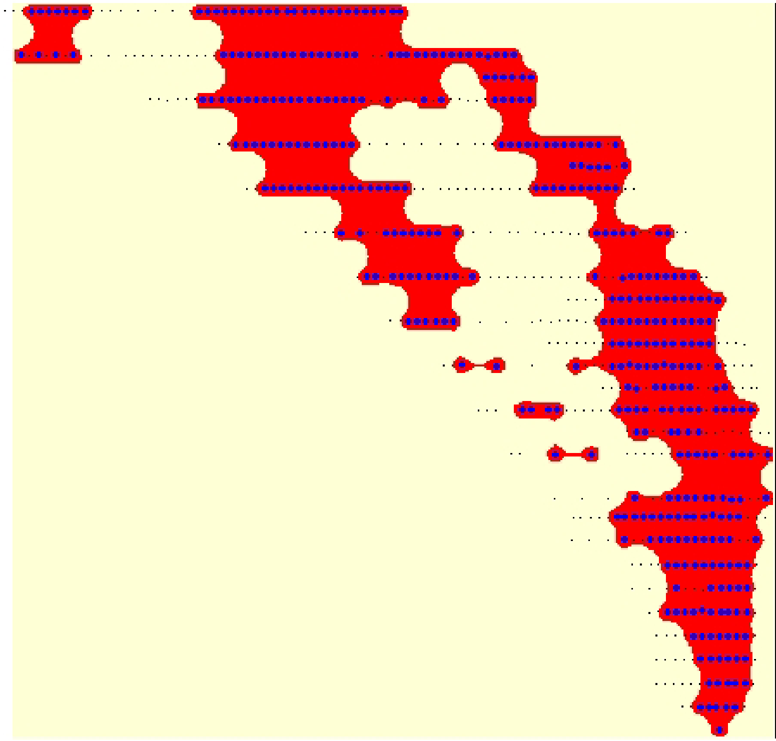
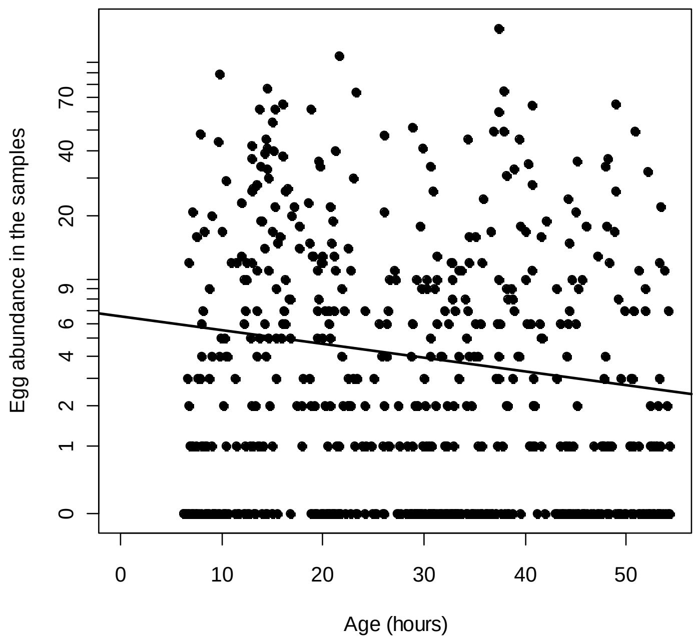


Figure 5. Delimitation of the spawning area for sardine in the region VIIIab.



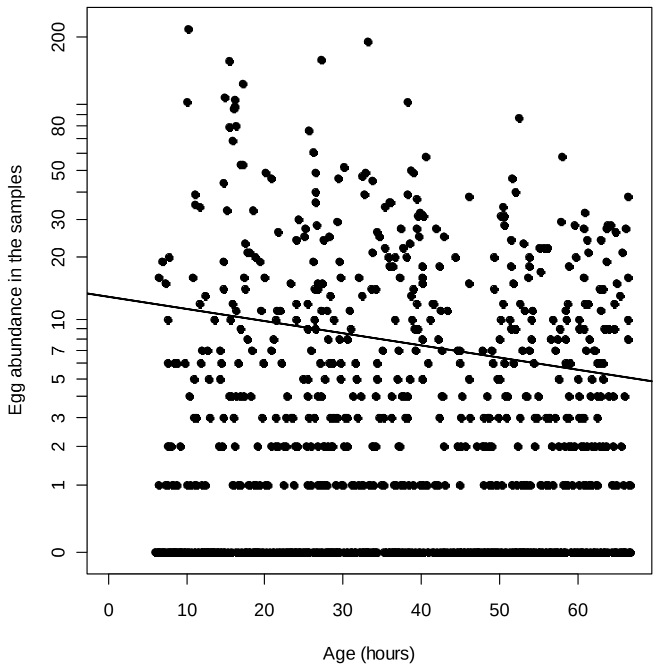
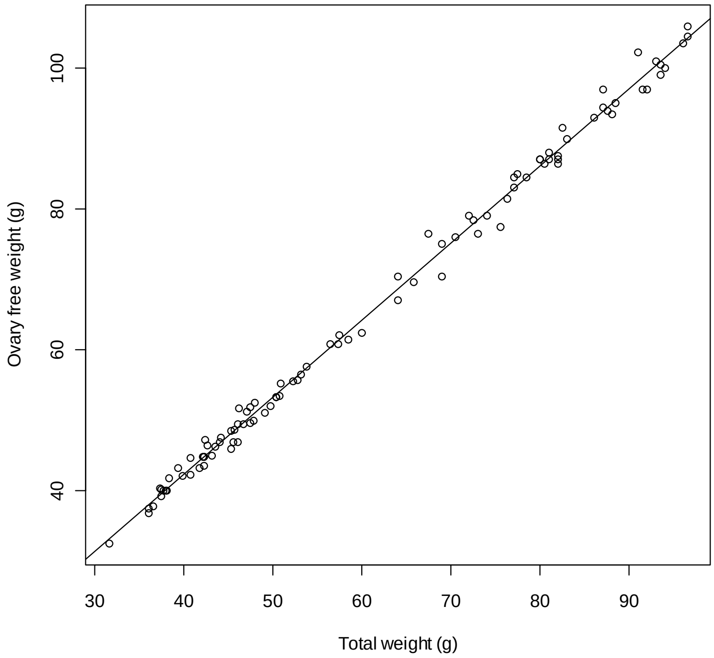


Figure 6. Exponential mortality model adjusted applying a GLM to the data obtained in the ageing following the Bayesian method (spawning peak 21:00h).The black line is the adjusted line. Data in Log scale. Upper panel area VIIIb up to 45ºN (IEO) and lower panel area VIIIab 45-48ºN (AZTI).



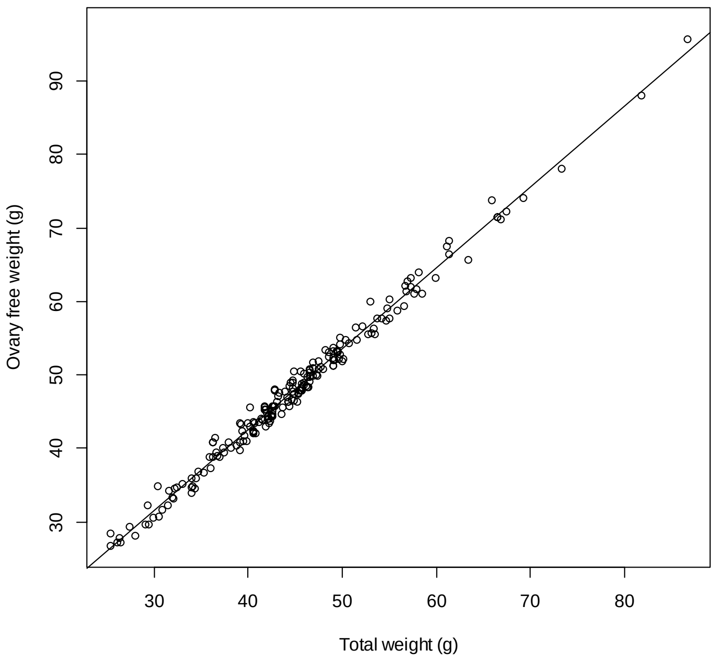


Figure 7. Linear regression model between gonad-free-weight and total weight fitted to non-hydrated females. Upper panel area VIIIb up to 45ºN (IEO) and lower panel area VIIIab 45-48ºN (AZTI).

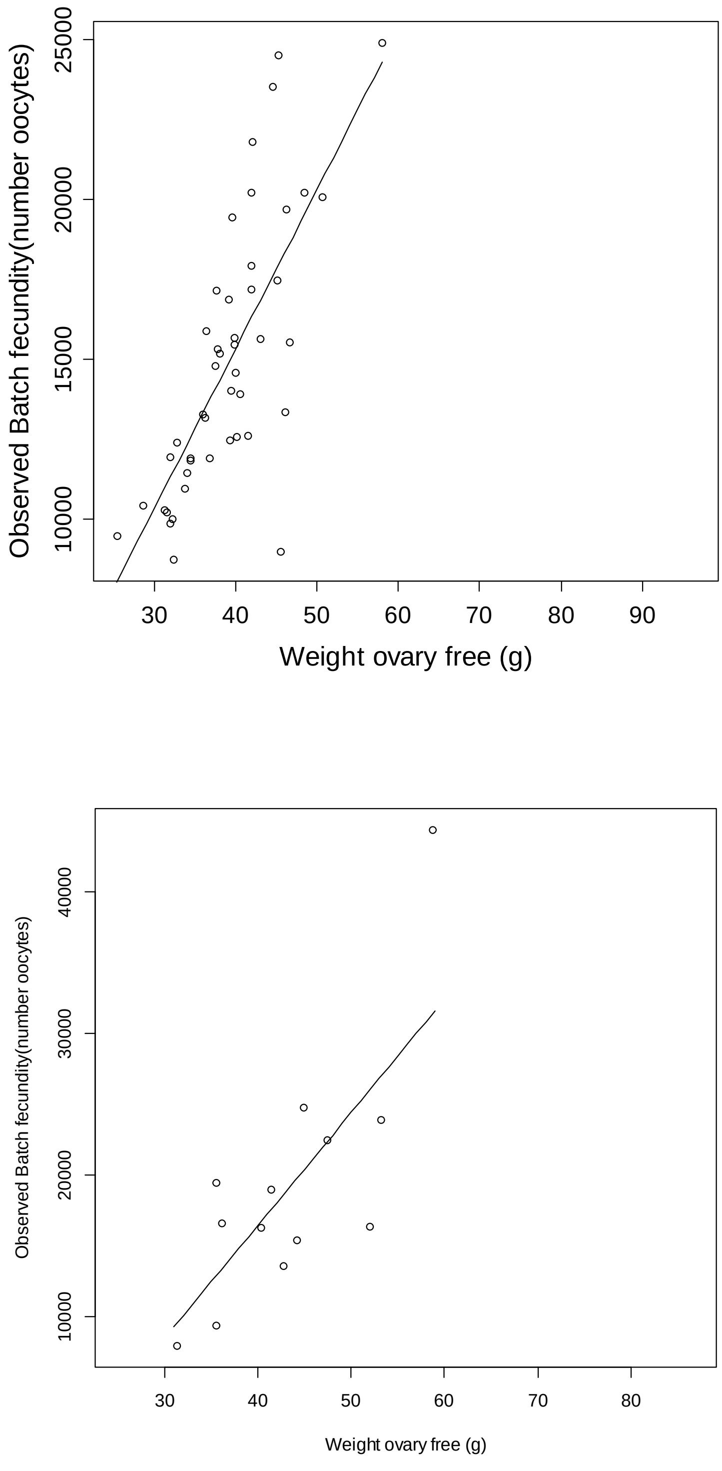


Figure 8. Generalised linear model between gonad-free-weight and hydrated oocyted fitted to hydrated females. Upper panel area VIIIb up to 45ºN (IEO) and lower panel area VIIIab 45-48ºN (AZTI).

Working Document to the Workshop on Atlantic Sardine (WKSAR) - Lisbon, September 26-30

Sardine growth data analysis

By L. Citores, A. Uriarte, A. Silva, P. Carrera, E. Dduhamel, L. Pawlowski, … et al. (other members of WGHANSA, to be further defined)

Available data for this study:

- Weight at age from **surveys**
  - 1986-2016 for cantabria and galicia (gaps in 1994, 1995)
  - 1996-2016 for portugal and cadiz (gaps in 2004, 2012)
  - 2000-2016 for biscay
  - Ages from 1 to 12
  - No quarters
- Weight and length at age from **catches**
  - 1991-2016 except for
  - Cadiz 1997-2014
  - Biscay 2002-2014
  - Ages from 0 to 14
  - Quarters 1-4
- Areas:
  - 9asc: Cadiz (cad)
  - 9asa: South Portugal (spor)
  - 9acs: South west Portugal (swpor)
  - 9acn: North Portugal (npor)
  - 9an: South Galicia (spor)
  - 8cw: North Galicia (npor)
  - 8ce: Cantabria (can)
  - 8ab: Bay of Biscay (bisc)

Shown in *growth_data.pptx* document:

- Row data (slides 3-11)

- Fitting using gams by age and area
- Fitting by age, year (or cohort) and area
- Fitting using gams by age and area splitted in temporal periods

Note: the graphs mentioned in the text refer to the slides (##) of the presentation made during the workshop. So for proper following of the text the reader is referred to the presentation laid down in the WKSAR report (named: "Sardine_Growth_presentation23112016.pptx")

Raw Data Visual analysis.

Preliminary analysis shown that East and West Cantabrian cannot be distinguished in the Survey → both regions were merged into Cantabria (VIIIc East)

Stationary visual analysis

Survey Analysis of the historical mean (1996-2016) Wages values for ages 1-7 shows a group of lower mean Wages from Cadiz to North Portugal, followed by South Galicia with intermediate values and finally Biscay followed by North Galicia and Cantabria with the highest values (Figure slide 4)

A very similar pattern is observed in the Catches weight at age analysis (1997-2014), with low mean Wages from Cadiz to North Portugal, followed by South Galicia with intermediate values and finally a third group composed of North Galicia, Cantabria and Biscay by with higher values (Figure slide 5).

Rather similar results are observed when analysing mean length at age in catches (figure slide 6).

Dynamic analysis of mean values in time:

Analysis of the time series of the mean weights (pool mean of ages 1-4) in Surveys (1996-2016) shows stable or increasing tendency in mean weights from Cadiz to North Portugal, *but decreasing tendencies in, Cantabria and Biscay (figures slide 7 bottom figure and figure 8), with North Galicia and South Galicia in intermediate place without a clear tendency*.

Analysis of the time series of the mean weights (pool mean of ages 1-4) in Catches (1997-2014) (second quarter) diverges from the previous picture as Cadiz has a decreasing trend in overall mean weights, while from South to North Portugal and South Galicia there mean weights increase particularly in recent years. NGalicia shows also a growing tendency but at higher mean values. Finally a decreasing tendency is shown in Cantabria and Biscay (figures slide 7 upper figure and figure 9) though more intense in Biscay. A similar pattern is seen when analysis the mean weight in catches during the third quarter (Figure Slide10)

Summary of Raw data analysis: *So the stationary analysis from both surveys and catches suggest two groups one from Cadiz to North Portugal and the other from NGal to Biscay with an intermediate region in SGal.*

However the analysis of the time series (dynamic analysis focussed on ages 1 to 4) suggest that mean weights of the southern group from South to North Portugal have shown some increasing tendency in the time series, and that SGal and NorthGal experienced a rather parallel increasing tendency to the southern group (though at higher mean weight levels), while Cantabria and Biscay have had a decreasing tendency in their mean weight in both areas though more intense in Biscay than in Cantabria. Mean weights in Cadiz (contrary to the southern group) have remained stable in surveys but have had a decreasing tendency in catches.

All these analysis suggest that Cadiz may have some different growth tendencies that the remainder areas. In any case the southern group from SPortugal to NPortugal has a rather consistent growth pattern and tendencies troughout the time series. The highest mean weights occur at the northern part of the Iberian regions and to a lesser extent in the Bay of Biscay. South Galicia is at a lower but intermediate level in comparison with the southern group. And in terms of the dynamic approach, South and North Galicia have some increasing tendency contrary to the decreasing tendency observed in Biscay and Cantabria. Therefore growth seems to be changing differently in Cadiz, and in the remaining southern Group (from South to North Portugal), in Galicia and in Cantabria + Biscay. So the heterogeneity in the growth patterns and tendencies in time across the Biscay and Iberian regions is high, suggesting partial independent dynamics of sardine among these regions.

Fitting data by age and area (Stationary analysis)

Weight and length data have been fitted using GAMs (generalized additive models) in R and 'mgcv' package. Age has been introduced as a continuous variable and area as a factor, including the interaction between these variables. Data was restricted to ages 1-4 and time period 2000-2016 for surveys and 2000-2014 for catches.

For each dataset (Surveys and catches) model fitting has been repeated 8 times, each one fixing a different area as the reference level of the area factor. Thus, obtained p values comparing areas two to two are summarized in the table below.

Results

Interactions in all cases are shown in the corresponding plots below (slides 14, 16 and 18). Similar groups have been detected for all datasets:

Survey Weights:

Looking at p values in the table (slide 15) different groups can be identified: Cadiz // NPort +SWPort+Sport // SGal // Cantabria+NGal //Biscay

Sgal - Biscay appear to be related (p>0.05) although biologically/geographically make no sense.

Catch Weights in the 2nd quarter:

Looking at p values in the table (slide 17) different groups can be identified: Cadiz // NPort +SWPort+Sport // SGal // Cantabria+NGal //Biscay

Sgal – Biscay and Sgal - Cantabría appear to be related (p>0.05) although biologically/geographically make no sense.

Catch Lengths in the 2nd quarter:

Looking at p values in the table (slide 19) different groups can be identified: Cadiz // NPort +SWPort+Sport // SGal // Cantabria+NGal //Biscay

Sgal – Biscay, Nport – Biscay and SWPort - Biscay appear to be related (p>0.05) although biologically/geographically make no sense.

So both stationary analysis from surveys and catches lead to the following groups: Cadiz // NPort +SWPort+Sport // SGal // Cantabria+NGal //Biscay

Introducing temporal variable in Survey data fitting

Weight data have been fitted using GAMs (generalized additive models) in R and 'mgcv' package. Age and year (or cohort) has been introduced as a continuous variable and area as a factor, including the interaction between the temporal variable and area. <u>Data was restricted to ages 1-4 and time period 2000-2016.</u>

Results

Interactions in all cases are shown in the corresponding plots. Fitted curves are shown for each age and area with the 95% confidence intervals. Curves whose intervals do no overlap could be considered different.

Different areas show different trends in time. Different time periods have been defined for a better description of the results.

Looking at plotted (slide 21) confidence intervals in the first period ngal, can and bisc are overlapped while, with lower, means cad, spor, swpor and npor present also overlapping intervals. These could define two main groups. In the second period just cad, spor, swpor and npor seem to have similar trends. In the last period there are not clear groups with more similar means.

Among general trends a clear decreasing trend is observed for Can and Bisc areas while the rest do not decrease or even increase slightly.

Three time periods have been defined to fit a growth curves across ages (slide 22). Period 1: 2000-2005, Period2: 2006-2010, Period3: 2011-2016. In period 1 ngal, can and bisc show similar growths patterns with similar smooth curves and overlapping confidence intervals. The rest of the areas present lower weight values defining another group with overlapping intervals as well. In the second period the similar shapes are observed although bisc mean is decreasing, and in the last period there are not distinguishable groups with wider overlapping Cis.

The 'cohort' variable has been also introduced as a temporal component (instead year). No significant changes in comparison with results above have been detected (slide 24).

In summary two groups have appeared consistently between 2000 and 2010: From Cadiz to NPortugal and from Ngal+ Can to *Bisc (with SGal at intermediate level closer southern and northern group in the first and second periods respectively)*. For the last period no clear group is distinguishable probably due to the increasing trend in mean weight of the southern group and the decreasing trend in the northern group.

Introducing temporal variable in Catch data fitting

Weight and length data have been fitted using GAMs (generalized additive models) in R and 'mgcv' package. Age and year (or cohort) has been introduced as a continuous variable and area as a factor, including the interaction between the temporal variable and area. Data was restricted to ages 1-4 , 2^{nd} quarter and time period 2000-2014.

Results

Catch Weights in the 2^{nd} quarter:

Interactions in all cases are shown in the corresponding plots below. Fitted curves are shown for each age and area with the 95% confidence intervals. Curves whose intervals do no overlap could be considered different.

Different areas show different trends in time (slide 26). As in the survey case a clear decreasing trend is observed for Can and Bisc and in this case for Cadiz a decreasing pattern is shown.

Three time periods have been defined to fit a growth curves across ages (slide 27). Period 1: 1991-2001, Period2: 2002-2007, Period3: 2008-2014. In period 1 there is no data for bisc area (this period has been removed in the previous fitting). Ngal and can show more similar trends with higher means while the rest present lower values, being sgal the area with the flattest growth curve. In the second period bisc area is included presenting a very similar trend to cantabria and in the final period, as for survey data, no clear groups are detected.

*A similar fitting has been done for 3^{rd} quarter data. Patterns are not completely different altough there are some difference in means, i.e. cantabria and biscay show more distant curves (slide 28).

In all periods, Cadiz shows invariantly the smallest mean weights at age.

In slide 29 growth curves fitted along years and ages introducing the interaction of both variables with the factor area are shown.

The ‘cohort’ variable has been also introduced as a temporal component (instead year). No significant changes in comparison with results above have been detected (slide 30).

In Summary the results from the analysis of the mean weight in catches are rather similar to those from surveys.

Catch Lengths in the 2nd quarter:

Results from fitting length data are very similar to those obtained for catch weight data. The correlation between both dataset is very high as shown in slide 31. Obtained fitted curves are shown in slides 32 to 35.

Conclusions:

There is southern group from Cadiz to North of Portugal, with close mean weights at age and rather parallel evolution towards higher values in recent years (with the exception of the decreasing trend in Cadiz).

A northern Group can be setup between NGal+ Cantabria and Biscay: Although the mean weights place closely NGal and Cantabria in terms of tendencies Cantabria and Biscay seems closer to each other (showing some decreasing tendency of mean weights at age in recent years, more pronounced in Biscay than in Cantabria). Therefore the dynamics in the northern regions in terms of growth is not homogenous as it is in the southern region.

South Galicia seems an intermediate group between the Southern and Northern groups, it has intermediate mean weights at age, but in terms of tendencies SGal and NGal have a positive tendency in time (as the southern group), while Cantabria and Biscay show a negative tendency (being stronger in Biscay).

Annex 4: Presentations

The following presentations were made to the WKSAR. They are included in full below.

1) Data from 4th quarter acoustic surveys for Southern sardine. Alexandra Silva.

2) Acoustics and DEPM surveys. Maria Manuel Angélico.

3) Age of very small sardines (below 10 cm) in Spring Surveys. Alexandra Silva.

4) Biological comparison between Bay of Biscay and English Channel sardines; first approach. M. Huret, E. Duhamel, P. Gatti, *et al*.

5) Data compilation: PIL eggs from DEPM and AEPM surveys. Maria Manuel Angélico and Paz-Díaz.

6) Demographic connectivity of sardine populations (Bay of Biscay and Iberian Coast ecoregion). Silva A., Riveiro I., Pawlowski L., Marques V., Garrido S., Carrera C., Duhamel E., Ibaibarriaga L., Uriarte A., *et al*.

7) 8.ab IEO-AZTI sardine DEPM estimates and sardine egg abundance. Isabel Riveiro.

8) Pelago (spring)–EcoCadiz (summer) sardine estimates comparison. Isabel Riveiro.

9) Temperature and food-mediated variability of Atlanto-Iberian European sardine populations. Susana Garrido, Alexandra Silva, Vitor Marques, Ivone Figueiredo, Philippe Bryère, Antoine Mangin, A. Miguel and P. Santos.

10) Sardine growth by areas from surveys and catches. A. Uriarte, L. Citores, A. Silva, E. Duhamel, *et al*.

11) Growth data. Leire Citores.

12) Catch-at-age data; Iberian sardine stock. Alexandra Silva.

13) Life-history data. Cristina Nunes.

14) Oceanographic conditions: connectivity through eggs, larvae, adults. Susana Garrido.

15) Microchemistry of sardine and anchovy otoliths from the Bay of Biscay. Paul Gatti, Martin Huret and Pierre Petitgas.

16) Quick elements to scrutinize sardine results from PELGAS surveys in 2003 and 2007. E. Duhamel, M. Doray, M. Huret, *et al*.

17) An overview of the abundance and distribution of sardine (*Sardine pilchardus*) in the eastern Celtic Sea and western Channel. Jeroen van der Kooij, Serena Wright and Joana Silva.

18) Sardine data in the Southwest. Jeroen van der Kooij.

19) PELAGO16: Sardine acoustic energy test areas. Vitor Marques.

20) Sardine maturity ogive in the Bay of Biscay. Lionel Pawlowski.

21) Sardine stock structure: SARDYN project and update. Alexandra Silva.

Data from 4th quarter acoustic surveys for Southern sardine

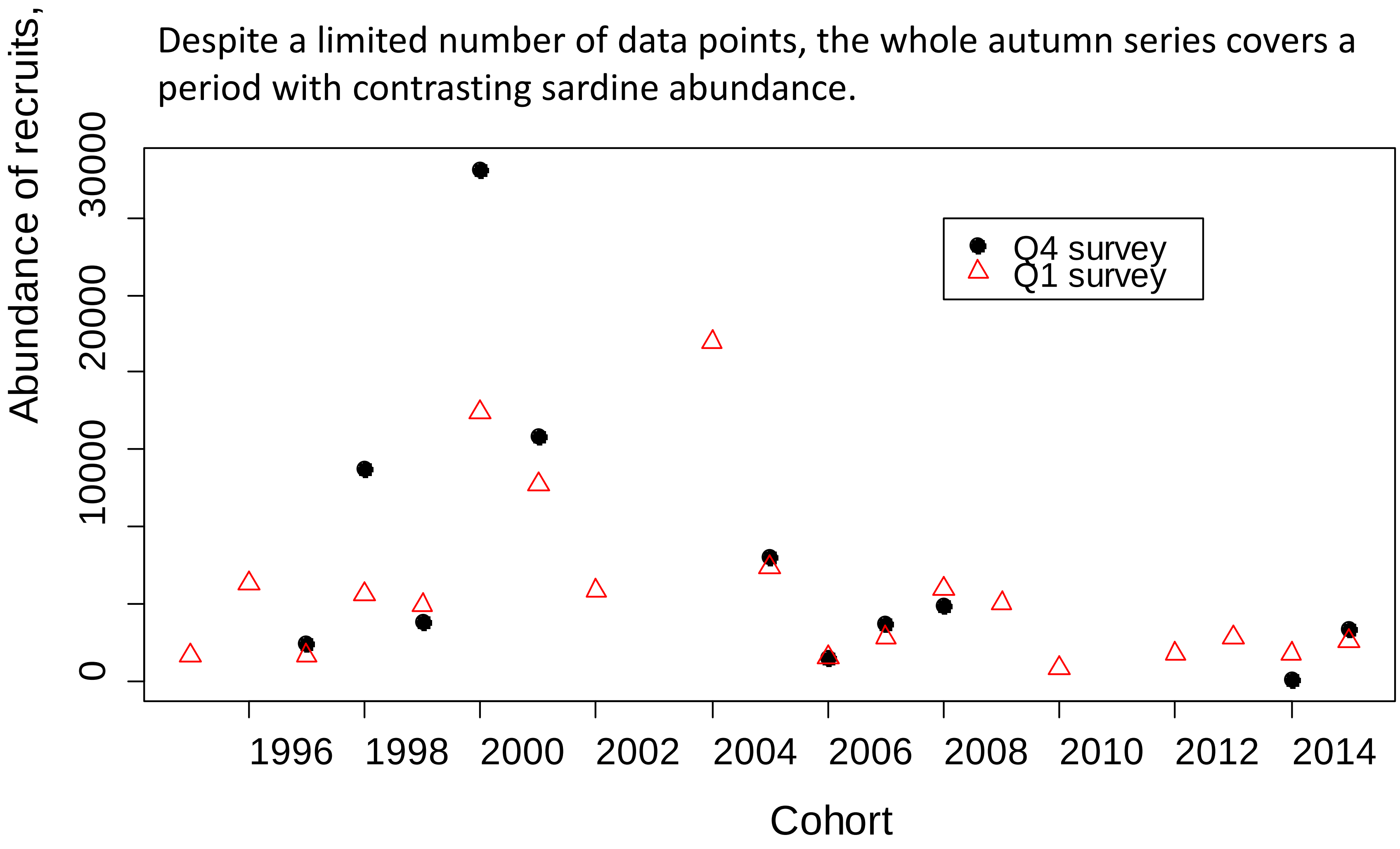
Background

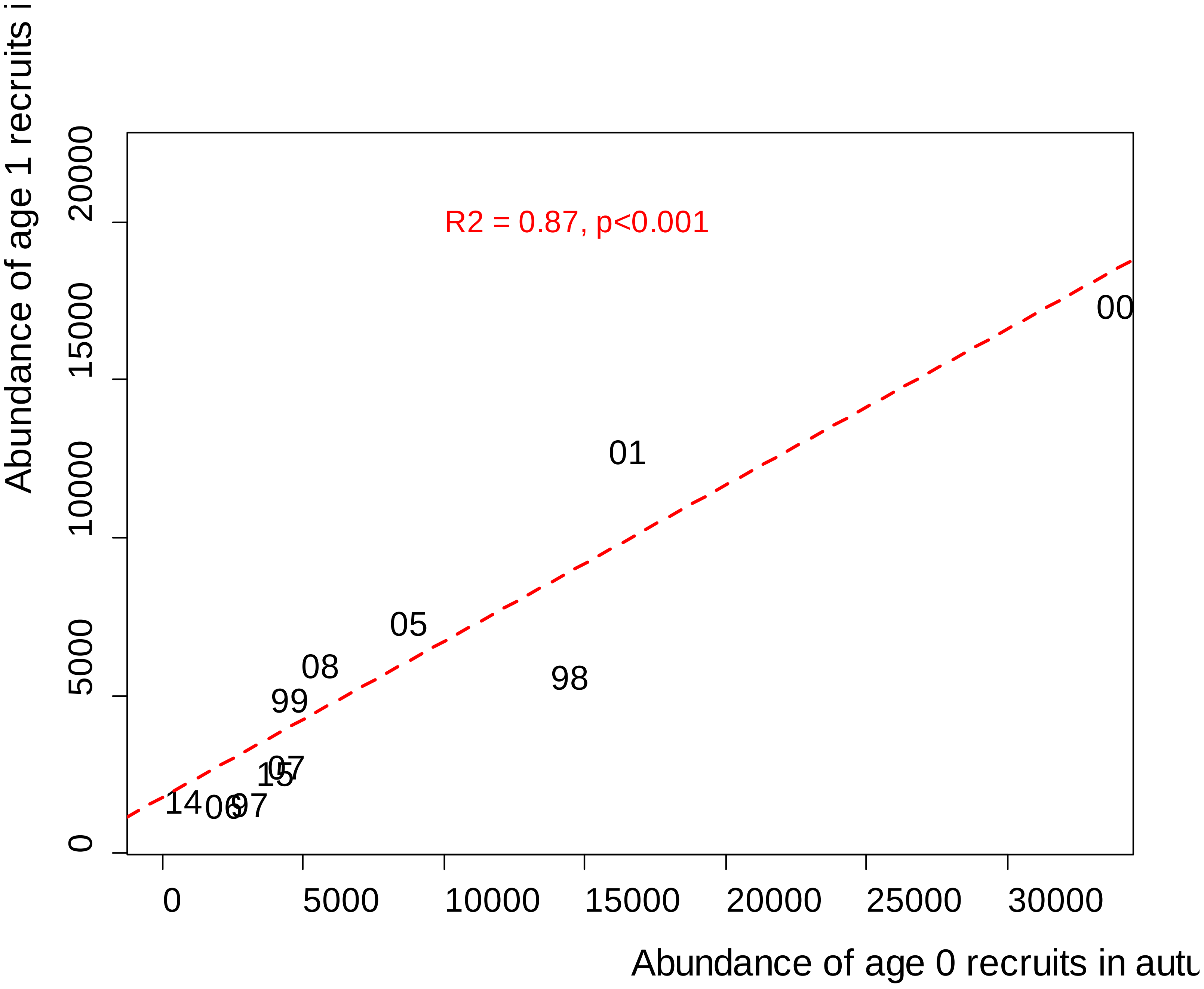
- Old series of Portuguese autumn surveys (October-December)
- Cover main sardine recruitment areas:, north and central Portugal and Cadiz in 1992, 1997 – 2001, 2005-2008 (10 surveys)
- Survey design similar to Spring surveys (?)

- Recent series of JUVESAR and ECOCADIZ-REC aim to assess recruitment

Year		2011	2012	2013	2014		2015	
Survey		JUVESAR	ECOCADIZ-REC	JUVESAR	ECOCADIZ-REC	JUVESAR	ECOCADIZ-REC	JUVESAR
Vessel		Noruega	Emma Bardán	Noruega	Ramón Margalef	Noruega	Ramón Margalef	Noruega
Objectives		Sardine recruitment	Sardine and anchovy recruitment	Sardine recruitment	Sardine and anchovy recruitment	Sardine recruitment	Sardine and anchovy recruitment	Sardine recruitment
Date		6 -22 December	10 - 27 November	5 -15 November	13 - 31 October	1 - 9 December	10 - 29 October	5 - 13 December
Region covered		Matosinhos-Lisbon	Cadiz	Caminha-Cape Espichel	Cadiz and South Portugal	Matosinhos - Peniche	Cadiz and South Portugal	Caminha-Cape Espichel
Transects		17	11	42	21	23	21	38
Fishing hauls	Pelagic trawl	-	10	11	15	4	21	13
	Botom trawl	6		6				
	Purse seine	1						
Comments		Bad weather, 6 days' interruption, vessel speed 5.5-7.5 knots; 80% of the typical recruitment area covered	Bad weather; frequent interruptions	Inter-transect distance in some areas reduced to 4 nm; depth covered until 50 m		Bad weather, interruptions; 80% of the typical recruitment area covered		Inter-transect distance in some areas reduced to 4 nm; depth covered until 60 m
Data available		Abundance and biomass at length for npor and swpor. Otoliths available.	Abundance and biomass at length and age for cad	Abundance and biomass by length for the whole area. Otoliths available.	Abundance and biomass at length and age for cad and spor	Abundance and biomass at length and age for npor. Ages aggregated in a 3+	Abundance and biomass at length and age for cad and spor	Abundance and biomass by age for the whole area.
Quality for recruitment assessment (1:good, 2: average, 3: poor)		3	1 (for Cadiz)	1	1	2	1	1

Despite a limited number of data points, the whole autumn series covers a period with contrasting sardine abundance.





Abundance of age 1 recruits i
0
5000
10000
15000
20000
R2 = 0.87, p<0.001
00
01
05
08
99
98
07
15
14
06
97
0
5000
10000
15000
20000
25000
30000
Abundance of age 0 recruits in autu

- ECOCADIZ-REC funded by EU
- JUVESAR funded by national projects and PT administration

- For discussion:
  - 1-2 month lag between surveys
  - Catchability dfferences between surveys (Ecocadiz-Juvesar, SAR-AUT-Juvesar)
  - May these surveys provide a recruitment index for the stock in the future ?

  - Utility in assessment: (not obvious with current calendar); increase precision of recruitment estimates ??

  - Utility in management ? (not obvious with current calendar)

WKSAR - Workshop on Atlantic Sardine (in preparation for benchmark 2017)

26-30 Set 2016, Lisbon, Portugal

Acoustics & DEPM surveys

WGACEGG 2015

Possible causes for the differences in the biomass estimation by acoustics and DEPM:

- **Time lag between surveys**

The surveys are not entirely carried out simultaneously (some areas and year 1+ month apart).
Differences in fish distribution, reproductive phase and interval from recruitment may play a significant role.

- **Population structure and behaviour**

The structure of the population available during each survey may vary according to period of surveying and fish behaviour. The phase of the reproductive cycle affects the spatial and depth distribution of the fishes, which in turn may have an impact on its availability for echosounding and trawling. Also the structure of the population if not completely captured by the surveying methods (both acoustics and DEPM) may lead to results of difficult interpretation. Fish distribution and behaviour are notably modified by the weather conditions, it is not uncommon to observe appreciable fish movements following events of stormy seas which may also affect the reproductive patterns.

- **Assignment of acoustic energy to species**

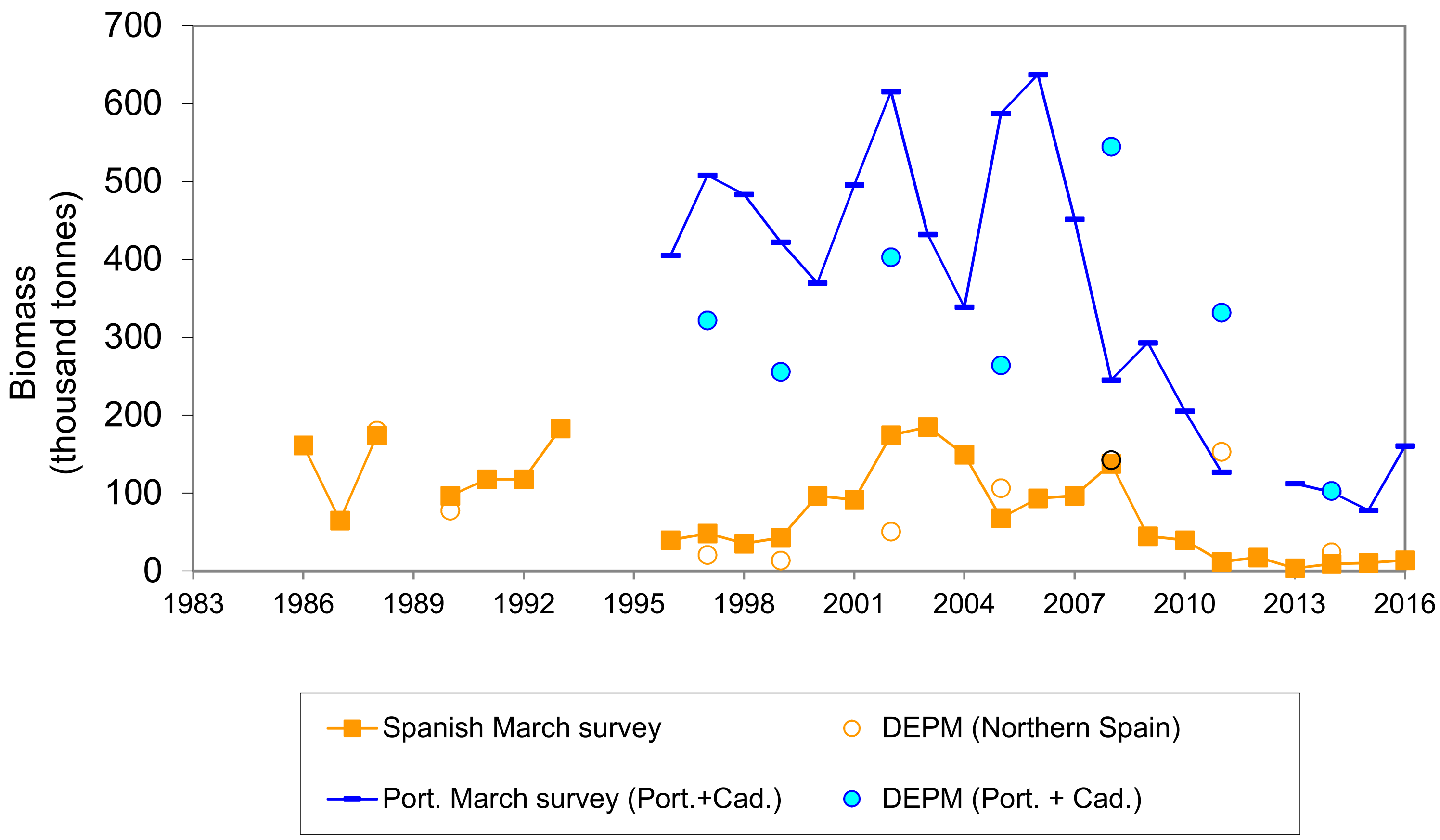
While the DEPM results derive from direct observations on fish eggs and ovaries, assignment of acoustic energy to species imply either a decision of the analyst on the school type or a partition of the energy based on the species composition of fishing hauls (sometimes in a number not as large as desired). In areas with significant species mixing and/or during periods of high plankton production the energy partition may be challenging. In addition depth corrected TS values may affect the estimations from surveys and the relative changes in biomass between years if they find contrasting bathymetrical distribution of fishes.

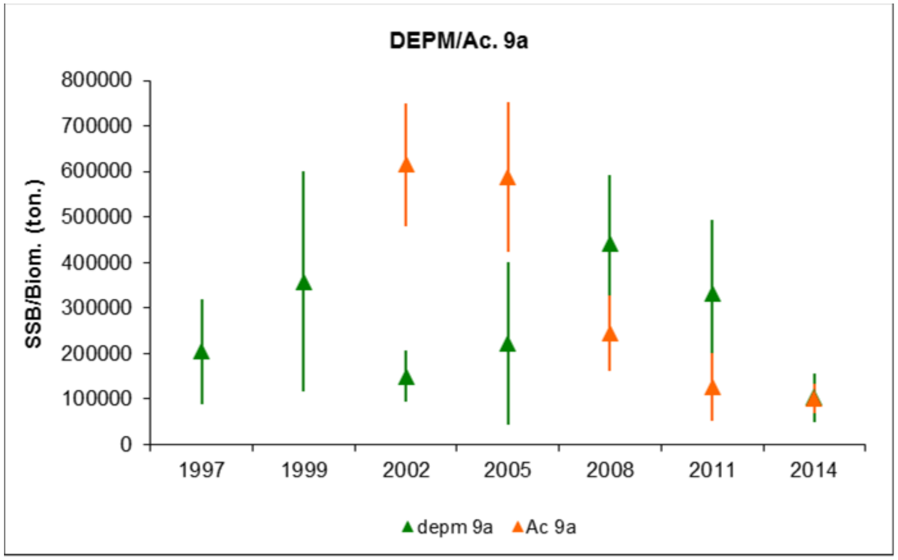
- **Estimation of reproductive parameters**

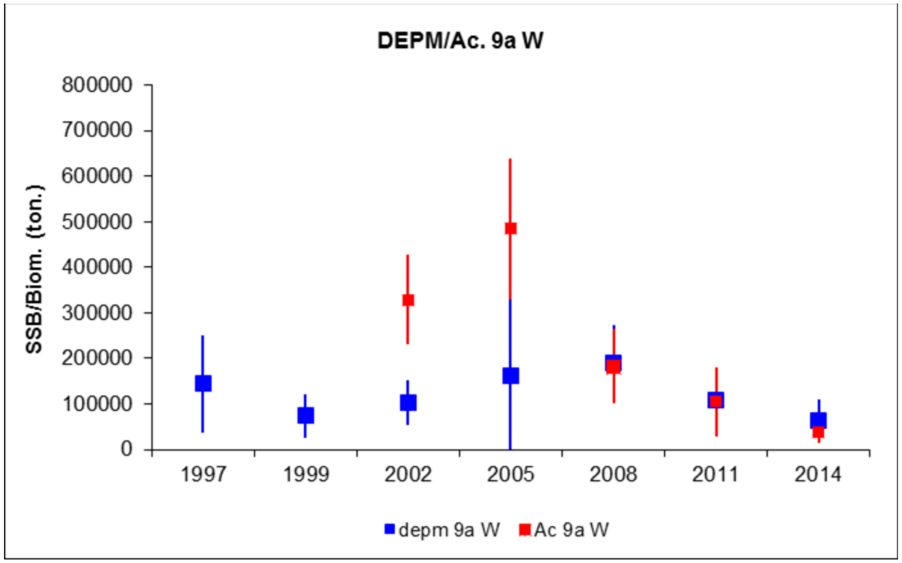
Some DEPM parameters such as spawning fraction, relative fecundity and egg mortality may be more complex to estimate for some particular surveys when sampling is not as comprehensive as desirable due to patchiness of the fish and eggs distributions. This is particularly relevant when the data available does not allow estimations stratified by geographical area or population length (age) composition.

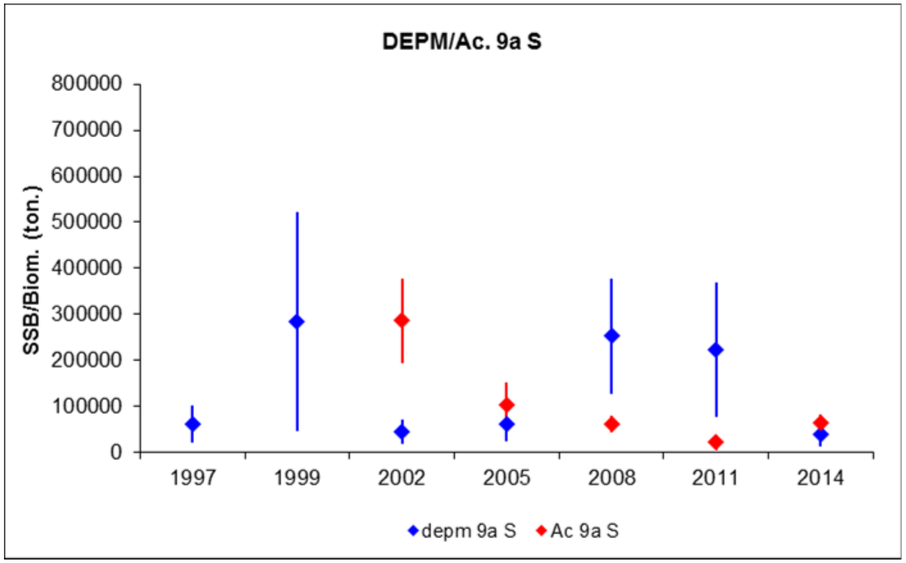
The Group agreed to develop further studies in order to better understand the differences found in the estimates from acoustics and DEPM, in some years. Additional exploration of the data (for sardine and anchovy) may consider:

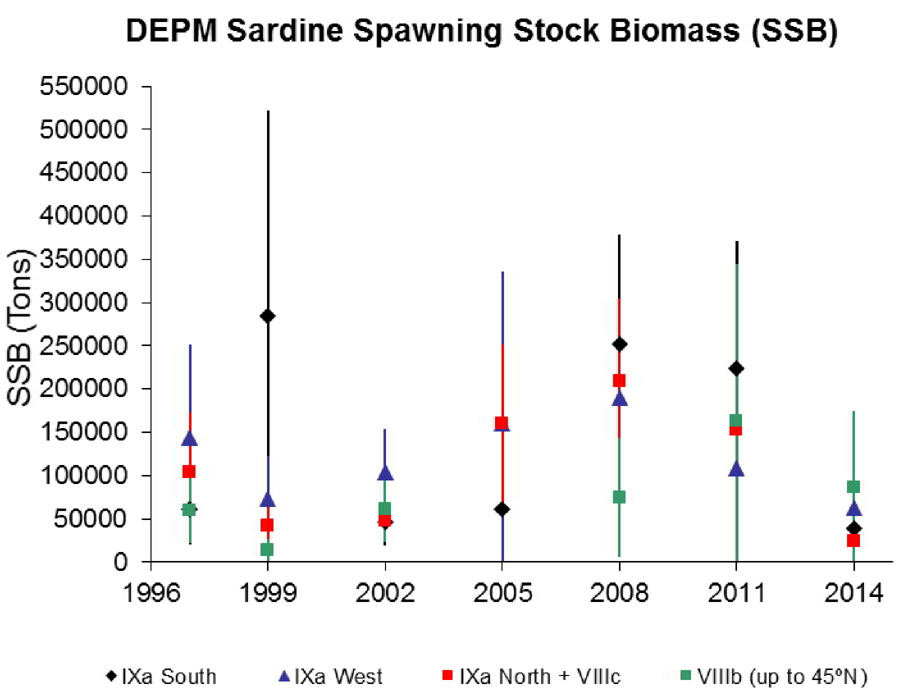
(i) analyse fish spatial and depth distribution during surveys to be compared
(ii) use same regional stratification of the information for both survey types
(iii) calculate biomass estimation by age (length) for sardine
(iv) utilize CUFES data for egg production estimation and comparison to estimations undertaken for PairoVET data,
(v) (discuss bias in energy partition for particular areas.

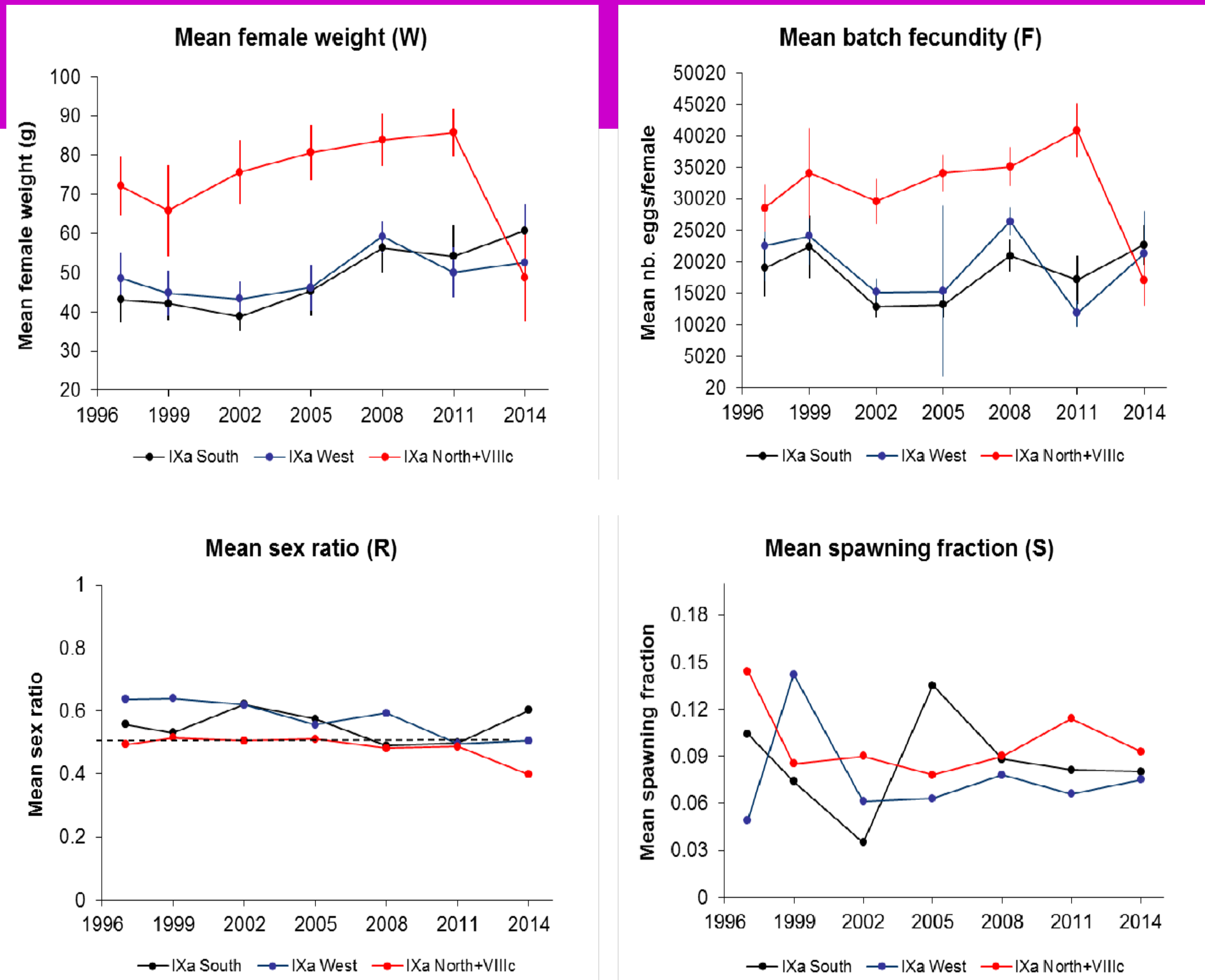

Biomass (thousand tonnes)
0
100
200
300
400
500
600
700
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016
Spanish March survey
DEPM (Northern Spain)
Port. March survey (Port.+Cad.)
DEPM (Port. + Cad.)

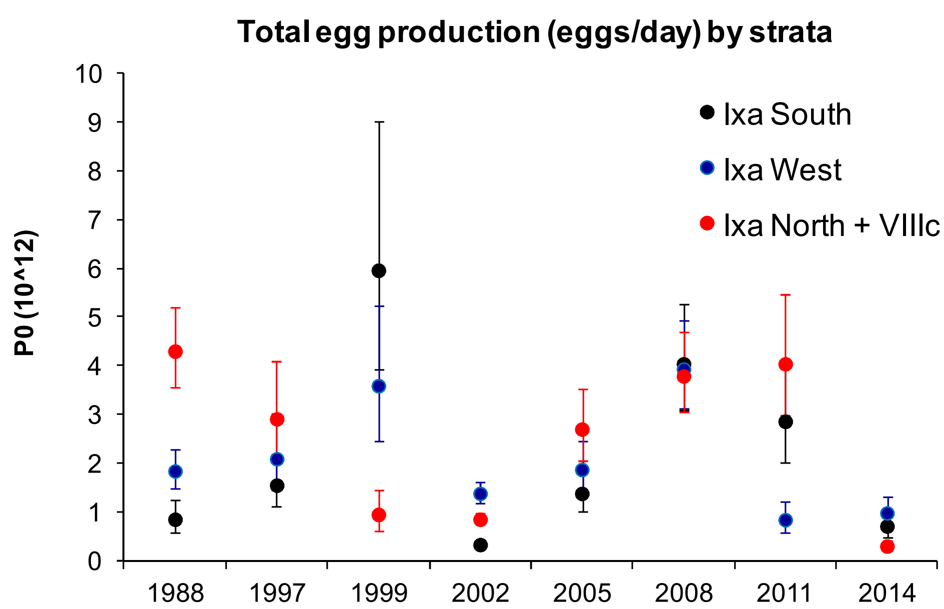

DEPM/Ac. 9a
SSB/Biom. (ton.)
800000
700000
600000
500000
400000
300000
200000
100000
0
1997
1999
2002
2005
2008
2011
2014
depm 9a
Ac 9a


DEPM/Ac. 9a W
SSB/Biom. (ton.)
800000
700000
600000
500000
400000
300000
200000
100000
0
1997
1999
2002
2005
2008
2011
2014
depm 9a W
Ac 9a W


DEPM/Ac. 9a S
SSB/Biom. (ton.)
800000
700000
600000
500000
400000
300000
200000
100000
0
1997
1999
2002
2005
2008
2011
2014
depm 9a S
Ac 9a S


DEPM Sardine Spawning Stock Biomass (SSB)
SSB (Tons)
550000
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
1996
1999
2002
2005
2008
2011
2014
IXa South
IXa West
IXa North + VIIIc
VIIIb (up to 45°N)

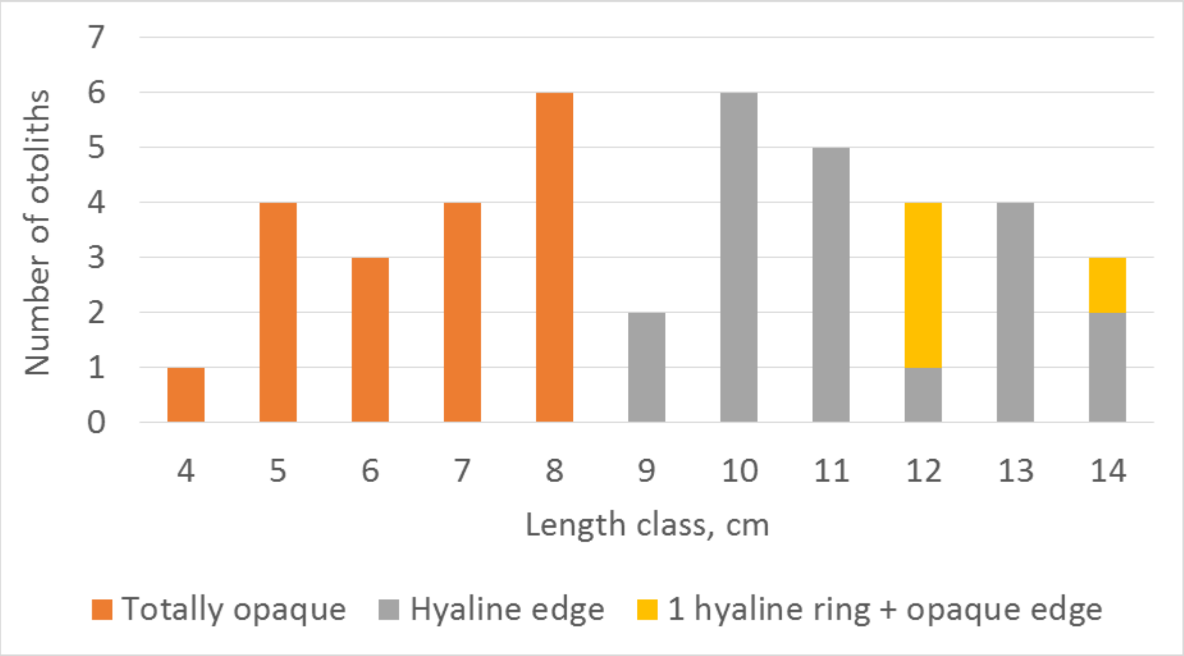

Mean female weight (W)
Mean female weight (g)
IXa South
IXa West
IXa North+VIIIc
Mean batch fecundity (F)
Mean nb. eggs/female
Mean sex ratio (R)
Mean sex ratio
Mean spawning fraction (S)
Mean spawning fraction


Total egg production (eggs/day) by strata
P0 (10^12)
0
1
2
3
4
5
6
7
8
9
10
1988
1997
1999
2002
2005
2008
2011
2014
Ixa South
Ixa West
Ixa North + VIIIc

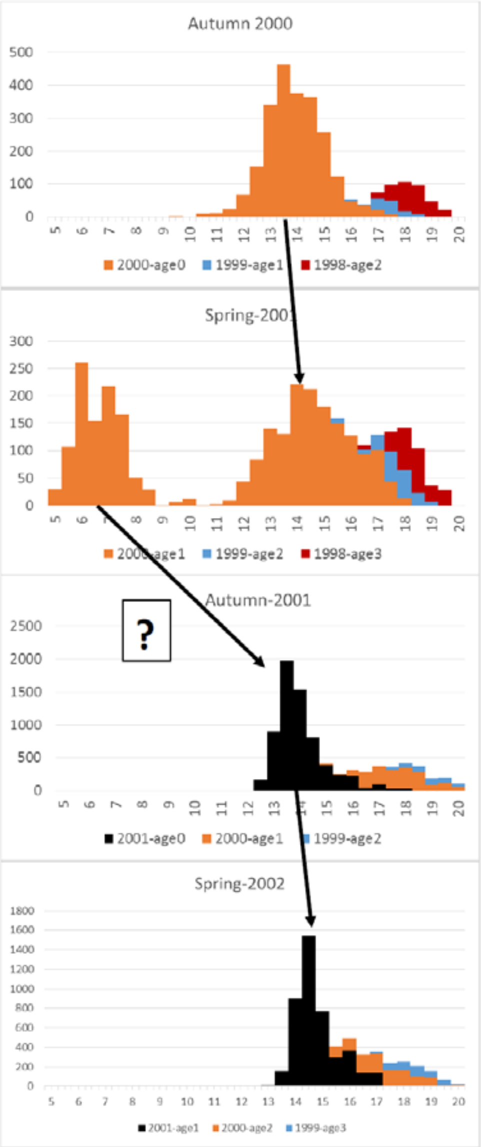
AGE OF VERY SMALL SARDINES (BELOW 10 CM) IN SPRING SURVEYS

(REMINDER AND DECISION)

OTOLITH APPEARENCE



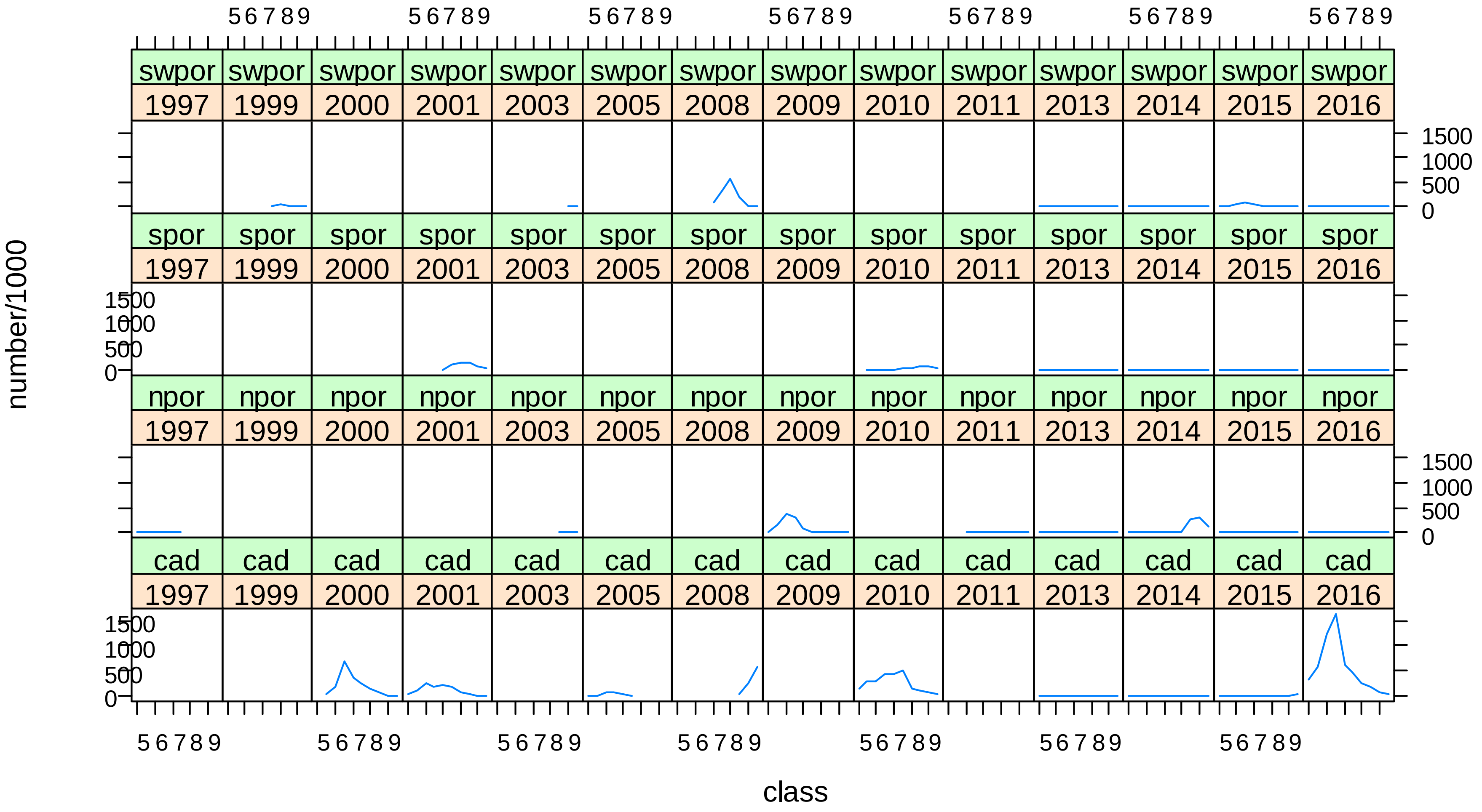
N = 42



Progression of 2000 and 2001 cohorts in Cadiz

Individuals >=9 cm already have 1 hyaline ring; survivors of those individuals next Spring will very likely have 2 hyaline rings and be classified in age 2

Individuals <9 cm will possibly enter the summer growth phase and not lay a hyaline edge until next winter; survivors are likely to be classified in age 1 next Spring.


swpor
spor
npor
cad
1997
1999
2000
2001
2003
2005
2008
2009
2010
2011
2013
2014
2015
2016
0
500
1000
1500
5 6 7 8 9
number/1000
class

% sardine below 10 cm in PT spring acoustic surveys

DECISIONS:

Exclude from survey index? Yes, desirable

Check the assignment of hauls to acoustic energy in this cases-Pass to WGACEGG

Check the otolith pattern and the length distribution

Need to re-calculate age composition…

Check South Galicia –Isabel will do it and give feed to WKSAR report

year	age.xs	total number	% below 10 cm
1997	51	13957	0.4
1999	138	11634	1.2
2000	1697	11875	14.3
2001	1511	20771	7.3
2003	16	13290	0.1
2005	124	25223	0.5
2008	2059	7031	29.3
2009	1013	9530	10.6
2010	2608	8862	29.4
2011	123	2821	4.3
2014	679	3558	19.1
2015	239	2403	10.0
2016	5397	9427	57.3

Biological comparison between bay of Biscay and English Channel sardines – first approach

M. Huret, E. Duhamel, P. Gatti…

-For the time being, samples from 2014

-3 surveys : PELGAS (Bay of Biscay, spring) : white

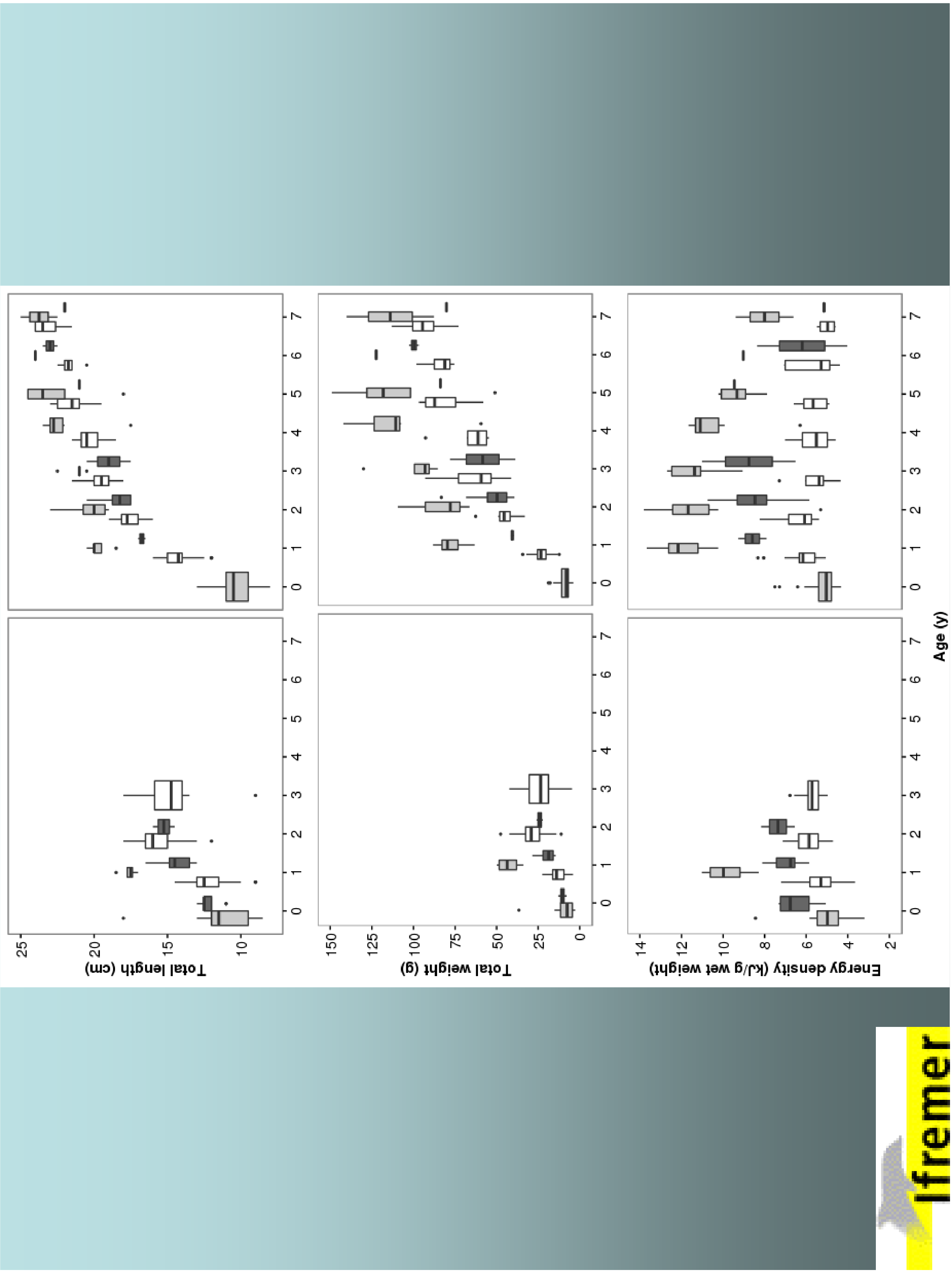
CGFS (Channel, sept/oct) : grey

IBTS (BoB, october) : dark

-Currently processing 2015 samples

-Same age reader

Ifremer


Total length (cm)
Total weight (g)
Energy density (kJ/g wet weight)
Age (y)

WKSAR - Workshop on Atlantic Sardine (in preparation for benchmark 2017)
26-30 Set 2016, Lisbon, Portugal

Data compilation

PIL eggs from DEPM & AEPM surveys

Historic info - Data compilation

available information per strata:

- ➢ south (stratum 1)
- ➢ west Pt (stratum 2)
- ➢ Galicia+Cantabric (stratum 3)

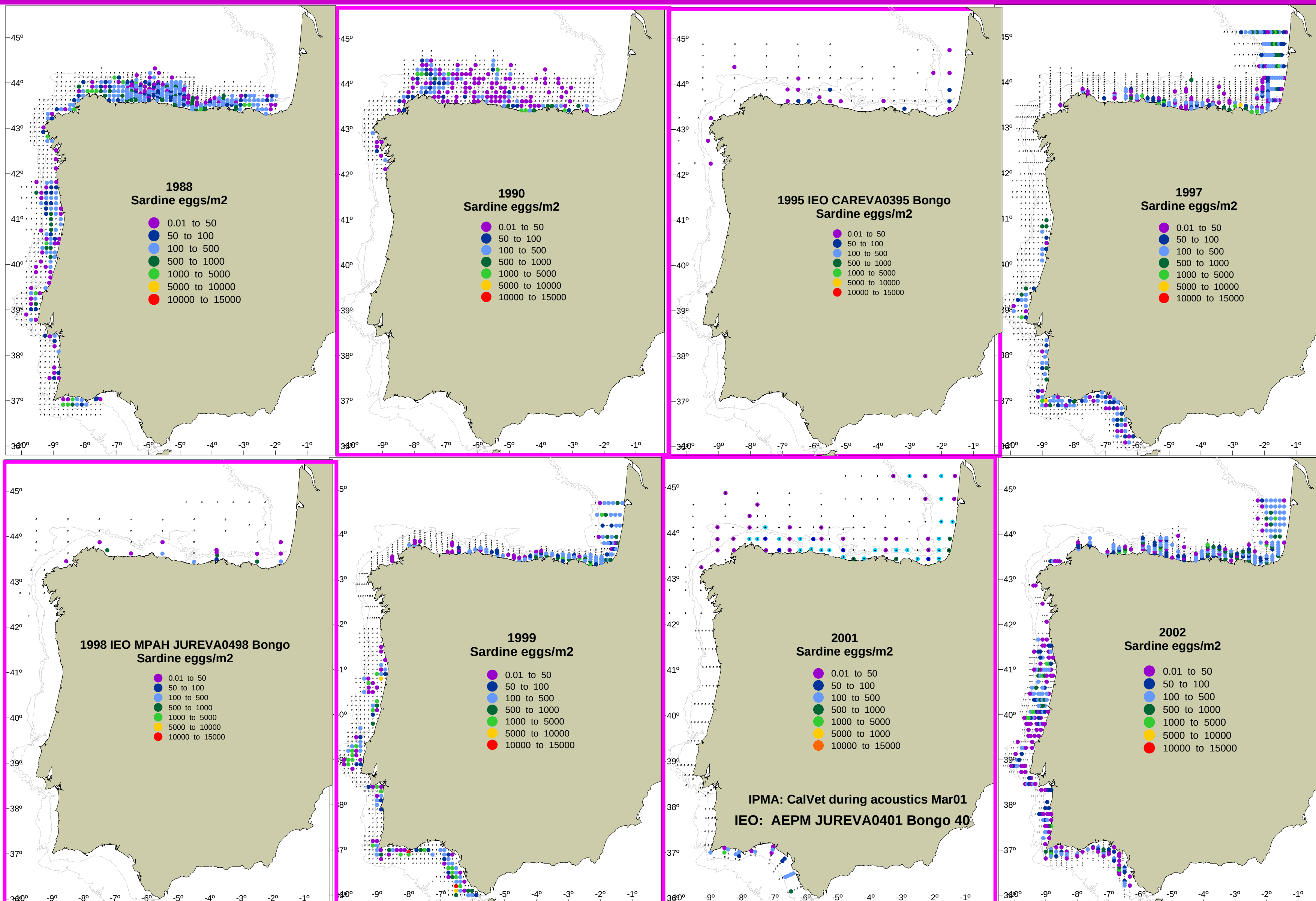
DEPM - PIL

DEPM / AEPM – HOM / MAC

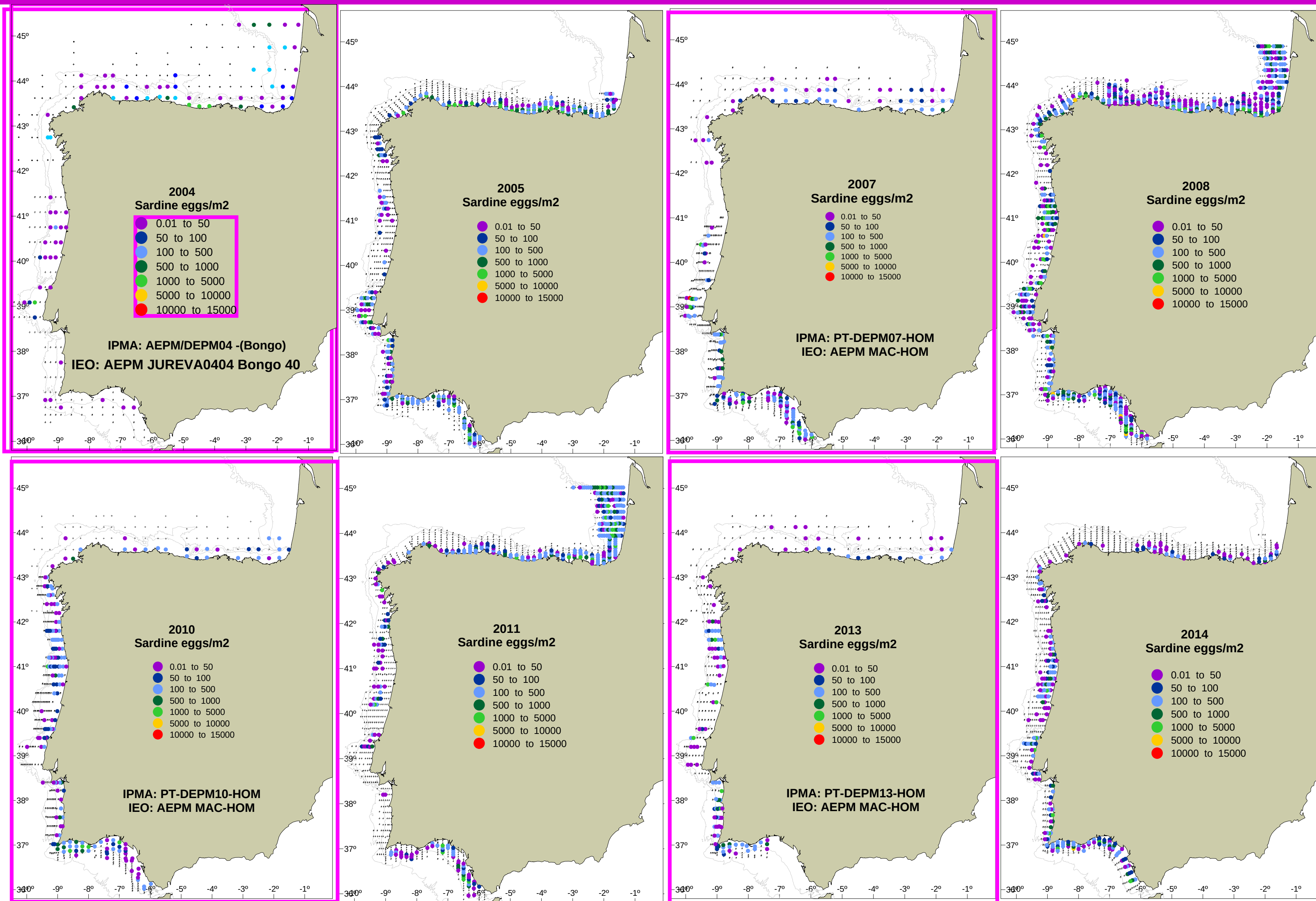
→ P0 per strata

year	egg data 11 stages	fish samples
1988	1 inc, 2, 3	1 inc, 2, na
1990	3	?
1995	?,?, 3	na, na, na
1997	1, 2, 3	1, 2, 3
1998	?, ?, 3	na, na, na
1999	1, 2, 3	1, 2, 3
2001	1, ?, 3	na, na, na
2002	1, 2, 3	1, 2, 3
2004	1, 2, 3 (no stgs)	na, na, na
2005	1, 2, 3	1, 2, 3
⇉ 2007	1, 2, 3	na, na, na
2008	1, 2, 3	1, 2, 3
⇉ 2010	1, 2, 3	na, na, na
2011	1, 2, 3	1, 2, 3
⇉ 2013	1 inc, 2, 3	na, na, na
2014	1, 2, 3	1, 2, 3
⇉ 2016	1, 2, 3	1, 2, na

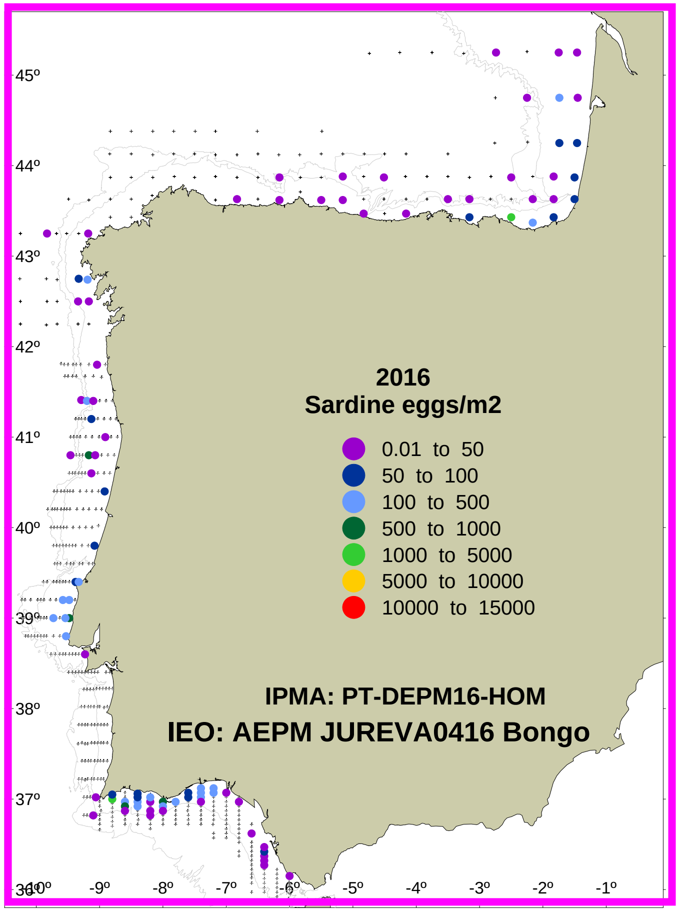
1988-1990-1995-1997-1998-1999-2001-2002



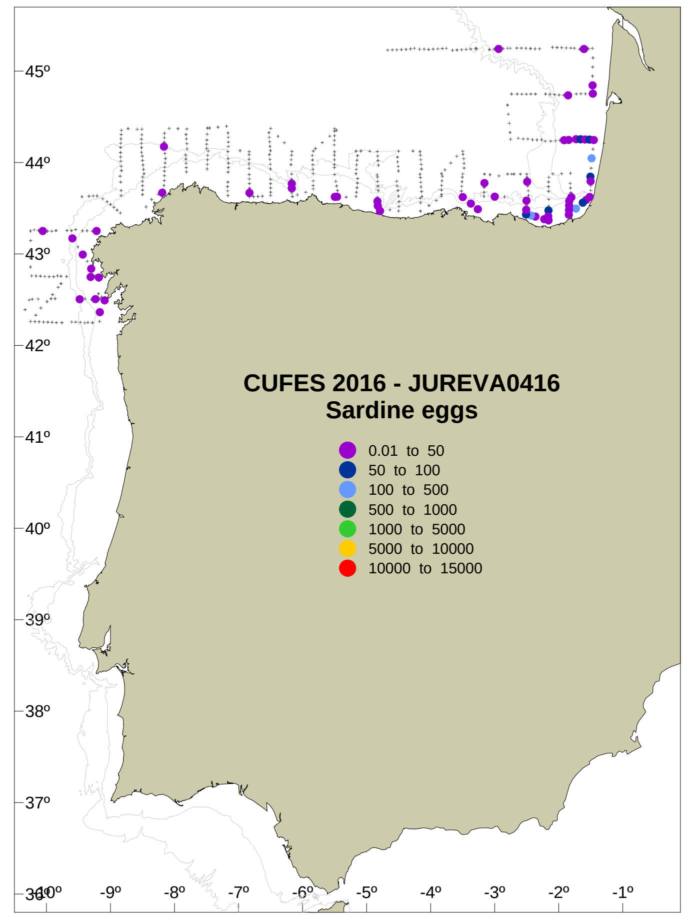
2004-2005-2007-2008-2010-2011-2013-2014



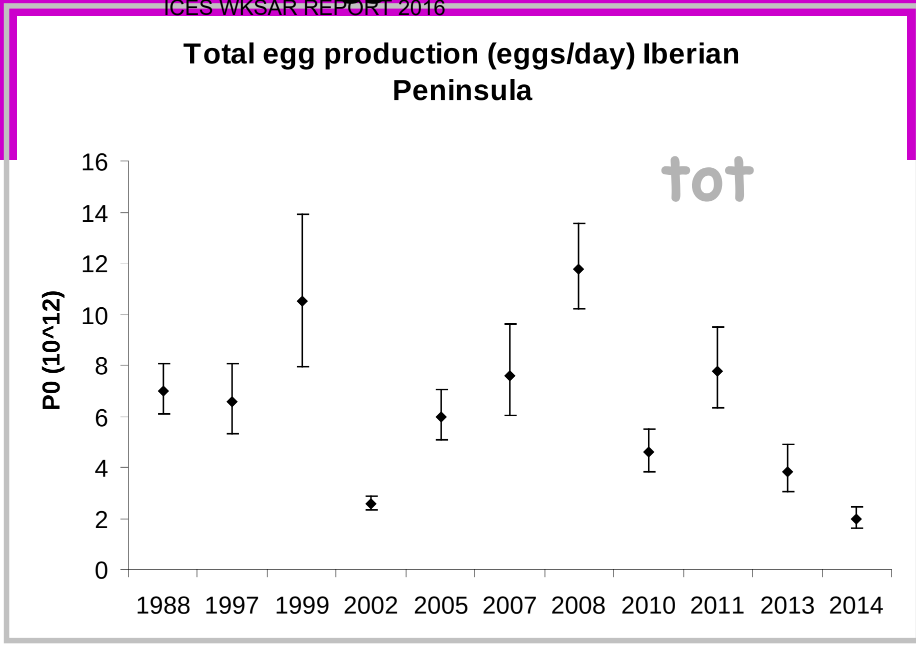
2016

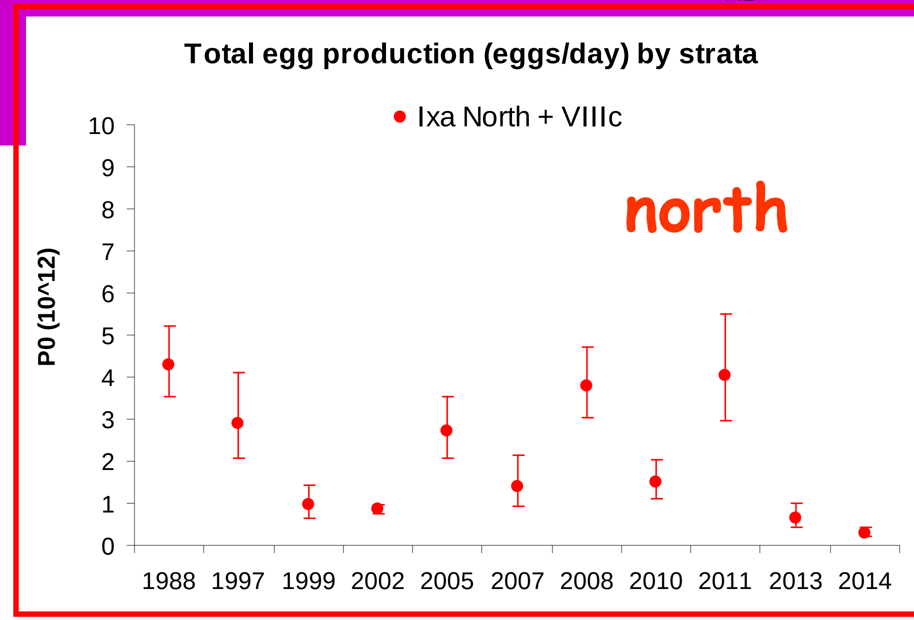


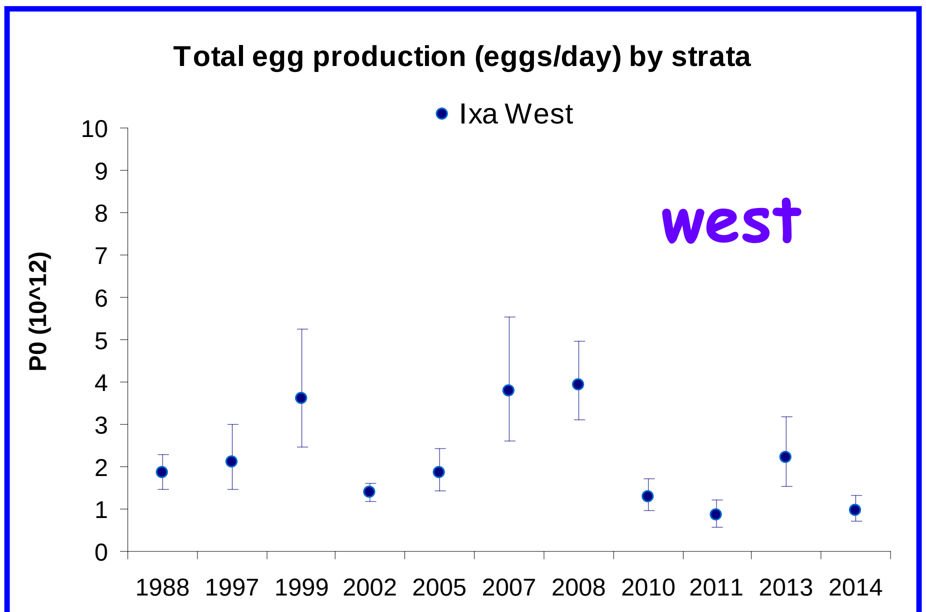
IEO
CUFES VS BONGO
JUREVA0416

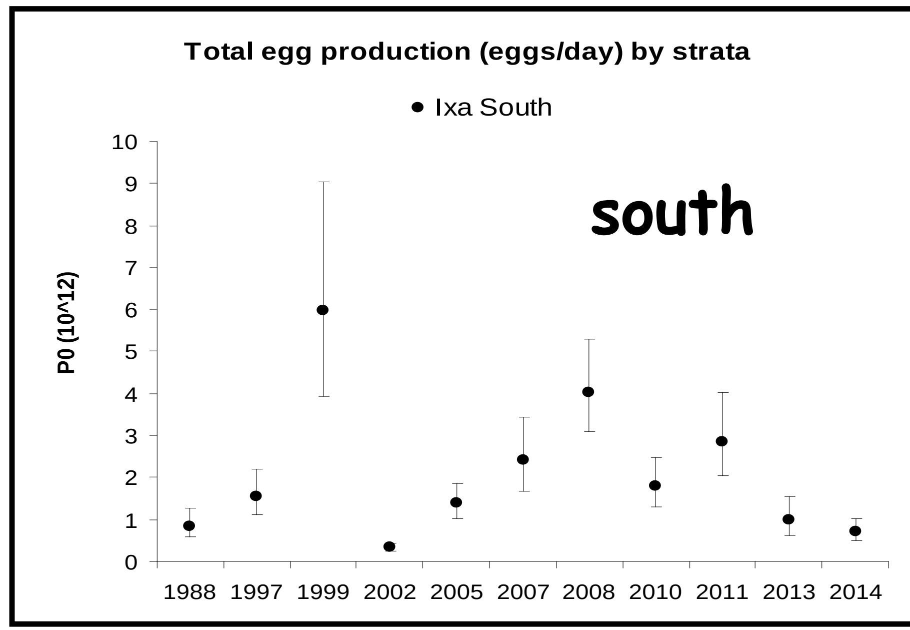


Egg Production







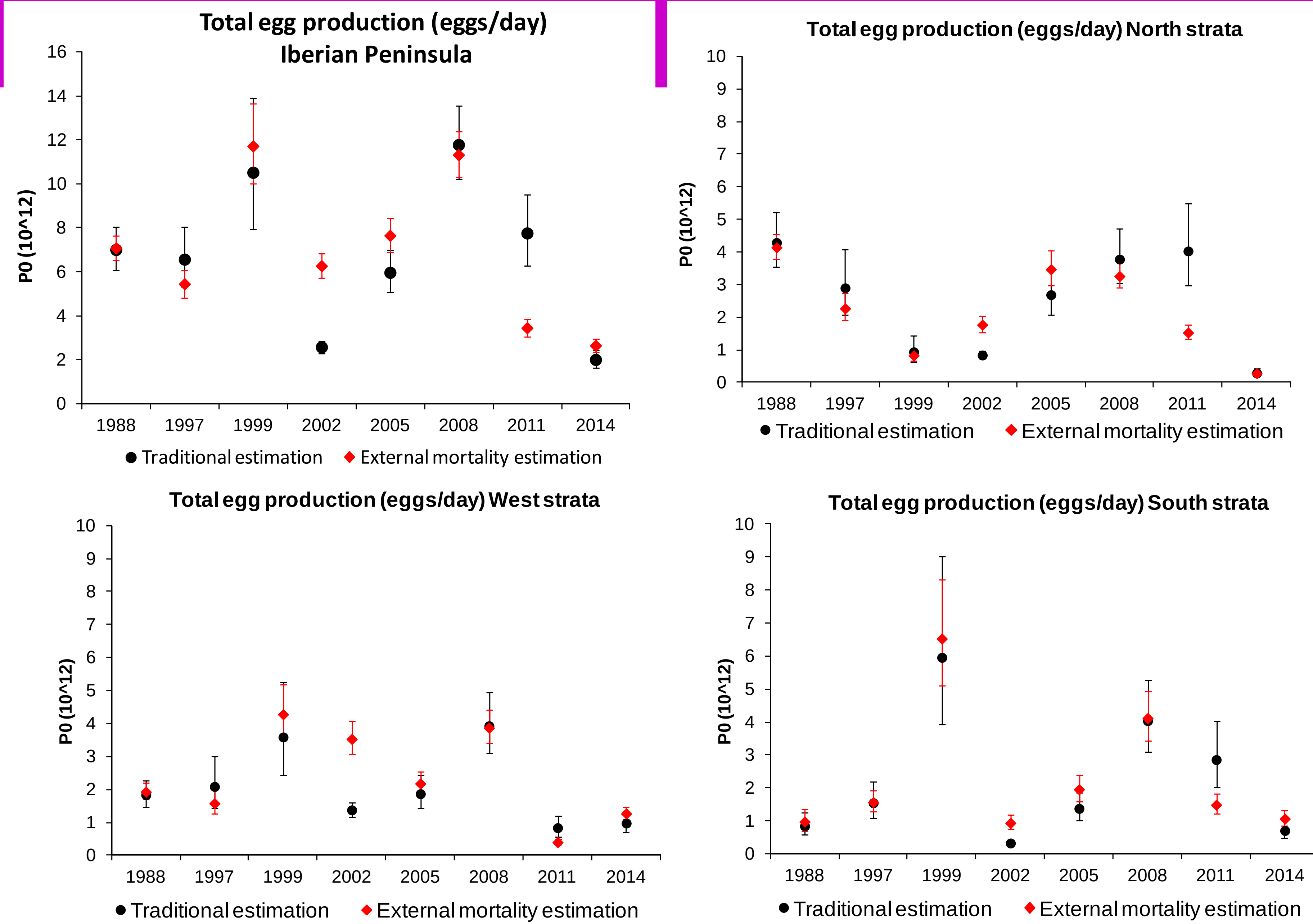


Egg Production

issues with egg production:

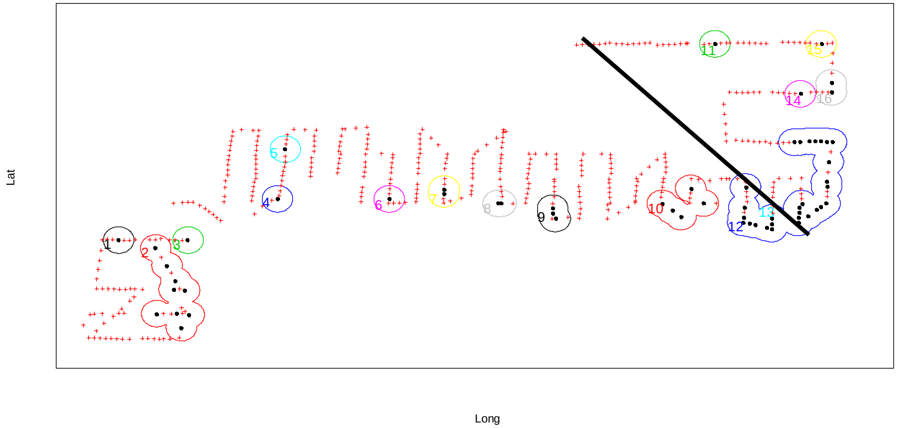
sampling coverage
coherent mortality for all strata

Egg Production with mortality from external model



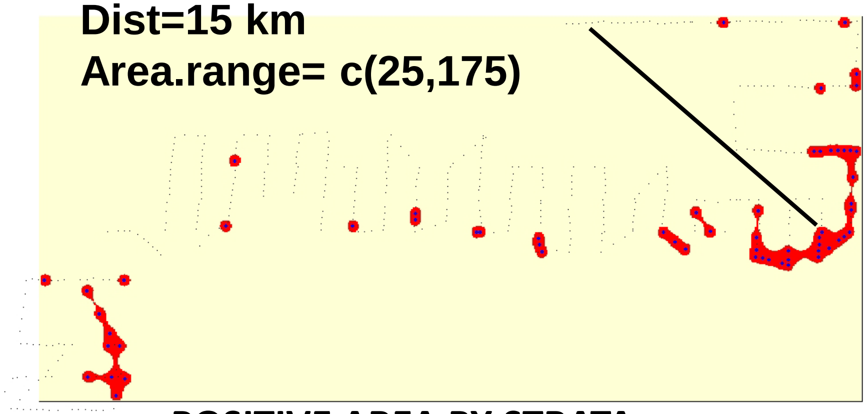
JUREVA 2016: Positive areas CUFES VS BONGO

CUFES JUREVA0416



positive.lim.win

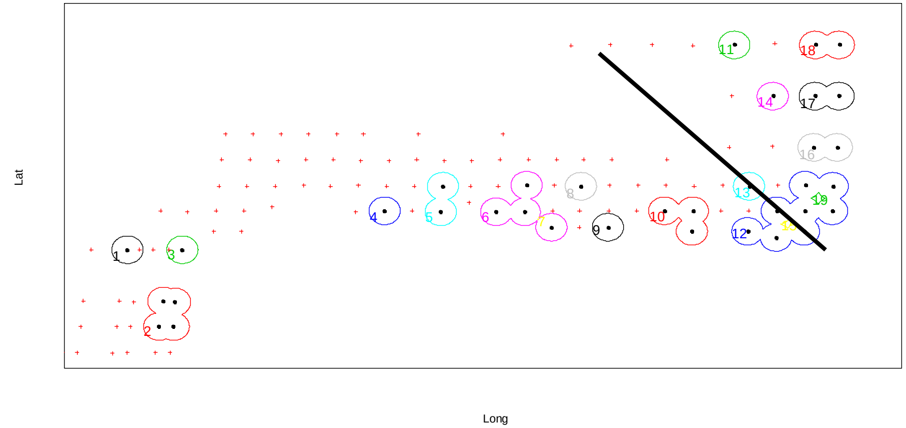
Dist=15 km
Area.range= c(25,175)



POSITIVE AREA BY STRATA

	IXa +VIIIc	VIIIb
TRUE	8045.08	3362.196

BONGO 40 JUREVA0416

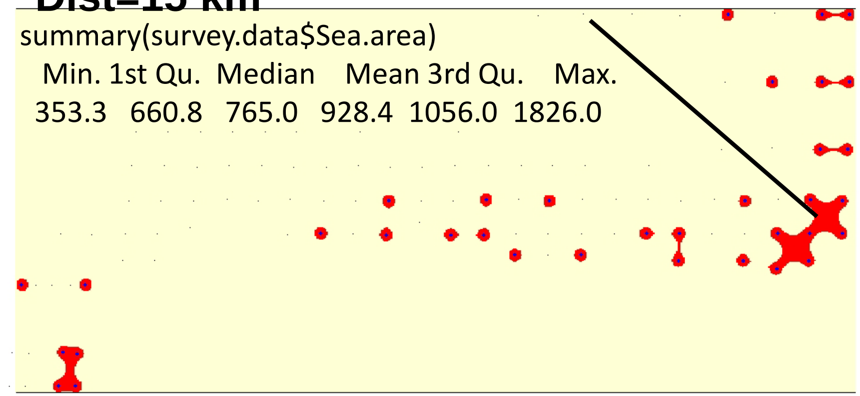


positive.lim.win

Dist=15 km

summary(survey.data$Sea.area)

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
353.3	660.8	765.0	928.4	1056.0	1826.0



POSITIVE AREA BY STRATA

	Ixa+VIIIc	VIIIb
TRUE	17163.33	12481.96

ICES WKSAR – 26-30 September 2016

DEMOGRAPHIC CONNECTIVITY OF SARDINE POPULATIONS (BAY OF BISCAY AND IBERIAN COAST ECOREGION)

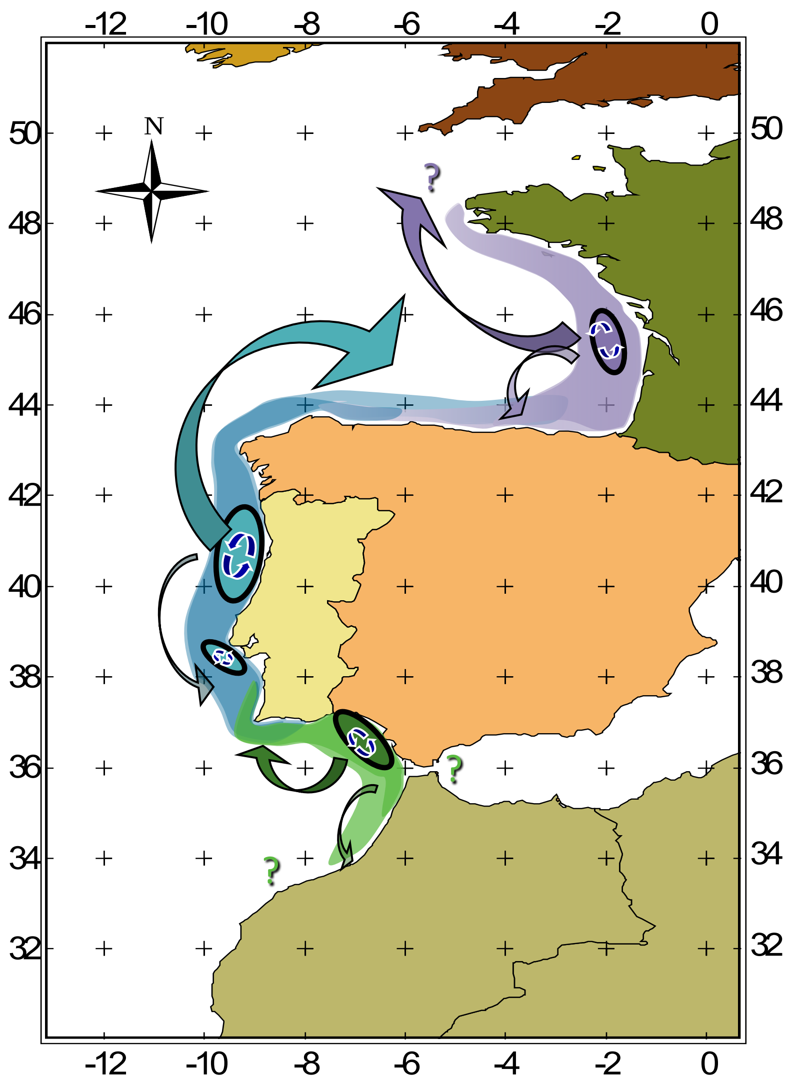
Silva A., Riveiro I., Pawlowski L., Marques V., Garrido, S. , Carrera C., Duhamel E., Ibaibarriaga, L., Uriarte A., ….

BACKGROUND

- Widely distributed fish species, such as sardine, are likely to show complex population structure
- Sardine in EU Atlantic waters may form a metapopulation
- Connectivity of local populations is likely at the early-life stage
- Connectivity may also take place through straying of recruits and adults
- Straying may be density-dependent and be facilitated by currents
- Straying confers persistence to less abundant and productive populations

Regional group of local populations linked by sufficient gene flow through migration, dispersal and straying of individuals to affect their mutual size, life history traits and dynamics

Straying (can be one-way) represents the movement of individuals away from their natal population.. (Secor et al 2009)



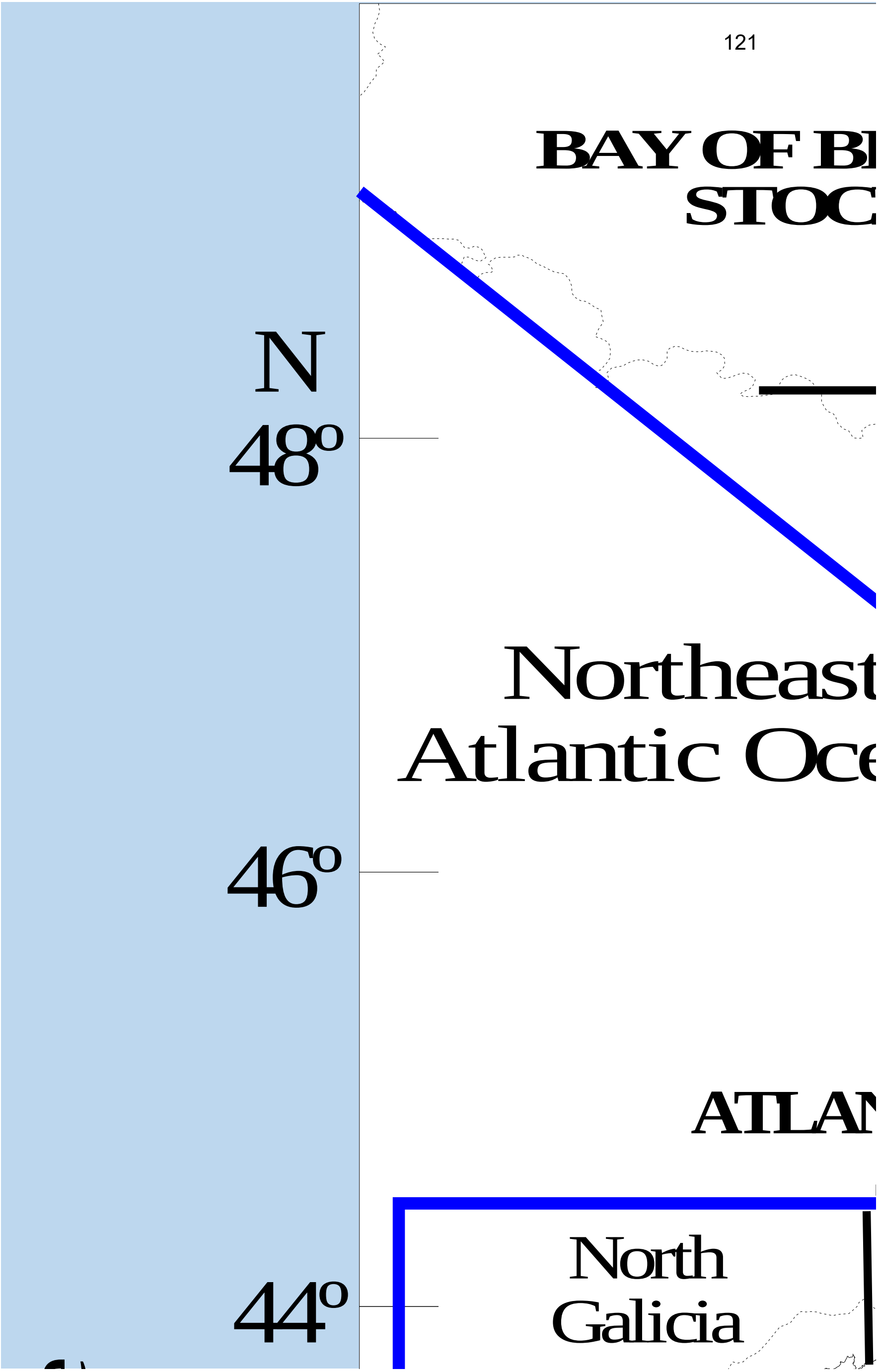
SARDYN: Conceptual scenario of sardine population structure, recruitment hotspots, cohort dispersal and connectivity.

Carrera and Porteiro, 2003
Cunningham and Roel, 2006
Skagen, 2006
Silva et al, 2009
….

QUESTIONS

- To what extent does the dynamics of each local population affects the dynamics of the other populations ?
- What is the origin of sardine from local “sink” areas, such as the Cantabrian Sea?
- Does the origin change over time ?
- During a period of poor recruitment off northwest Iberia (“source area”) may other source areas such as the Bay of Biscay contribute to avoid local depletion ?

- DATA:
  - Abundance by area, cohort and age in spring acoustic surveys 2000-2016
  - Positive area and mean density by area in spring acoustic surveys
  - Catches (in number) by quarter, area, cohort and age 1999 – 2015



ANALYSIS

1. Description of area-based recruitment dynamics, total mortality and cohort dispersal (SURVEY DATA)

- 14 cohorts (1999-2012), 6 age groups (1-6 years), 8 areas (bisc, can, ngal, sgal, npor, swpor, spor, cad)
- Two-part GAM:
  - Presence/absence model $Presence \sim age * area + cohort * area$
  - Count model $Counts \sim area * cohort * age$

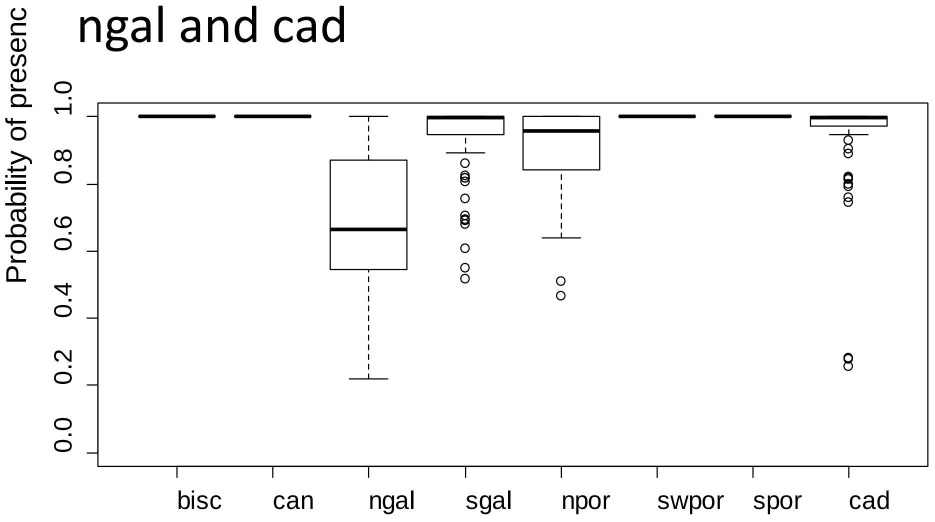
$$Abundance \sim Presence * Counts$$

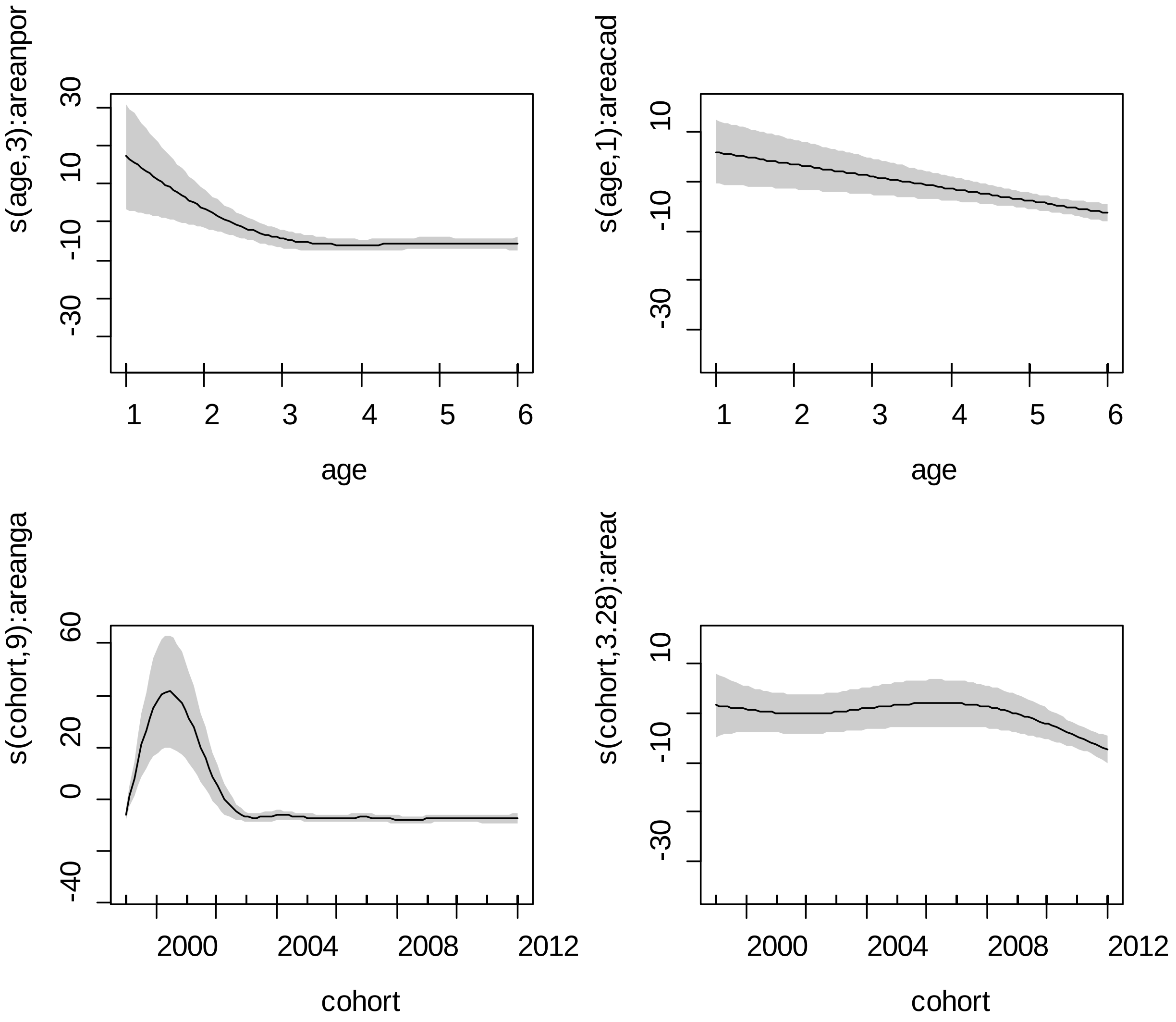
- Areas coded with numbers increasing from the southern extreme and expressing the distance between their mean points (e.g. Cadiz = 0.37, Biscay = 10.87)
- Model selection by log-likelihood ratio tests; changes in AIC between models examined as well.

RESULTS

• Presence model:

- Explains 53% of the deviance
- Sardine presence decreases significantly with age in npor and cad
- Changes by cohort are only significant in ngal and cad





RESULTS

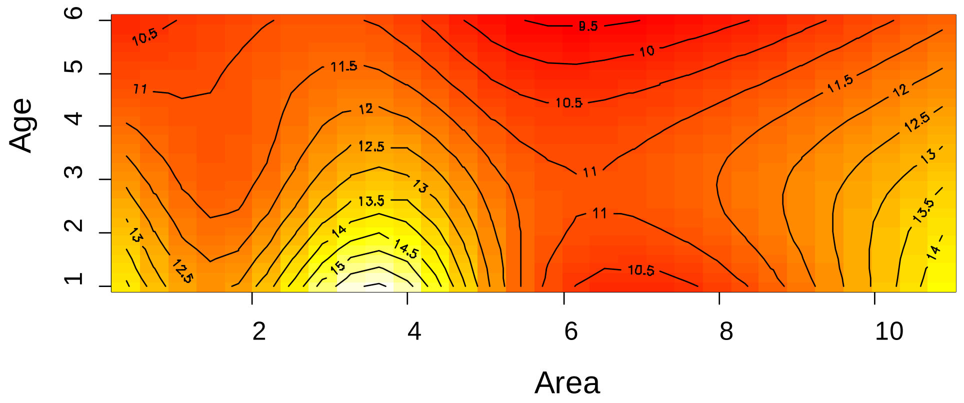
- Count model:

$$Counts \sim intercept + \ age \ * area + cohort \ * area$$

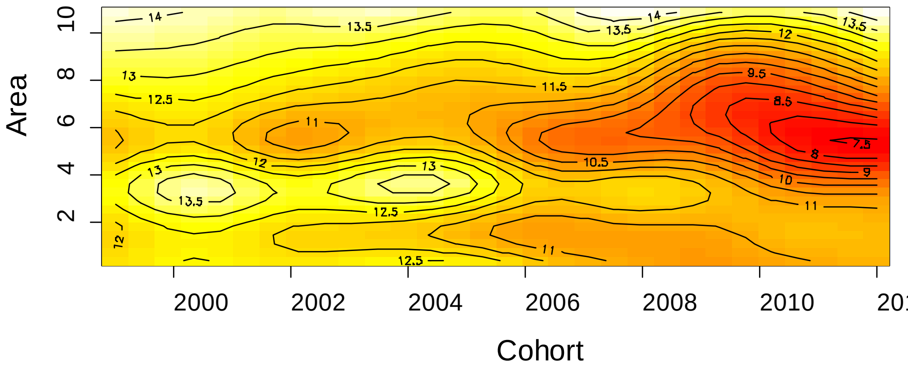
- Explains 74.2% of the deviance (N=559,edf=57.9)

- The number (>0) of sardine (by area, cohort and age) is explained by the addition of two smooth non-linear effects: a variable mortality+migration across areas and a variable distribution of cohorts-age by area; different cohorts show comparable mortality+migration.

Age * area (view of 2005 cohort)



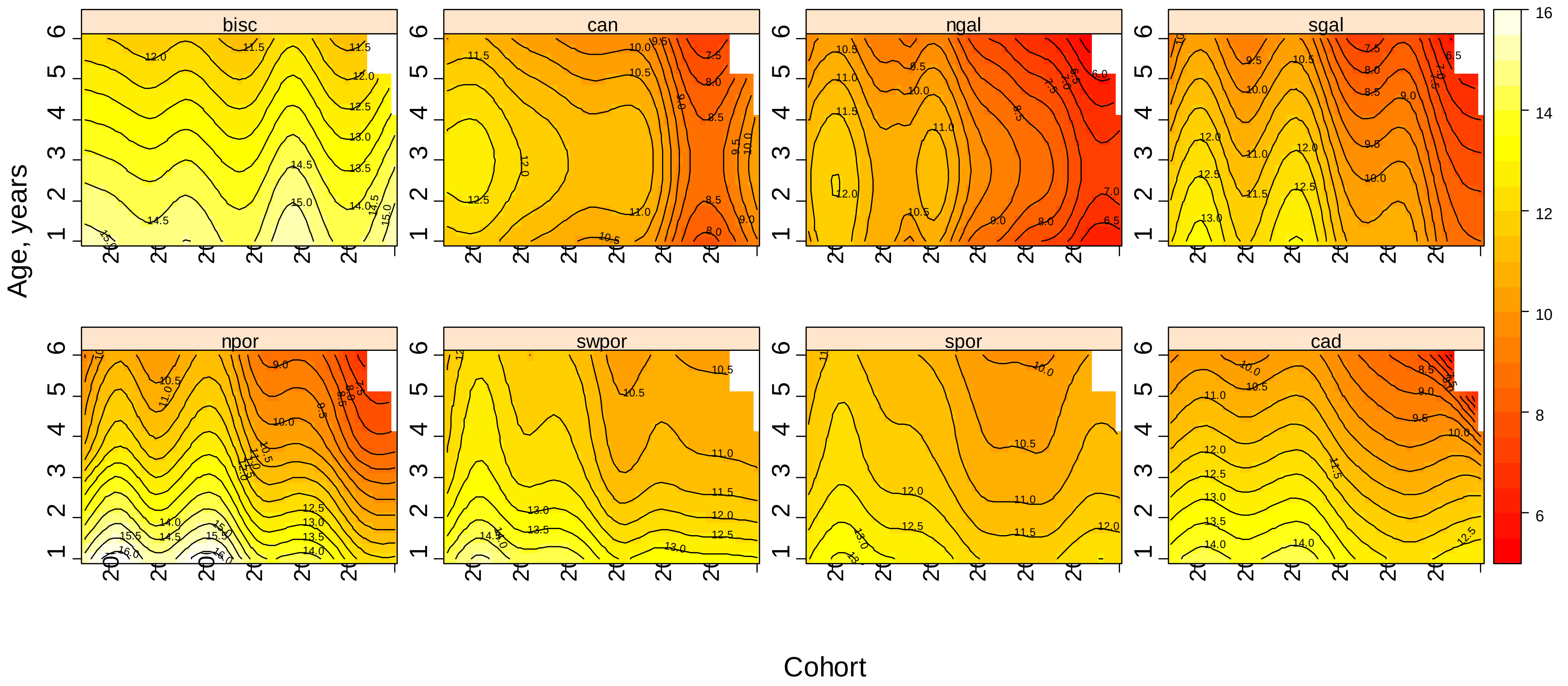
Cohort * area (view of age 3 dist



RESULTS

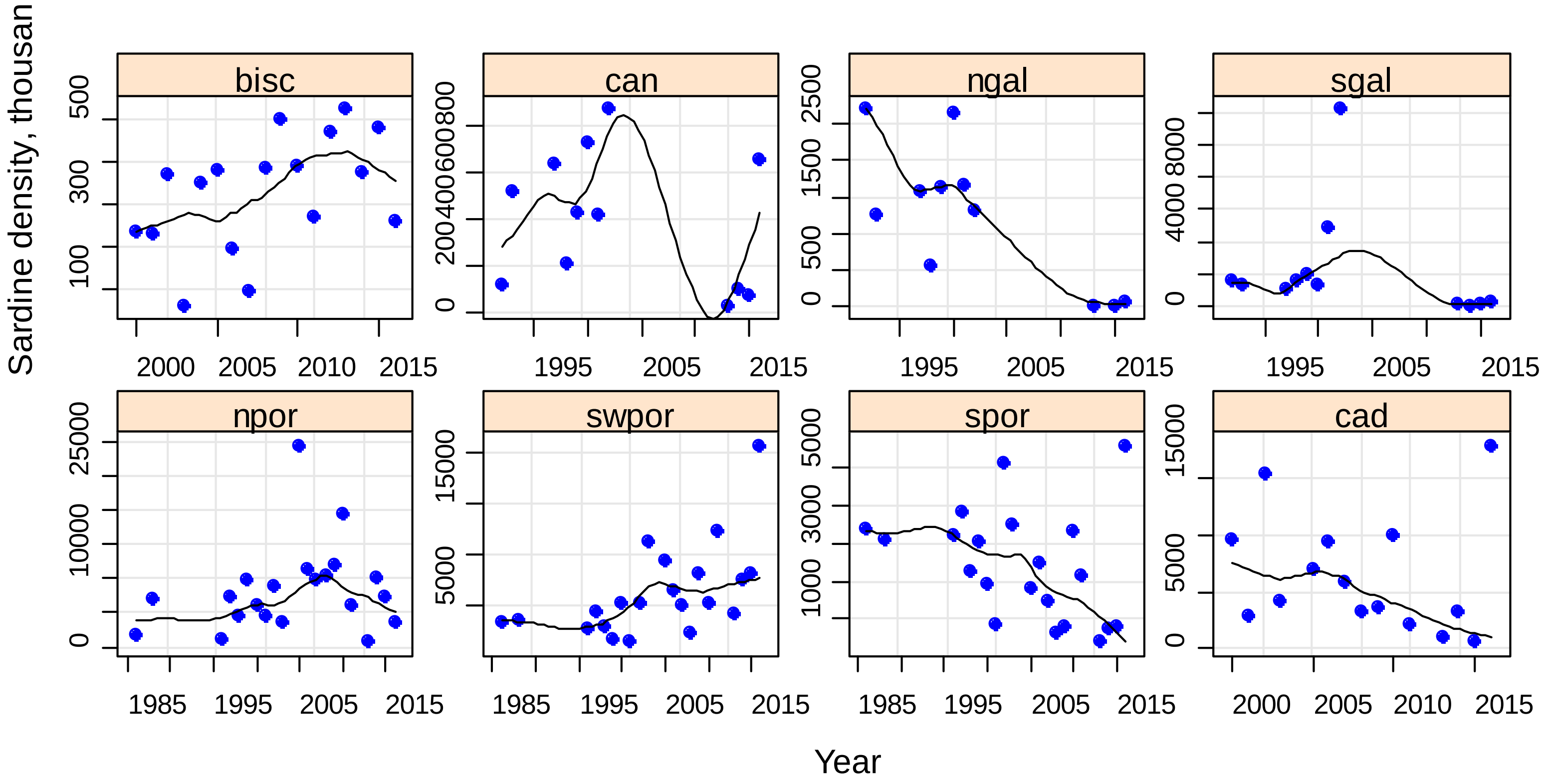
- Abundance model:

Distribution of cohorts' abundance-at-age by area



RESULTS

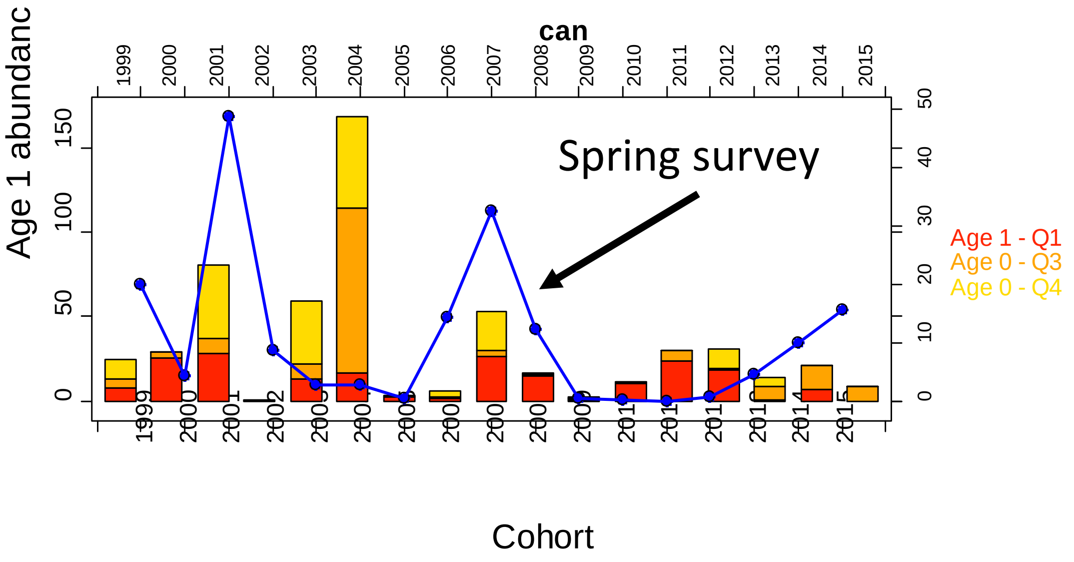
- Suggest can and ngal are "supplied" by sardine straying from the south or the north, or both
- Straying may depend on subpopulation proximity and density of the source population
  - ✓ In terms of proximity, more plausible from Biscay to Cantabrian Sea
  - ✓ In terms of density, more plausible from the western areas (e.g.North Portugal) to ngal and can

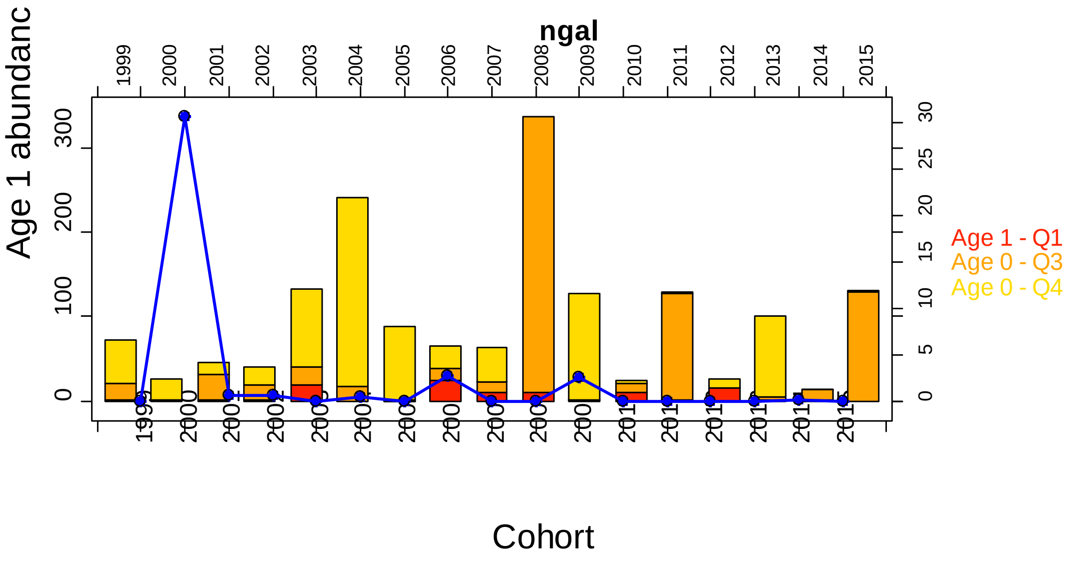


RESULTS

- Up to now we “forgot” the influence of fisheries…

CATCHES BY QUARTER OF 0 AND 1 YEAR OLDS PRIOR TO SPRING SURVEYS





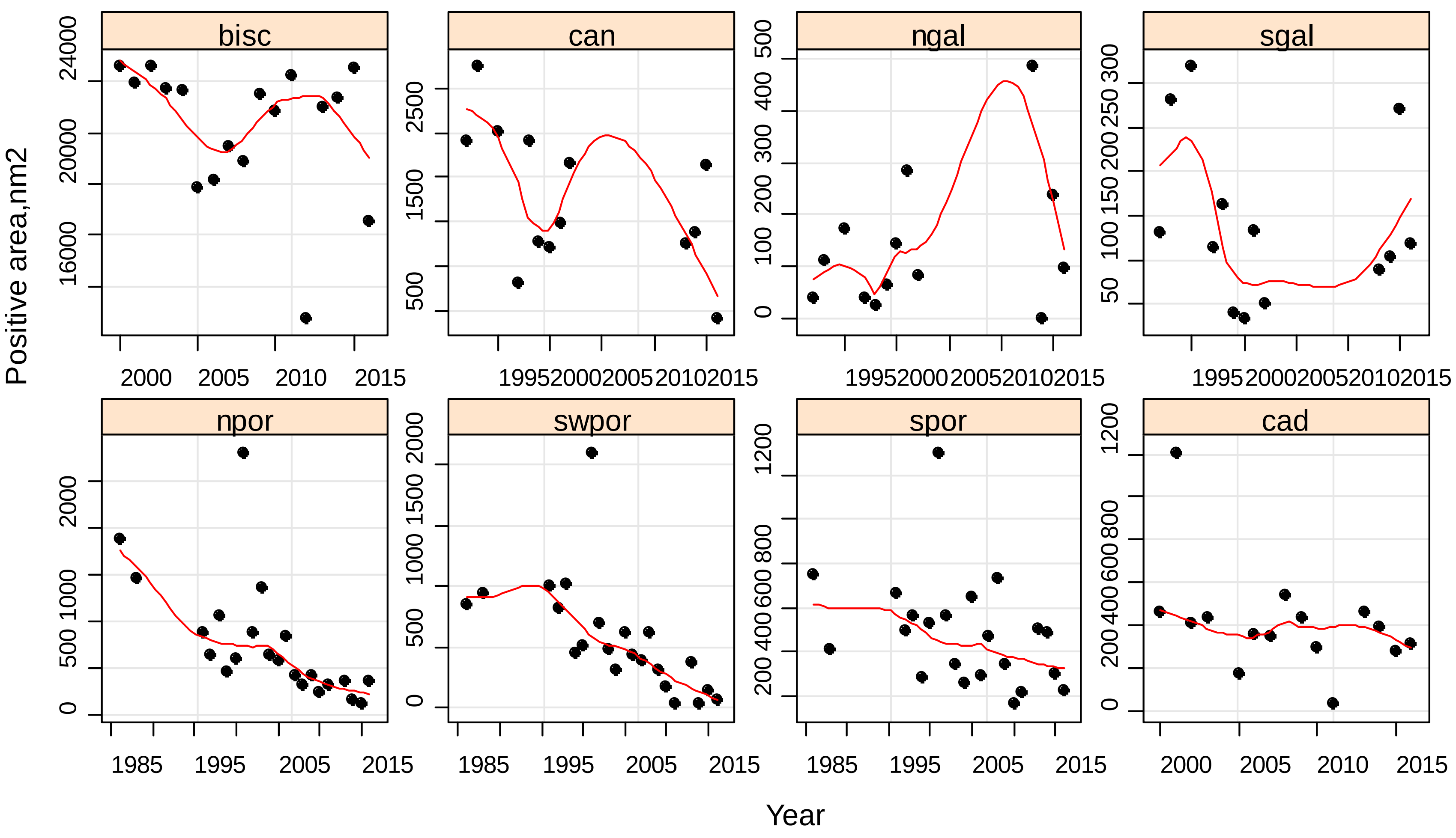
- Are catches of strong cohorts coming from the landing area ?
- Or from neighbour recruitment areas ?

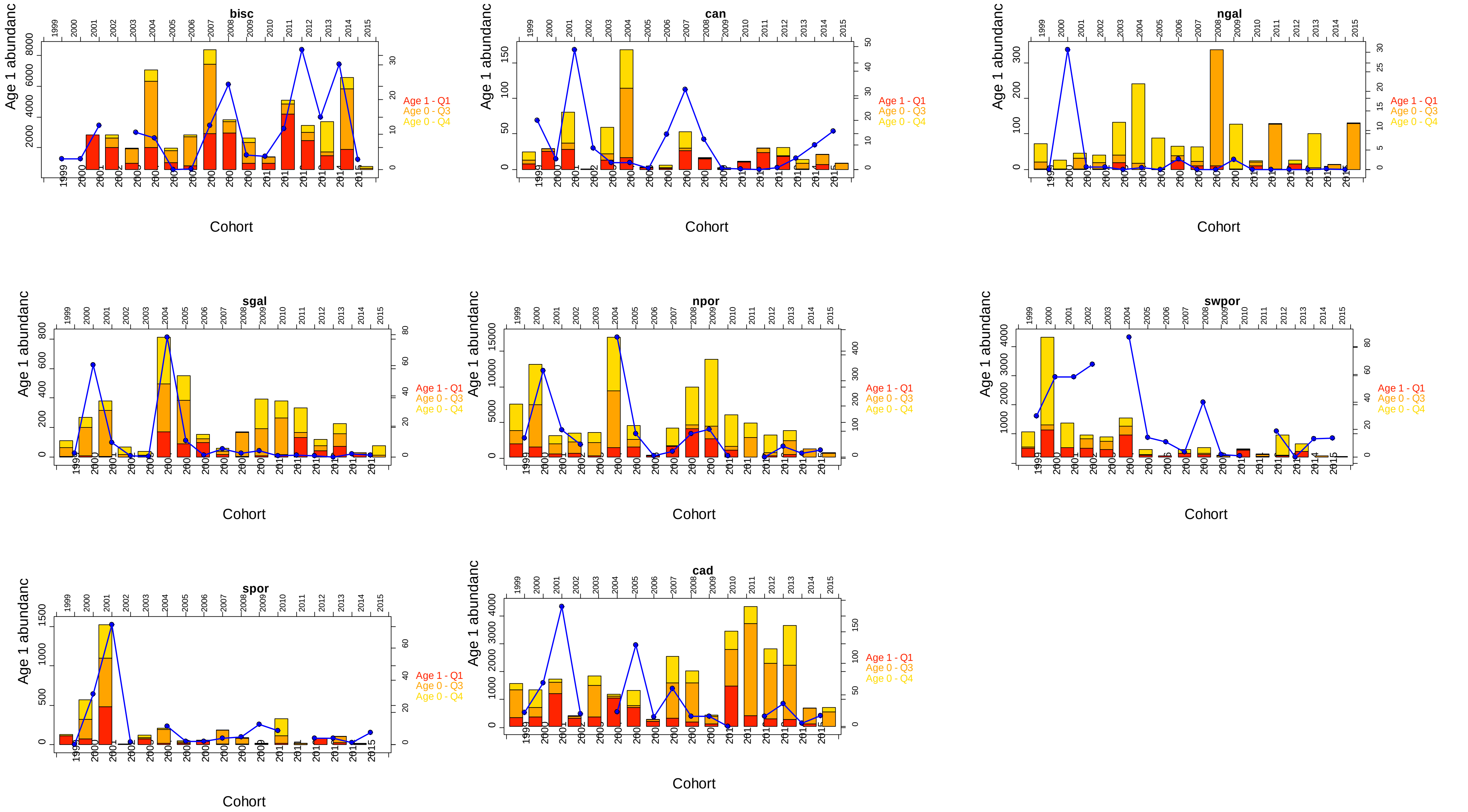
FINAL COMMENTS AND FOOD FOR THOUGHT

- Stronger connectivity of North Galicia and Cantabrian Sea with the western areas than to Bay of Biscay
- Strong cohorts stray from North Portugal to North Galicia and Cantabria during their first 2-3 years of life
- Despite the high abundance of recruits in Biscay in recent years, there is no evidence of massive immigration to northern Spanish areas or more to the south, suggesting the Biscay sardine cannot “rescue” the Iberian coast population

- To what extent is fishing of 0-group and 1-year-olds affecting our perception of recruitment variations and connectivity between areas ?

- The Bay of Biscay is an extensive area: is recruitment always synchronous between the Southern (Gironde, Adour) and northern, Britanny (Loire) areas ?


bisc
can
ngal
sgal
npor
swpor
spor
cad
Positive area,nm2
Year


bisc
can
ngal
sgal
npor
swpor
spor
cad
Age 1 abundanc
Cohort
Age 1 - Q1
Age 0 - Q3
Age 0 - Q4

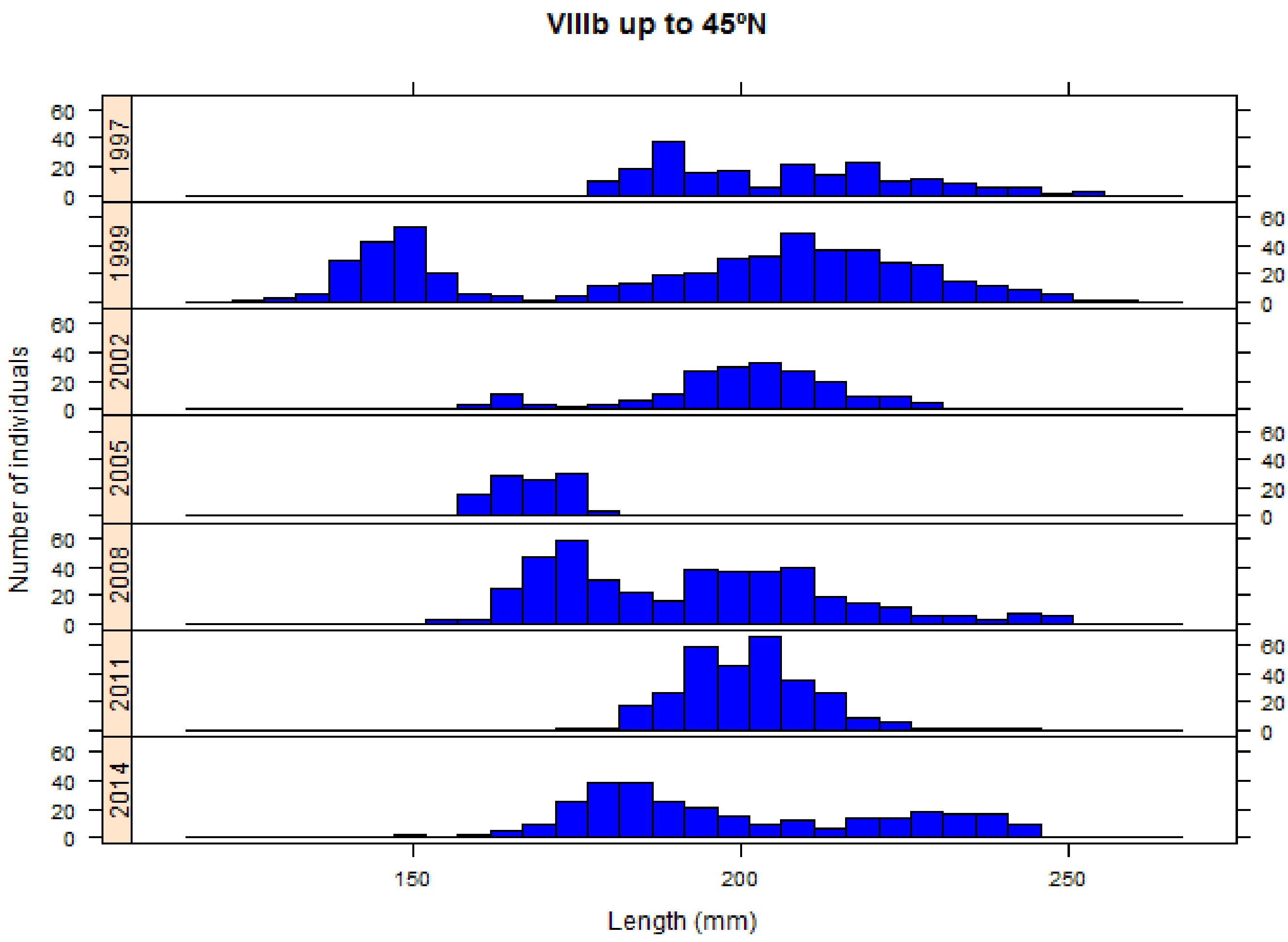
8ab IEO-AZTI sardine DEPM estimates and sardine egg abundance

IEO

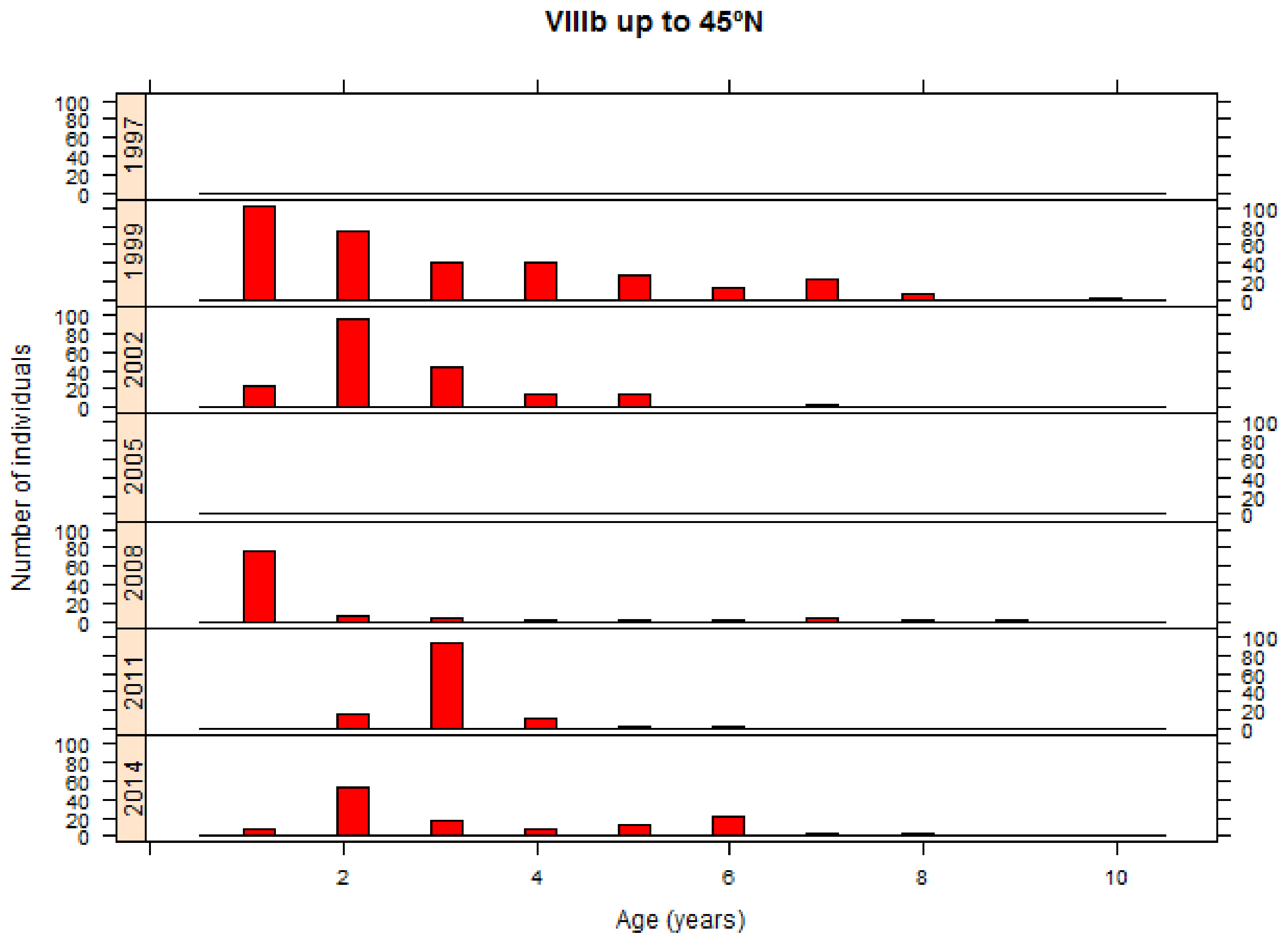
Year	Survey area (Km^2)	Positive area (Km^2)	P0 tot (eggs/day) (x10^{12})(CV%)	Female Weight (g) (CV%)	Batch Fecundity (CV%)	Sex Ratio (CV%)	Spawning Fraction (CV%)	Spawning Biomass (tons)(CV%)
1997	20149	12755	1.74(20)	74.5(12)	32269(17)	0.508(8)	0.131(10)	60332(31)
1999	6793	5724	0.45(13)	63.6(13)	32704(45)	0.535(11)	0.124(15)	13200(52)
2002	11888	9154	1.67(18)	62.9(6)	24577	0.492(23)	0,143	60720
2008	10187	8167	1.4(23)	55.4(11)	15849(29)	0.483(9)	0.137(24)	73942(47)
2011	14091	12400	2.72(16)	61.3(9)	30383(4)	0.51(20)	0.066(49)	162930(55)
2014	13480	7914	1.70 (28)	65.51 (22)	25545 (24)	0.59 (12)	0.084 (25)	86624 (51)

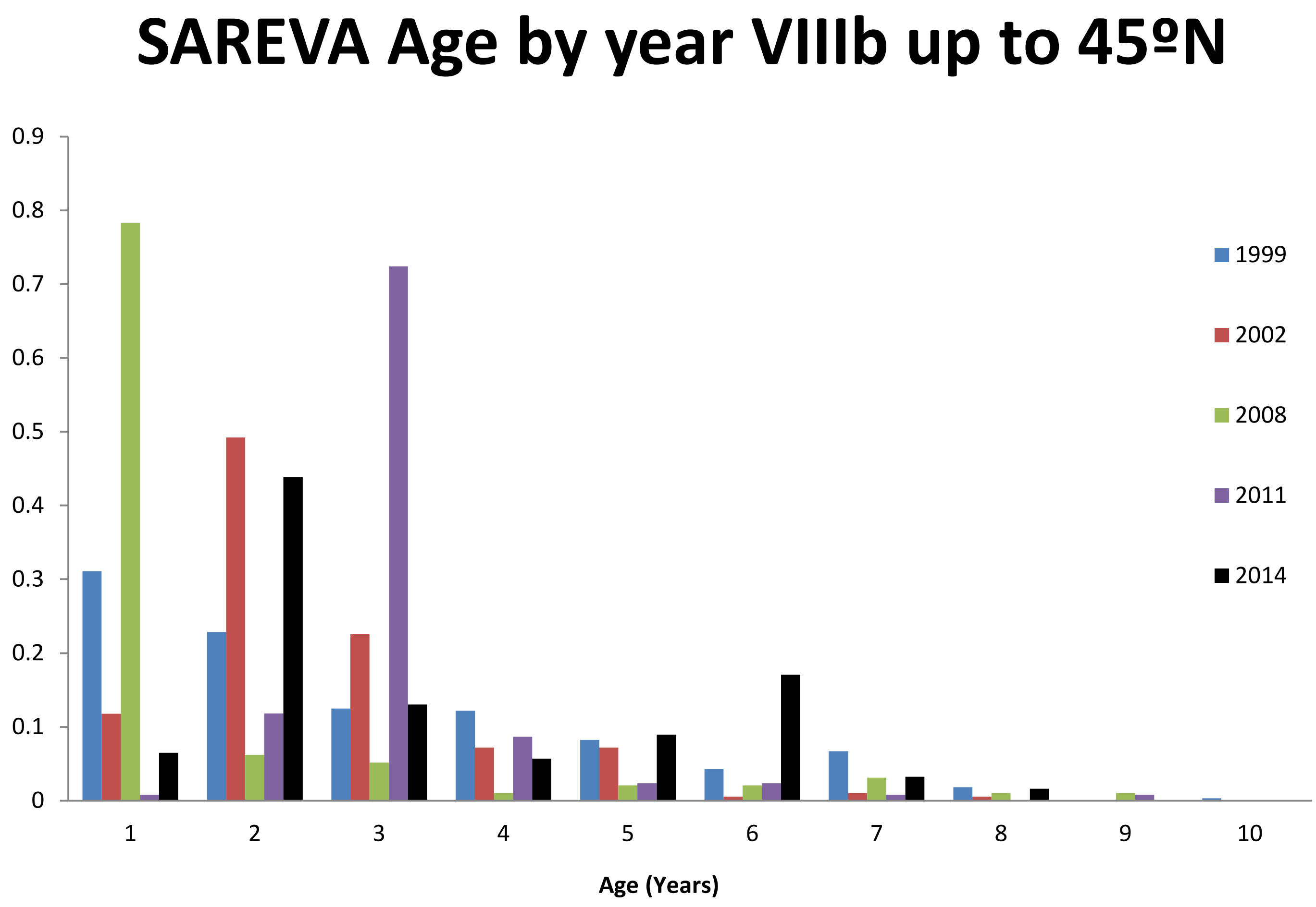
**2005 was not sampled because of the bad weather

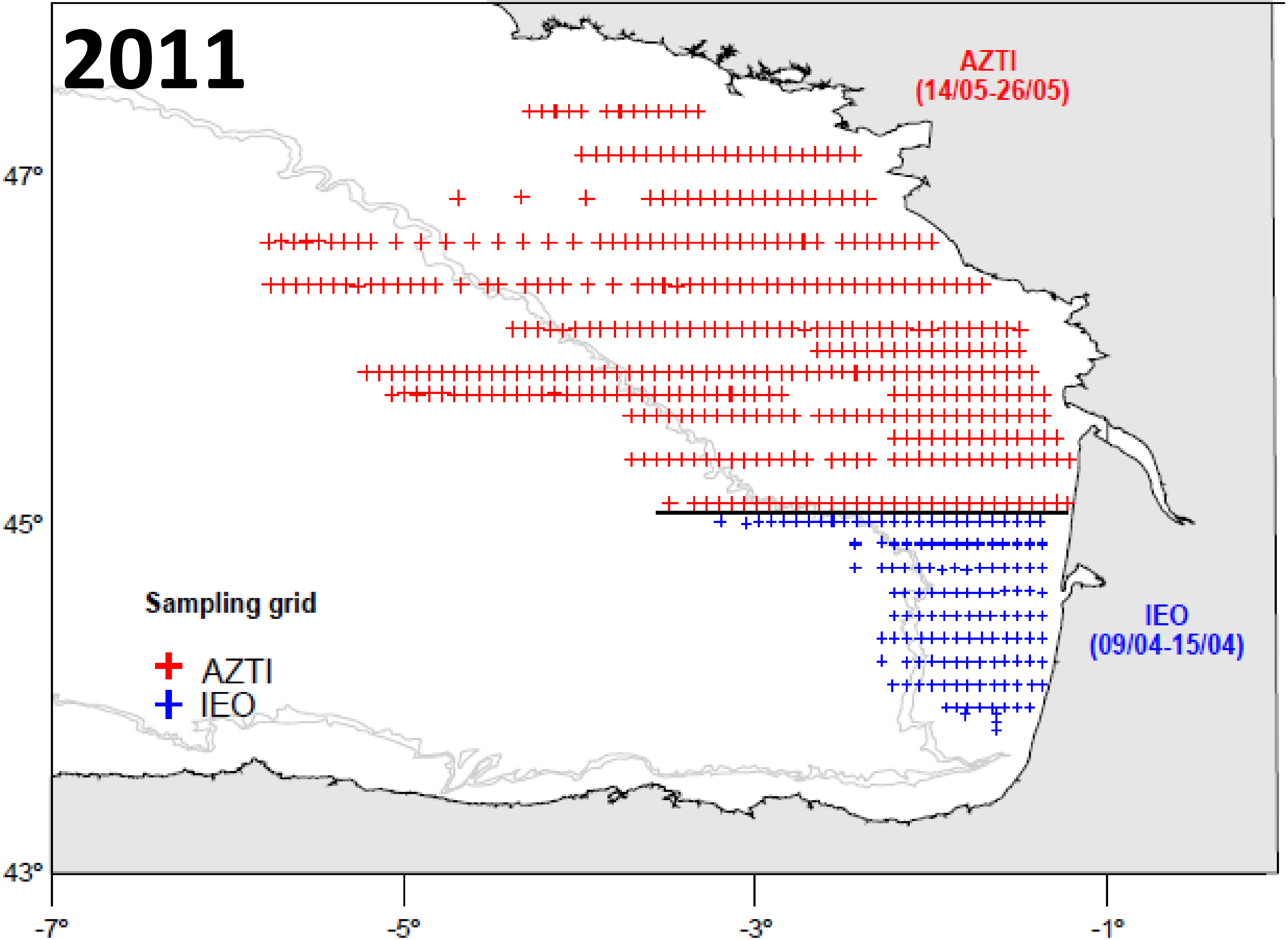
SAREVA Length distribution by years



SAREVA Age distribution by years




SAREVA Age by year VIIIb up to 45ºN
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7
8
9
10
Age (Years)
1999
2002
2008
2011
2014

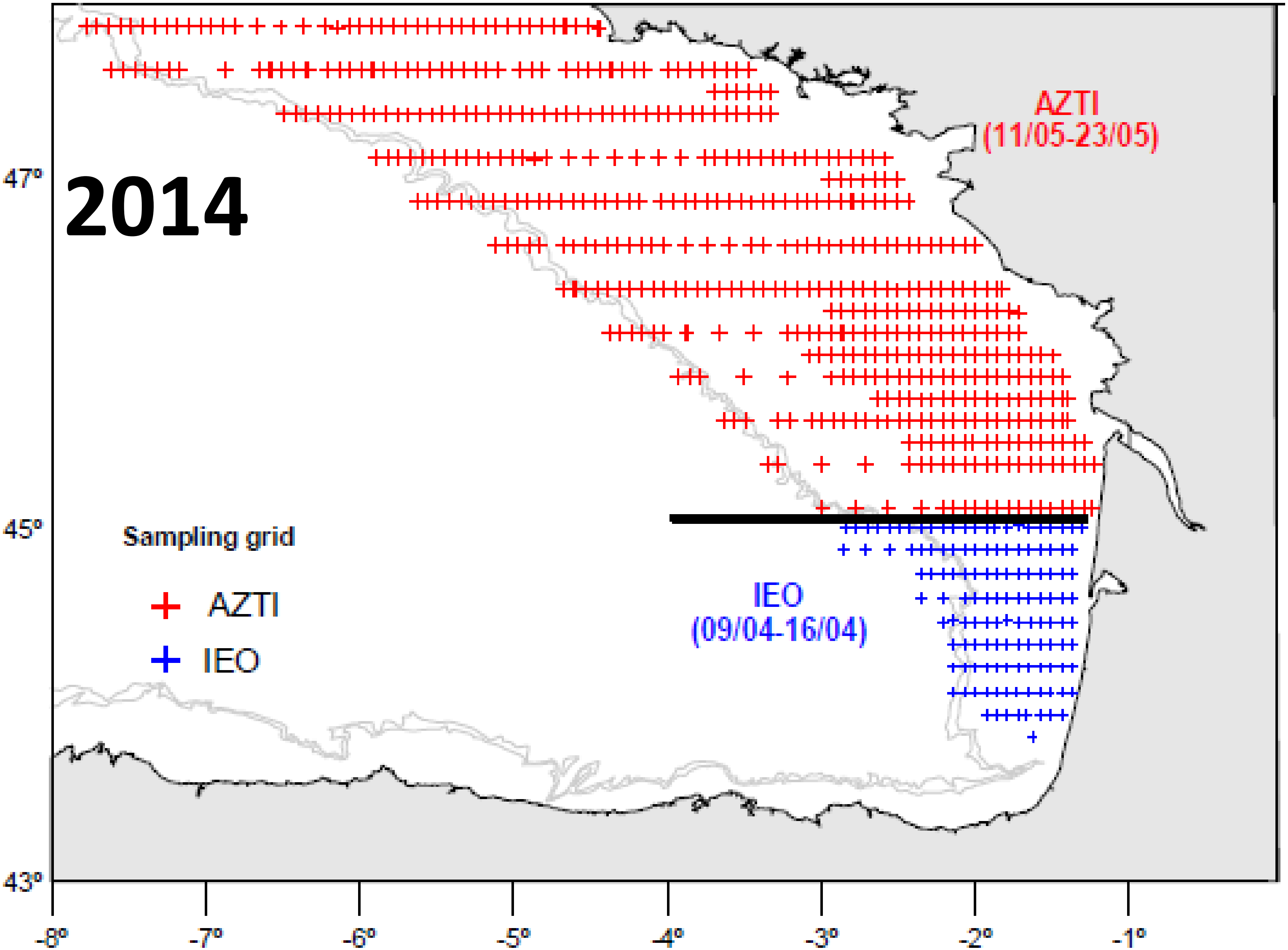

2011
AZTI
(14/05-26/05)
47°
45°
43°
-7°
-5°
-3°
-1°
Sampling grid
AZTI
IEO
IEO
(09/04-15/04)

2011

Institute	IEO	AZTI
Survey area	VIII until 45 °N	VIII 45-48°N
ICHTHYOPLANKTON		
R/V	Cornide de Saavedra	Investigador
Date	09/04-15/04	16-26/05/2011
Transects	11	33
PairoVET stations	134	421
Positive stations	114	136
Tot. Eggs (nº nets)	2764 (1 net)	2951(2 nets)
Max eggs/m2	2322	1870
Temp (10m) min/mean/max	13/14/14.7	12/16.3/17.88
SSS	34.7/35.4/35.8	33.5/35.18/35.8
SST		13/16.6/18.6
Max age	54.4	
CUFES stations	83	894
Positive CUFES stations	77	322
Tot. Eggs CUFES	22328	9509
Max eggs/m3	92.12	73.47
Hydrographic stations	134	421
ADULTS		
Number Hauls R/V (total)	12	
- Pelagic Trawls	12	
- Bottom trawls	-	-
Numer Hauls C/V	-	9
Number (+) trawls	3	5
Number (+) trawls used for analysis		
Depth range (m)	63-143	21-1000
Time range	During the hole day	During the hole day
Total sardine individuals	302	305
Length range (mm)	145-243	143-222
Weight range (g)female &male	41.7-101.8	23.1-82.8
Female for histology	129	95
Hydrated females	14	25
Otholites	129	129
Female Ages Range	1-9	1-7

2011 DEPM PARAMETERS

Institute	IEO-AZTI
Area	VIIIab
Eggs 2011	
Survey area (Km^2)	68185
Positive area (Km^2)	33245
P0 ($eggs/m^2/day$)	138.25 (19.1)
Z ($hour^{-1}$)	-0.0141* (41.6)
Daily mortality rate (%)	28.71
P0 tot (eggs/day)	4.60×10^{12} (19.1)
Adults 2011	
Female Weight (g)	54.08 (6.9)
Batch Fecundity	25336 (9.5)
Sex Ratio	0.451(14.8)
Spawning Fraction	0.133 (33.8)
Spawning Biomass – thousand tons	136.56 (43.2)


2014
AZTI
(11/05-23/05)
IEO
(09/04-16/04)
Sampling grid
AZTI
IEO
47º
45º
43º
-8º
-7º
-6º
-5º
-4º
-3º
-2º
-1º

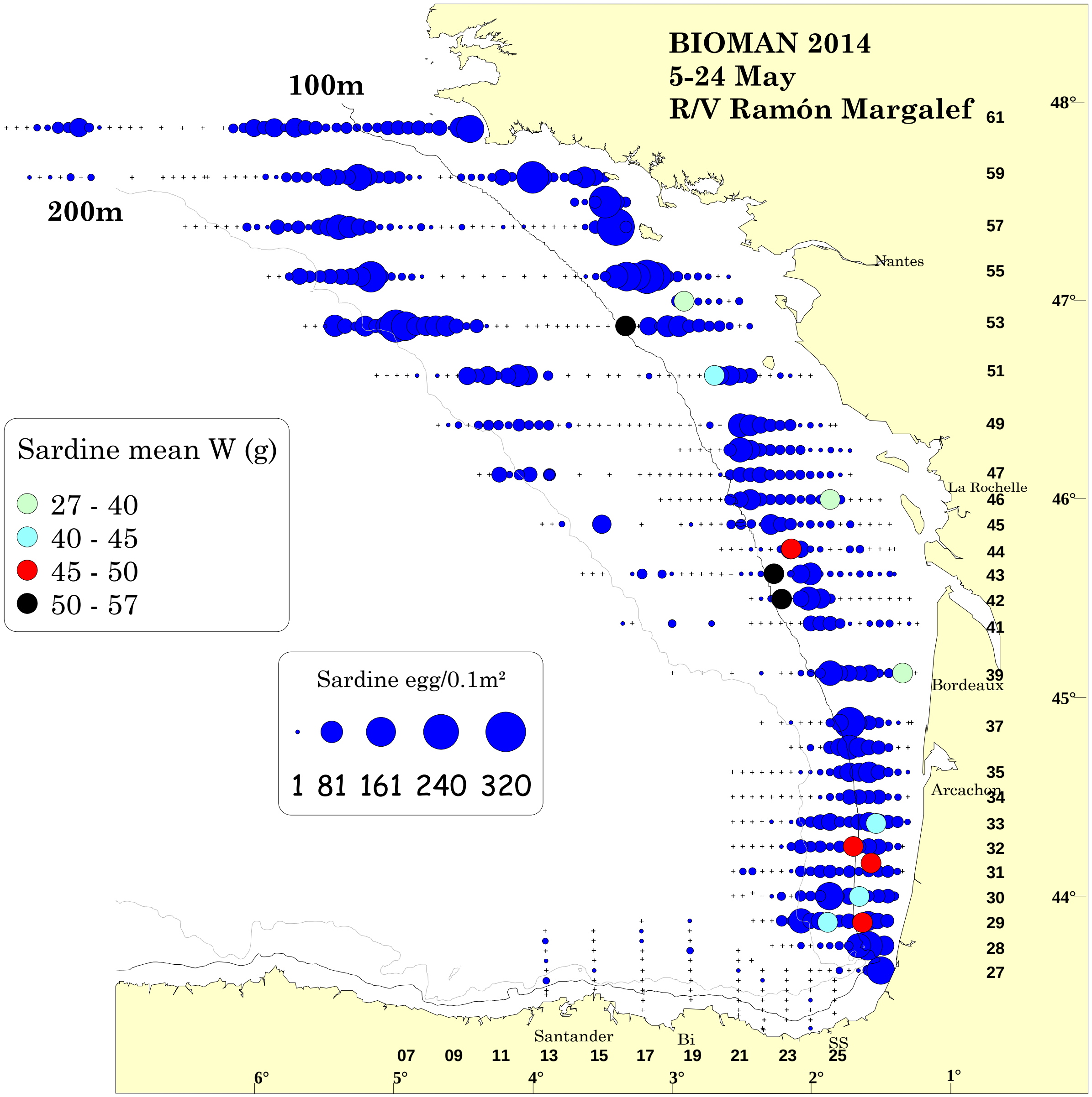
2014

Institute	IEO	AZTI
Survey area	VIIIb up to 45 °N	VIIIab 45-48°N
ICHTHYOPLANKTON		
R/V	Vizconde de Eza	Ramón Margalef
Date	09/04-16/04	11/05-23/05
Transects	11	18
PairoVET stations	128	520
Positive stations	77	310
Tot. Eggs (n° nets)	1449 (1 net)	8245 (2 nets)
Max eggs/m2	2619	4220
Temp (10m) min/mean/max	12.3/13.2/14.5	11.8/14.2/15.5
SSS	33.8/34.8/35.6	29.9/34.3/35.6
CUFES stations	122	1183
Positive CUFES stations	98	642
Tot. Eggs CUFES	12067	14812
Max eggs/m^3	90.7	94.8
Hydrographic stations	127	520
ADULTS		
Number Hauls R/V (total)	13	30
- Pelagic Trawls	13	30
Numer Hauls C/V	-	-
Number (+) trawls	3	8
Time range	During daylight hours	24hours
Total sardine individuals	324	623
Length range (mm)	151-247	133-234
Weight range (g)female &male	24-113.5	13.7-97.1
Female for histology	148	218
Hydrated females	51	21
Otholites	146	354

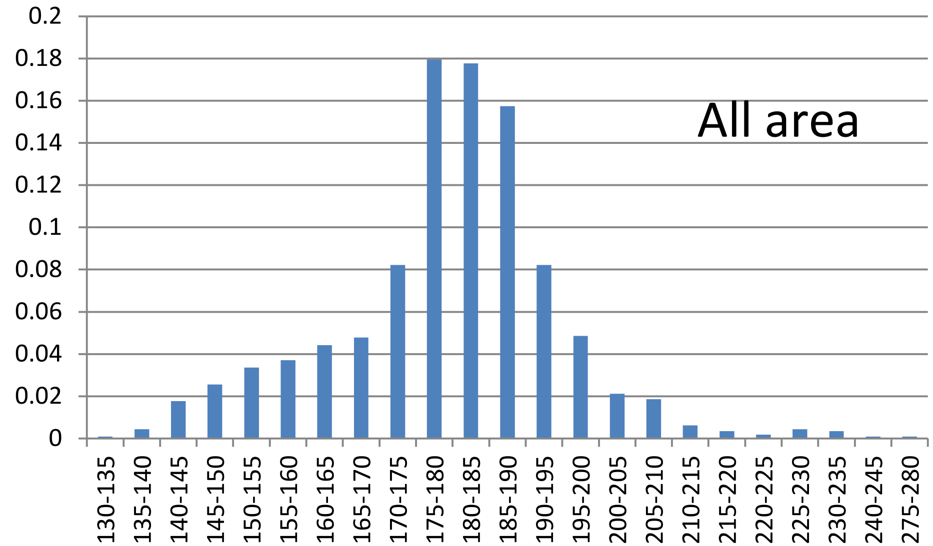
2014 DEPM PARAMETERS

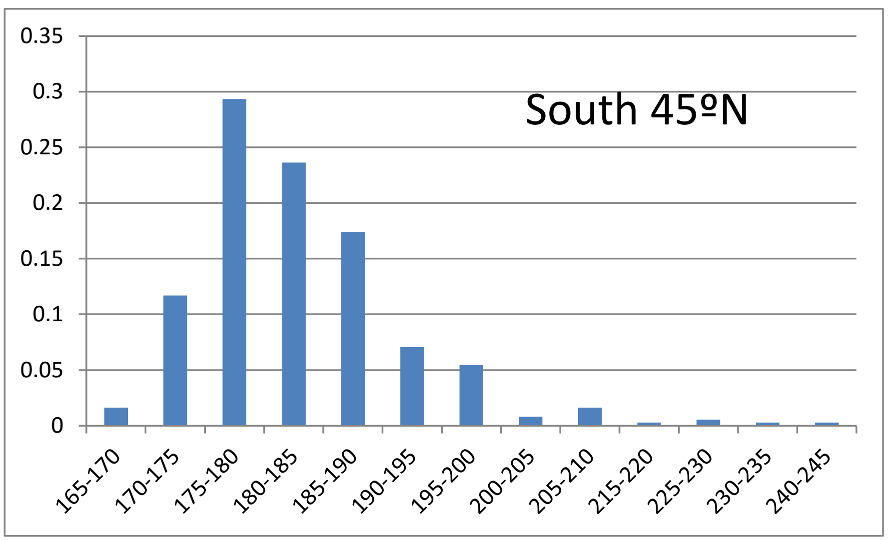
Institute	IEO	AZTI	IEO-AZTI
Area	VIIIb up to 45°N	VIIIab 45-48°N	VIIIab
Eggs 2014			
Survey area (Km^2)	13480.4	69943.6	83424
Positive area (Km^2)	7913.8	46511.8	54425.6
P0 (eggs/m^2/day)	214.2 (27.6)	129.4 (15.2)	
Z ($hour^{-1}$)	-0.021*** (28.7)	-0.013***(29.8)	
P0 tot (eggs/day)	1.70×10^{12} (27.6)	6.02×10^{12} (15.2)	7.72 (13)
Adults 2014			
Female Weight (g)	65.51 (22)	48.46 (5)	
Batch Fecundity	25545 (24)	21056 (12)	
Sex Ratio	0.59 (12)	0.482 (18)	
Spawning Fraction	0.084 (25)	0.089 (23)	
Spawning Biomass (tons)	86624 (51)	322974 (35)	409598 (30)

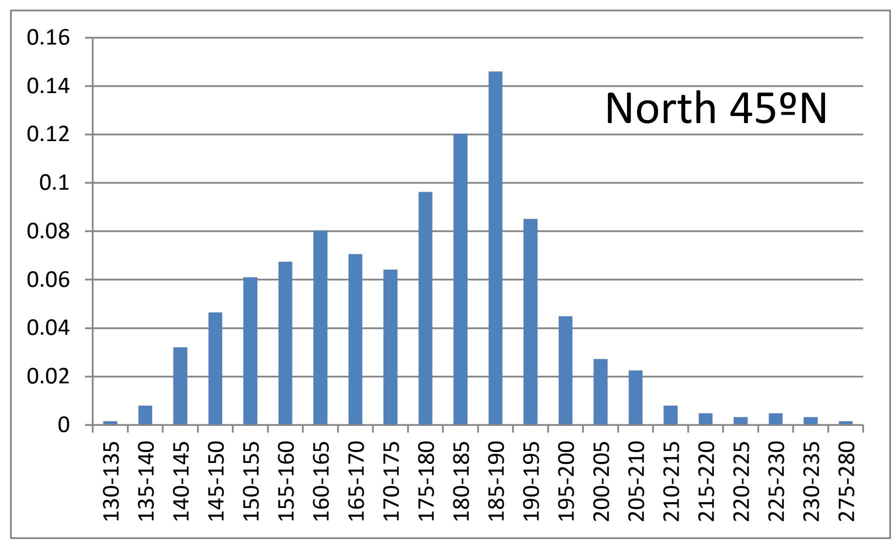
2014 8ab Bioman data



2014 8ab bioman L distribution







2014 8ab Bioman data by ages

Parameter	estimate	S.e.	CV
Ptot	7.52E+12	1.07E+12	0.1428
R'	0.52	0.004	0.0076
S	0.10	0.019	0.1800
F	18,729	1,371	0.0732
Wf	48.36	2.17	0.0449
DF	21.06	4.05	0.1921
Spawning Biomass	**369,803**	88,518	0.2394
Mature population	0.83	0.0967	0.1168
Biomass	**446,569**	124,496	0.2788
Wt	39.37	4.05	0.1029

Parameter	estimate	S.e.	CV
Spawning Biomass	**369,803**	88,518	0.2394
Mean Partial Maturity	0.83	0.097	0.1168
Total Stock Biomass	**446,569**	124,496	0.2788
Wt	39.37	4.05	0.1029
Population (millions)	11,340	3,800	0.3351
% at age 1	0.46	0.138	0.3014
% at age 2	0.42	0.092	0.2209
% at age 3	0.09	0.022	0.2525
% at age 4	0.02	0.008	0.4695
% at age 5	0.01	0.004	0.4638
% at age 6+ in mass	0.01	0.004	0.4894
Numbers at age 1	5,118	2,985	0.5833
Numbers at age 2	4,775	1,025	0.2145
Numbers at age 3	1,021	320	0.3135
Numbers at age 4	207	71	0.3422
Numbers at age 5	101	42	0.4178
Numbers at age 6+	96	54	0.5606
% at age 1 in mass	0.31	0.111	0.3602
% at age 2 in mass	0.50	0.073	0.1468
% at age 3 in mass	0.13	0.024	0.1954
% at age 4 in mass	0.03	0.013	0.3901
% at age 5 in mass	0.02	0.007	0.4109
% at age 6+ in mass	0.02	0.007	0.4074
B at age 1 (Tons)	139,386	78,057	0.5600
B at age 2 (Tons)	221,934	52,460	0.2364
B at age 3 (Tons)	56,073	17,957	0.3202
B at age 4 (Tons)	14,556	4,898	0.3365
B at age 5 (Tons)	7,369	3,239	0.4395
B at age 6+ (Tons)	7,996	4,192	0.5242
Weight at age 1 (g)	26.5	2.62	0.0989
Weight at age 2 (g)	44.9	1.00	0.0224
Weight at age 3 (g)	53.3	0.80	0.0150
Weight at age 4 (g)	67.5	2.30	0.0340
Weight at age 5 (g)	70.3	3.73	0.0530
Weight at age 6+ (g)	78.9	7.78	0.0987
Lenght at age 1 (cm)	152.5	3.75	0.0246
Lenght at age 2 (cm)	181.2	1.47	0.0081
Lenght at age 3 (cm)	193.8	0.68	0.0035
Lenght at age 4 (cm)	181.2	26.10	0.1441
Lenght at age 5 (cm)	211.5	2.27	0.0107
Lenght at age 6+ (cm)	220.6	6.45	0.0292

2014 8ab Bioman data

South 45ºN

Parameter	estimate	S.e.	CV
Spawning Biomass	**34,335**	11,872	0.3458
Mean Partial Maturity	1.00	0.000	0.0000
Total Stock Biomass	**34,335**	11,872	0.3458
Wt	47.46	0.90	0.0190
Population (millions)	722	245	0.3397
% at age 1	0.00	0.003	0.9944
% at age 2	0.82	0.018	0.0215
% at age 3	0.12	0.011	0.0896
% at age 4	0.03	0.008	0.2319
% at age 5	0.01	0.007	0.5115
% at age 6	0.00	0.003	1.0057
Numbers at age 1	2	2	1.0218
Numbers at age 2	594	199	0.3358
Numbers at age 3	88	32	0.3630
Numbers at age 4	25	12	0.4924
Numbers at age 5	10	6	0.5655
Numbers at age 6	2	3	1.0726
% at age 1 in mass	0.00	0.002	1.0000
% at age 2 in mass	0.80	0.021	0.0270
% at age 3 in mass	0.13	0.012	0.0901
% at age 4 in mass	0.04	0.012	0.2697
% at age 5 in mass	0.02	0.012	0.5290
% at age 6 in mass	0.01	0.007	1.0000
B at age 1 (Tons)	80	82	1.0218
B at age 2 (Tons)	27,239	9,280	0.3407
B at age 3 (Tons)	4,521	1,658	0.3667
B at age 4 (Tons)	1,529	801	0.5242
B at age 5 (Tons)	732	433	0.5916
B at age 6 (Tons)	234	251	1.0726
Weight at age 1 (g)	32.7	0.00	0.0000
Weight at age 2 (g)	44.3	0.75	0.0169
Weight at age 3 (g)	49.9	1.20	0.0242
Weight at age 4 (g)	59.6	5.26	0.0884
Weight at age 5 (g)	70.8	3.08	0.0435
Weight at age 6 (g)	98.3	0.00	0.0000
Lenght at age 1 (cm)	157.3	0.00	0.0000
Lenght at age 2 (cm)	180.4	0.61	0.0034
Lenght at age 3 (cm)	189.5	1.50	0.0079
Lenght at age 4 (cm)	201.1	3.08	0.0153
Lenght at age 5 (cm)	218.2	3.00	0.0138
Lenght at age 6 (cm)	223.3	0.00	0.0000

North 45ºN

Parameter	estimate	S.e.	CV
Spawning Biomass	**352,394**	97,016	0.2753
Mean Partial Maturity	0.81	0.107	0.1319
Total Stock Biomass	**434,740**	138,967	0.3197
Wt	38.67	4.36	0.1127
Population (millions)	11,258	4,284	0.3805
% at age 1	0.49	0.143	0.2911
% at age 2	0.39	0.095	0.2442
% at age 3	0.09	0.024	0.2834
% at age 4	0.02	0.009	0.5401
% at age 5	0.01	0.004	0.5276
% at age 6	0.01	0.004	0.5235
Numbers at age 1	5,497	3,370	0.6131
Numbers at age 2	4,366	1,083	0.2480
Numbers at age 3	983	356	0.3619
Numbers at age 4	189	73	0.3882
Numbers at age 5	95	45	0.4790
Numbers at age 6	100	61	0.6107
% at age 1 in mass	0.34	0.121	0.3584
% at age 2 in mass	0.47	0.078	0.1660
% at age 3 in mass	0.12	0.027	0.2212
% at age 4 in mass	0.03	0.015	0.4477
% at age 5 in mass	0.02	0.008	0.4711
% at age 6 in mass	0.02	0.008	0.4344
B at age 1 (Tons)	149,756	88,686	0.5922
B at age 2 (Tons)	202,964	55,423	0.2731
B at age 3 (Tons)	54,314	19,972	0.3677
B at age 4 (Tons)	13,499	5,025	0.3723
B at age 5 (Tons)	6,914	3,488	0.5044
B at age 6 (Tons)	8,276	4,737	0.5724
Weight at age 1 (g)	26.4	2.69	0.1019
Weight at age 2 (g)	45.0	1.20	0.0266
Weight at age 3 (g)	53.6	0.86	0.0160
Weight at age 4 (g)	68.6	2.43	0.0354
Weight at age 5 (g)	70.4	4.33	0.0615
Weight at age 6 (g)	78.3	8.13	0.1038
Lenght at age 1 (cm)	152.4	3.87	0.0254
Lenght at age 2 (cm)	181.3	1.76	0.0097
Lenght at age 3 (cm)	194.2	0.63	0.0033
Lenght at age 4 (cm)	179.5	31.31	0.1744
Lenght at age 5 (cm)	210.9	2.60	0.0123
Lenght at age 6 (cm)	220.5	6.83	0.0310

2014 8ab BIOMAN data

North 45ºN

Parameter	estimate	S.e.	CV
Ptot	6.38E+12	1.00E+12	0.1571
R'	0.52	0.004	0.0086
S	0.09	0.020	0.2160
F	18,696	1,361	0.0728
Wf	48.16	2.52	0.0523
DF	19.02	4.30	0.2261
Spawning Biomass	**352,394**	97,016	0.2753
Mature population	0.81	0.1069	0.1319
Biomass	**434,740**	138,967	0.3197
Wt	38.67	4.36	0.1127

South 45ºN

Parameter	estimate	S.e.	CV
Ptot	1.20E+12	3.14E+11	0.2621
R'	0.53	0.006	0.0113
S	0.18	0.041	0.2228
F	18,989	948	0.0499
Wf	49.97	1.24	0.0248
DF	36.67	8.27	0.2255
Spawning Biomass	**34,335**	11,872	0.3458
Mature population	1.00	0.0000	0.0000
Biomass	**34,335**	11,872	0.3458
Wt	47.46	0.90	0.0190

sardine egg abundance series from BIOMAN survey

Year	Pil egg abundance
1999	1.057E+12
2000	5.034E+12
2001	2.202E+12
2002	7.819E+12
2003	3.264E+12
2004	7.834E+12
2005	1.087E+13
2006	3.837E+12
2007	2.330E+12
2008	9.367E+12
2009	6.051E+12
2010	1.035E+13
2011	4.290E+12
2012	5.600E+12
2013	5.474E+12
2014	8.209E+12
2015	5.520E+12
2016	8.558E+12

In these data are not included the cantabric coast and the extended area surveyed in 2014, 2015 and 2016

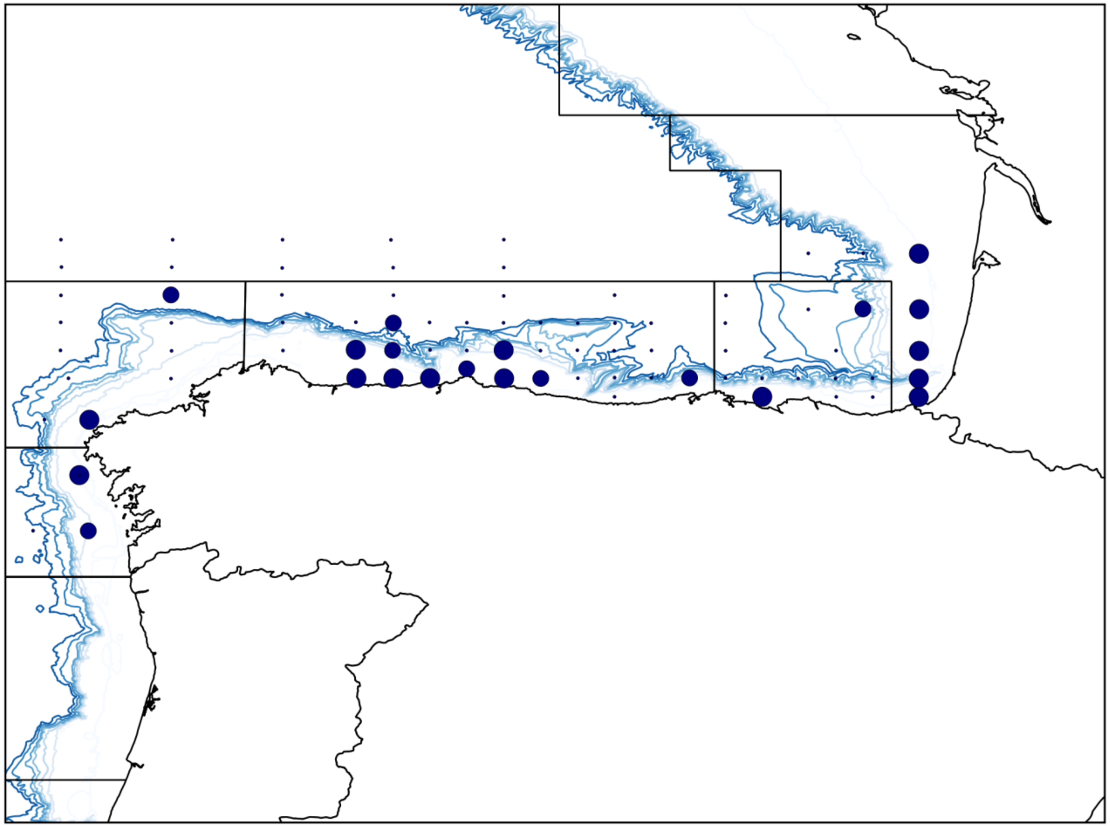
These data are used already on the Survey trends-based assessment on sardine 8ab&7

Sardine eggs in AEPM surveys

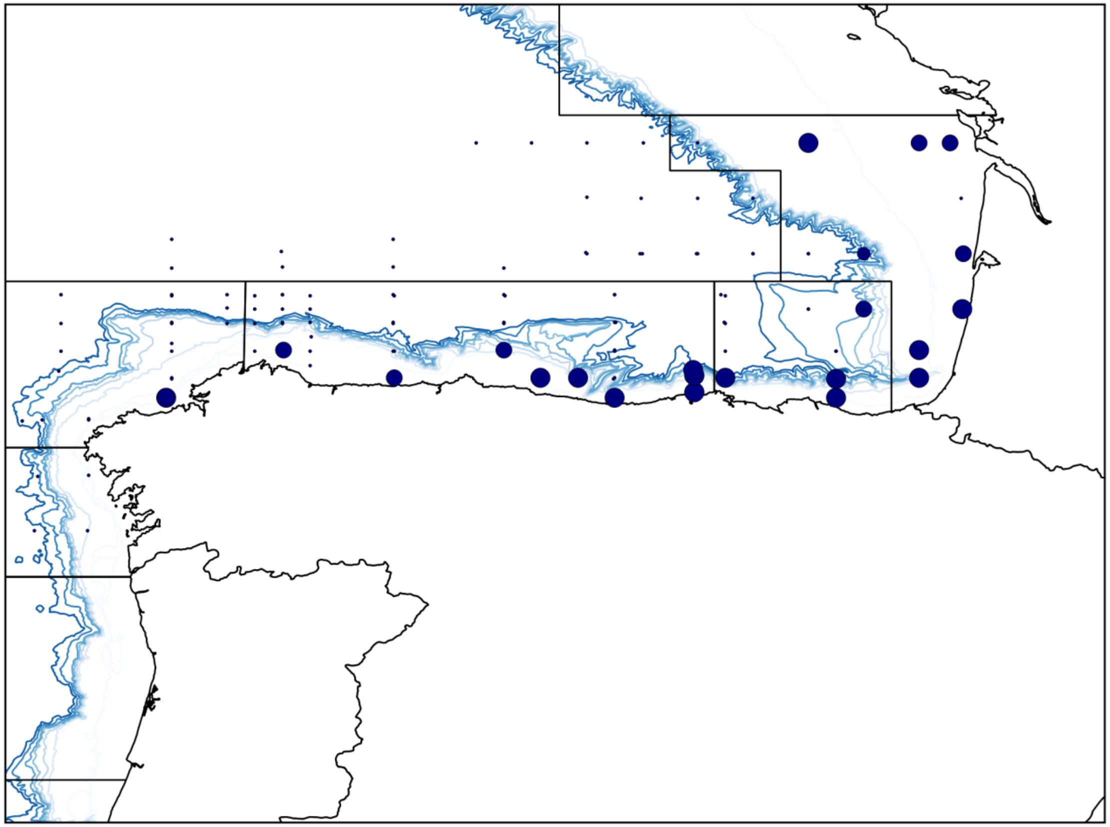
Years available (IEO)

- 1995 (30/03-14/04)
- 1998 (14/03-27/04)
- 2000 (28/03-30/04)
- 2001 (16/03-28/04)
- 2004 (19/03-29/04)
- 2007 (16/03-30/04)
- 2010 (01/03-30/04)
- 2013 (07/03-22/04)
- 2016 (07/03-28/04)

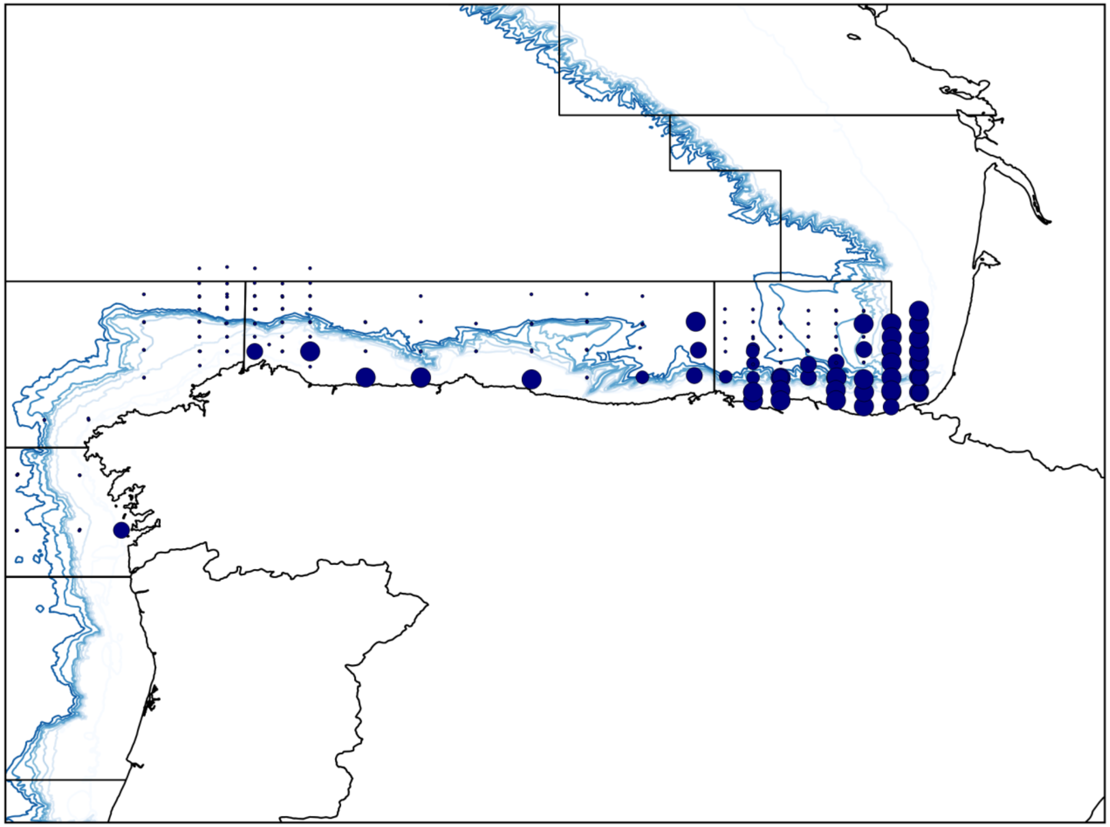
1995



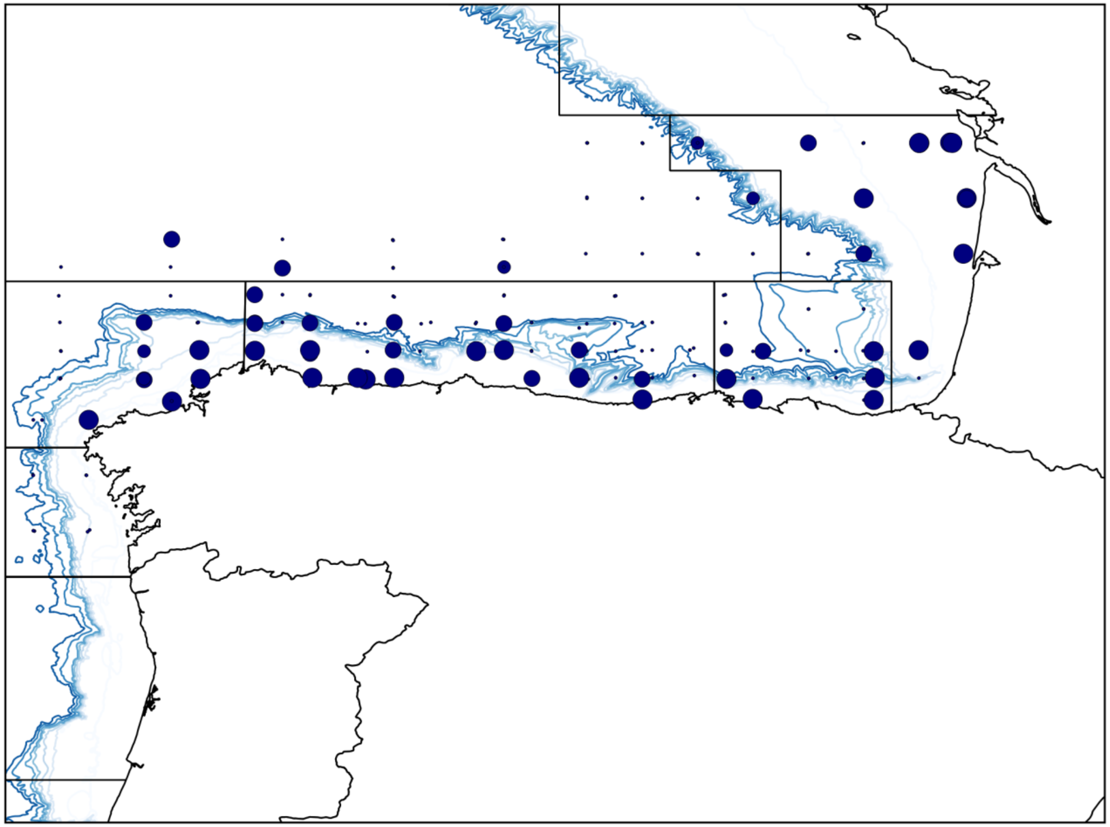
1998



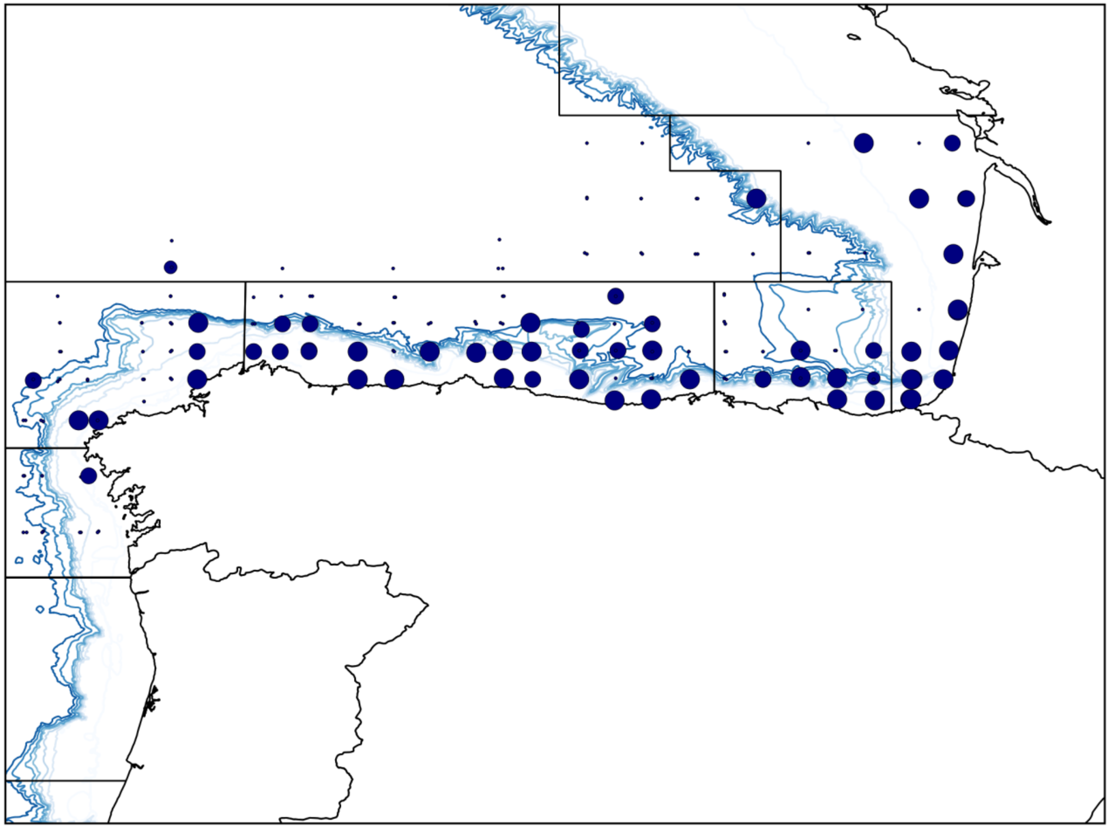
2000



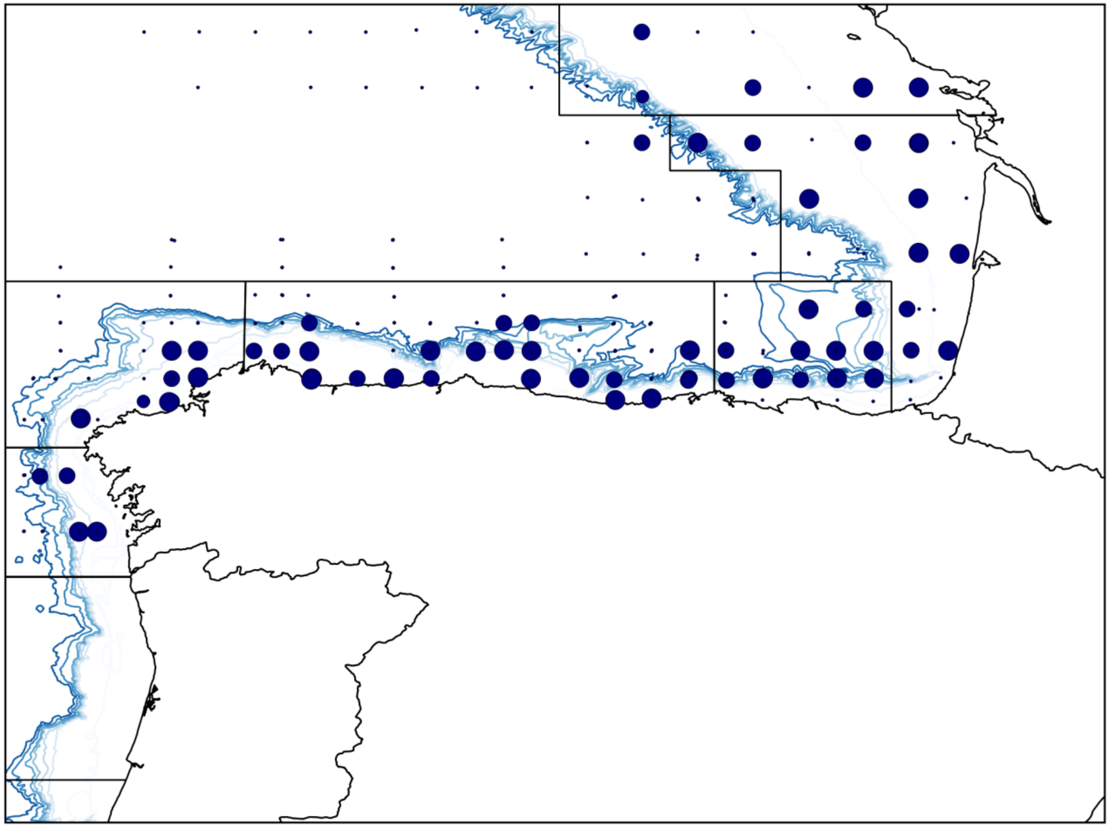
2001



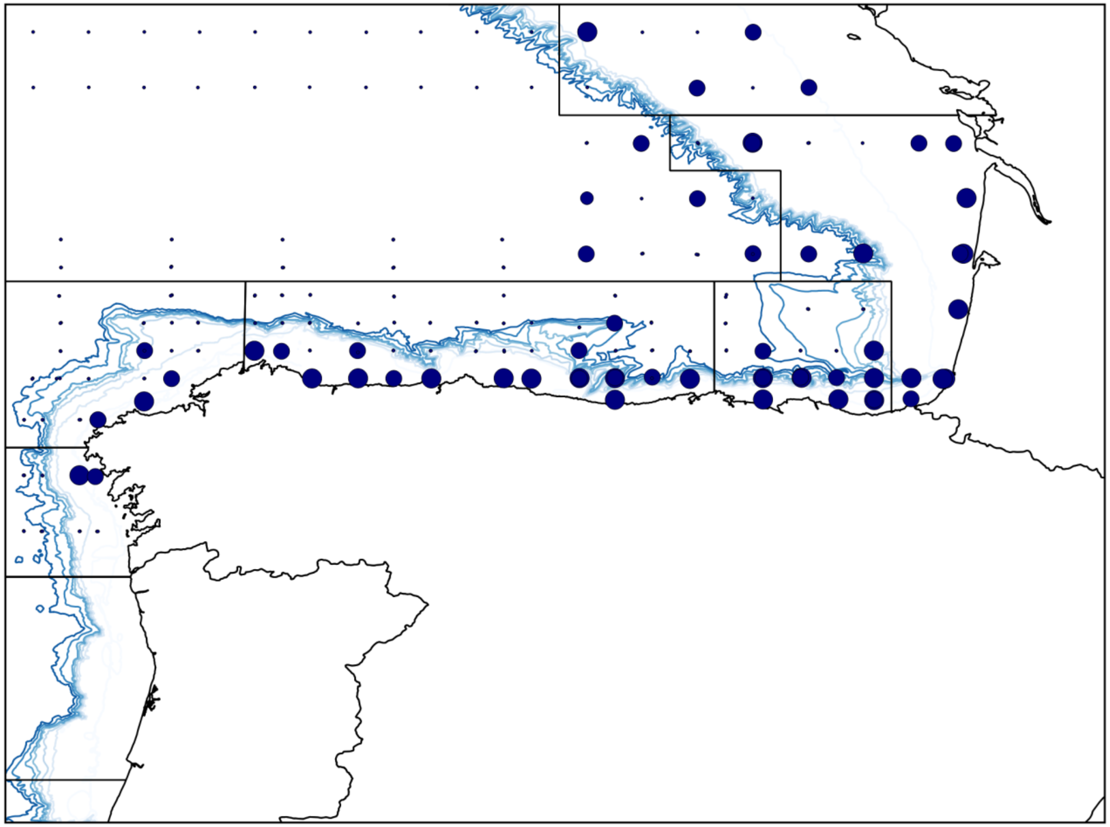
2004



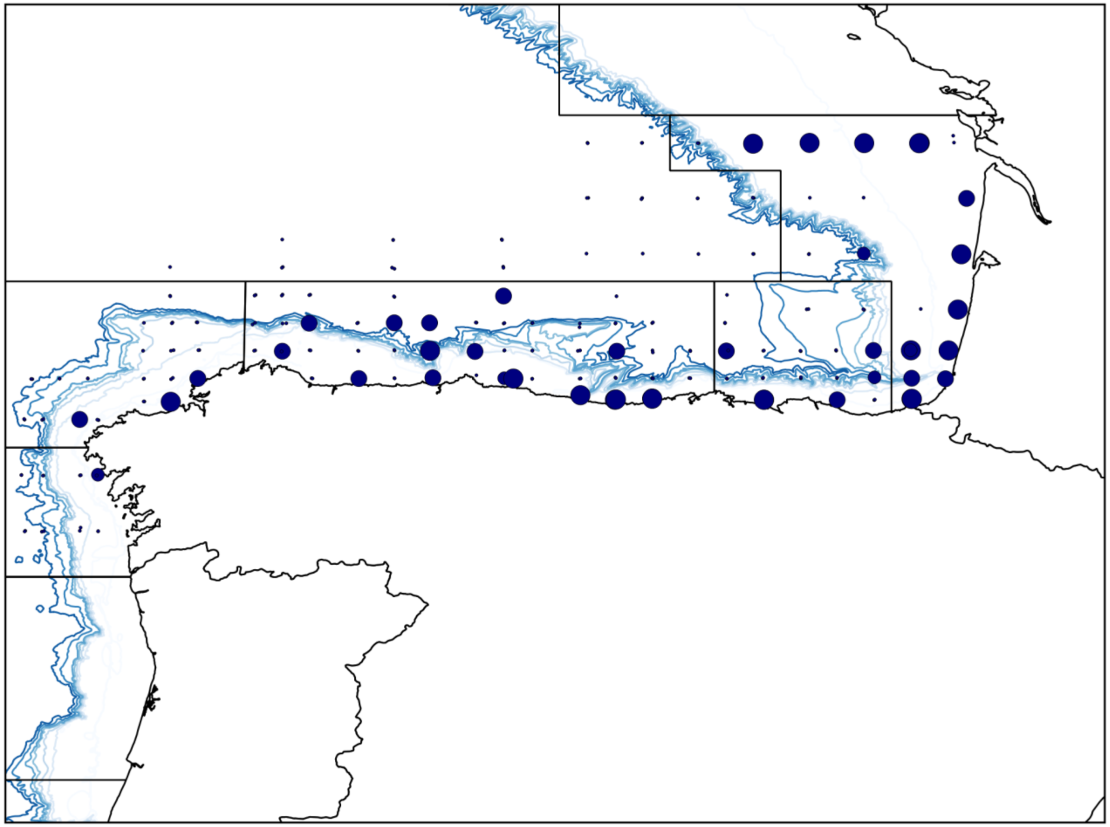
2007



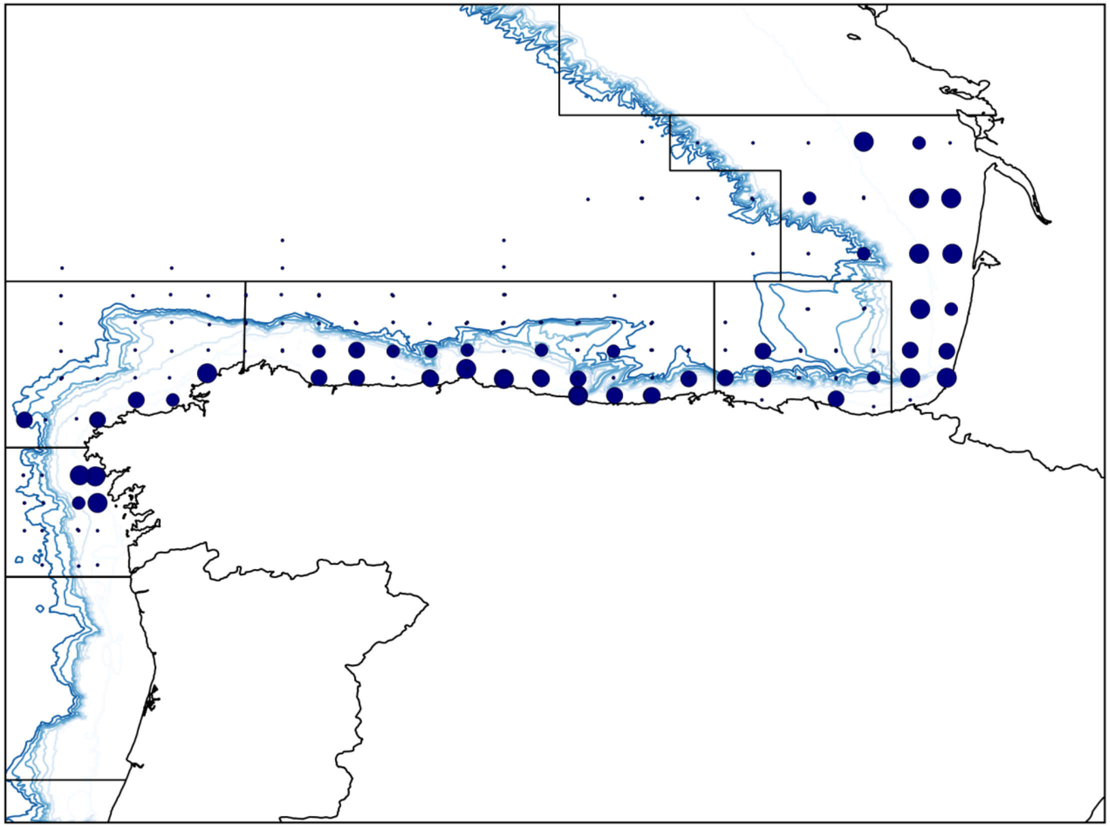
2010



2013



2016



Years available (AZTI)

- Every 3 years from 1998 until 2016
- Dates: March-April

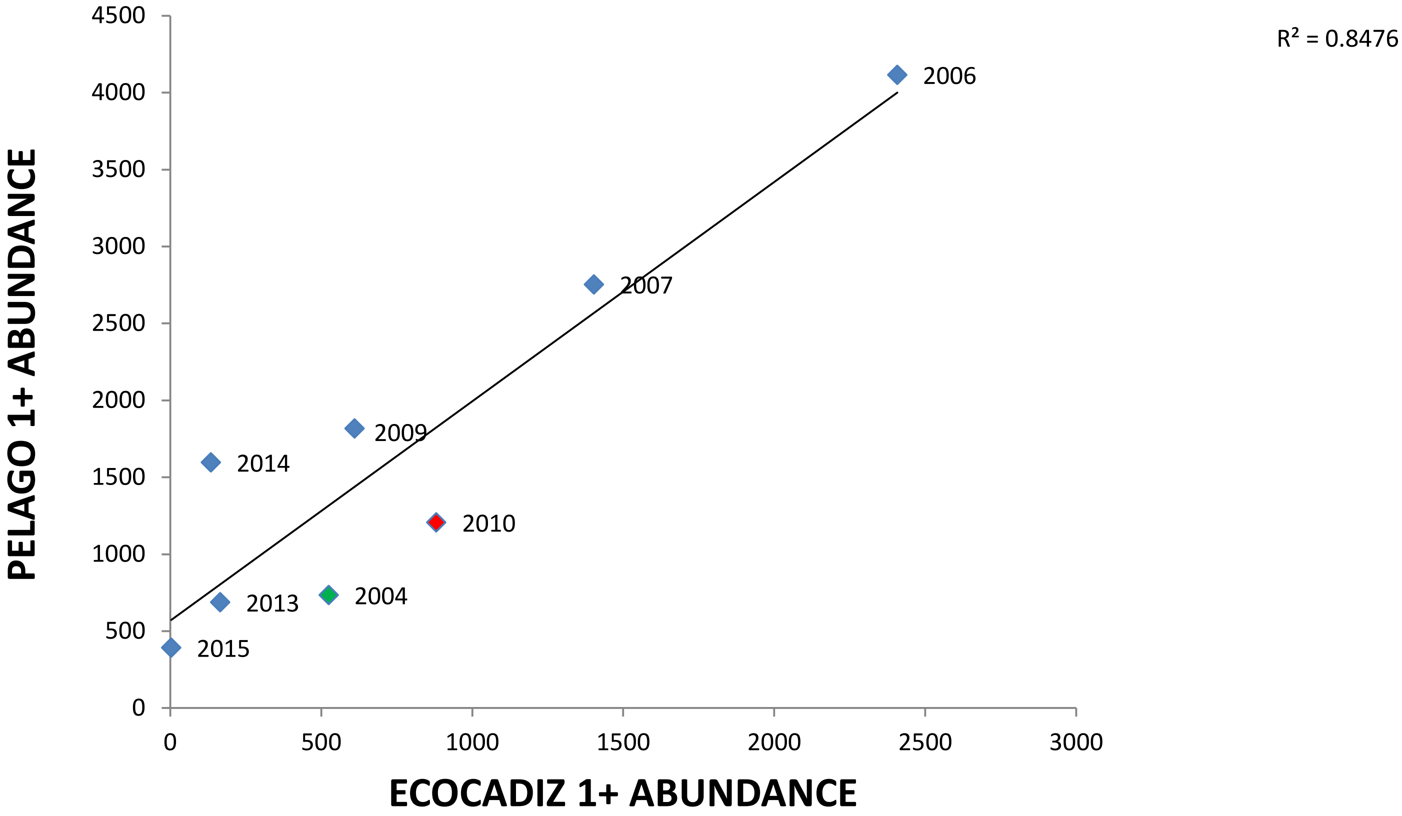
	A	B	C	D	E	F	G	H	I	J	K
1	Year	Survey	Station	Long	Lat	Eggs/m^2 Sar	Eggs Sar	Date	Sampler	Stratum	Area
2	2013	CAREVA0313	1	-4,745	45,751	0	0	07032013	Bongo 40	VIIIb	1829,42984
3	2013	CAREVA0313	2	-4,251	45,751	0	0	07032013	Bongo 40	VIIIb	1716,75089
4	2013	CAREVA0313	3	-3,741	45,747	0	0	07032013	Bongo 40	VIIIb	1718,58306
5	2013	CAREVA0313	4	-3,243	45,744	0	0	08032013	Bongo 40	VIIIb	1727,74396
6	2013	CAREVA0313	5	-2,739	45,751	0	0	08032013	Bongo 40	VIIIb	1703,00955
7	2013	CAREVA0313	6	-2,248	45,751	0	0	08032013	Bongo 40	VIIIb	1722,24742
8	2013	CAREVA0313	7	-1,744	45,749	15,3999793	13	08032013	Bongo 40	VIIIb	1434,59546
9	2013	CAREVA0313	8	-1,435	45,753	0	0	08032013	Bongo 40	VIIIb	1446,50462
10	2013	CAREVA0313	9	-1,328	45,251	0	0	09032013	Bongo 40	VIIIb	1398,86799
11	2013	CAREVA0313	10	-1,762	45,251	372,934212	305	09032013	Bongo 40	VIIIb	1625,14198
12	2013	CAREVA0313	11	-2,251	45,256	0	0	09032013	Bongo 40	VIIIb	1677,35906
13	2013	CAREVA0313	12	-2,737	45,255	0	0	09032013	Bongo 40	VIIIb	1720,41524
14	2013	CAREVA0313	13	-3,243	45,253	0	0	09032013	Bongo 40	VIIIb	1757,05881
15	2013	CAREVA0313	14	-3,749	45,25	0	0	09032013	Bongo 40	VIIIb	1717,66698
16	2013	CAREVA0313	15	-4,251	45,253	0	0	09032013	Bongo 40	VIIIb	1716,75089
17	2013	CAREVA0313	16	-4,738	45,254	0	0	10032013	Bongo 40	VIIIb	1834,92637
18	2013	CAREVA0313	17	-4,754	44,751	0	0	10032013	Bongo 40	IXa N + VIIIc	1841,339
19	2013	CAREVA0313	18	-4,246	44,751	0	0	10032013	Bongo 40	IXa N + VIIIc	1746,06574
20	2013	CAREVA0313	19	-3,743	44,747	0	0	10032013	Bongo 40	VIIIb	1681,9395
21	2013	CAREVA0313	20	-3,244	44,748	0	0	10032013	Bongo 40	VIIIb	1732,3244
22	2013	CAREVA0313	21	-2,744	44,748	0	0	11032013	Bongo 40	VIIIb	1737,82093
23	2013	CAREVA0313	22	-2,243	44,755	0	0	11032013	Bongo 40	VIIIb	1703,00955
24	2013	CAREVA0313	23	-1,767	44,748	174,891979	162	11032013	Bongo 40	VIIIb	1593,99495
25	2013	CAREVA0313	24	-1,35	44,749	0	0	11032013	Bongo 40	VIIIb	1364,0566

PELAGO (spring)-ECOCADIZ (summer) SARDINE ESTIMATES COMPARISON

INSTITUTO ESPAÑOL DE OCEANOGRAFÍA

ipma
instituto português do mar e da atmosfera

PELAGO-ECOCADIZ SARDINE ESTIMATES

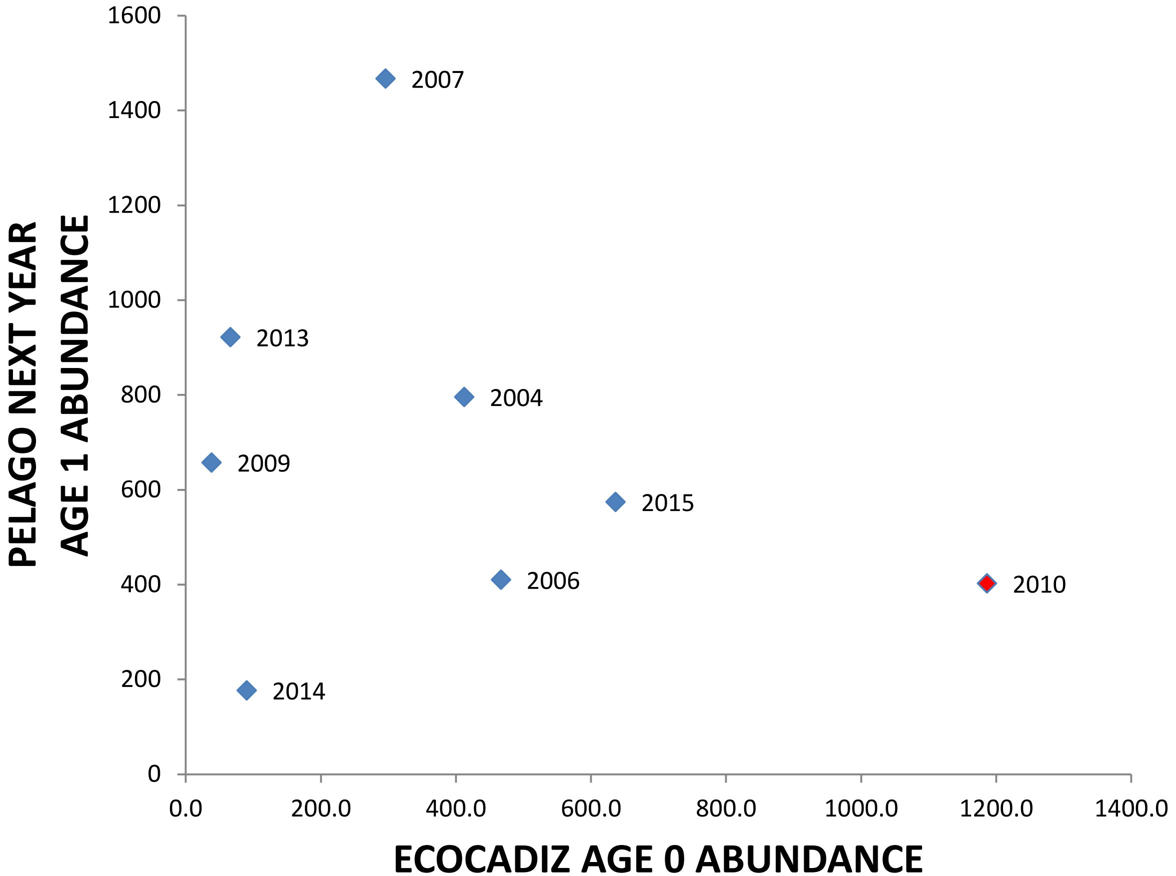


ABUNDANCE

2004: PELAGO only covered the Portuguese area (and was performed in June)

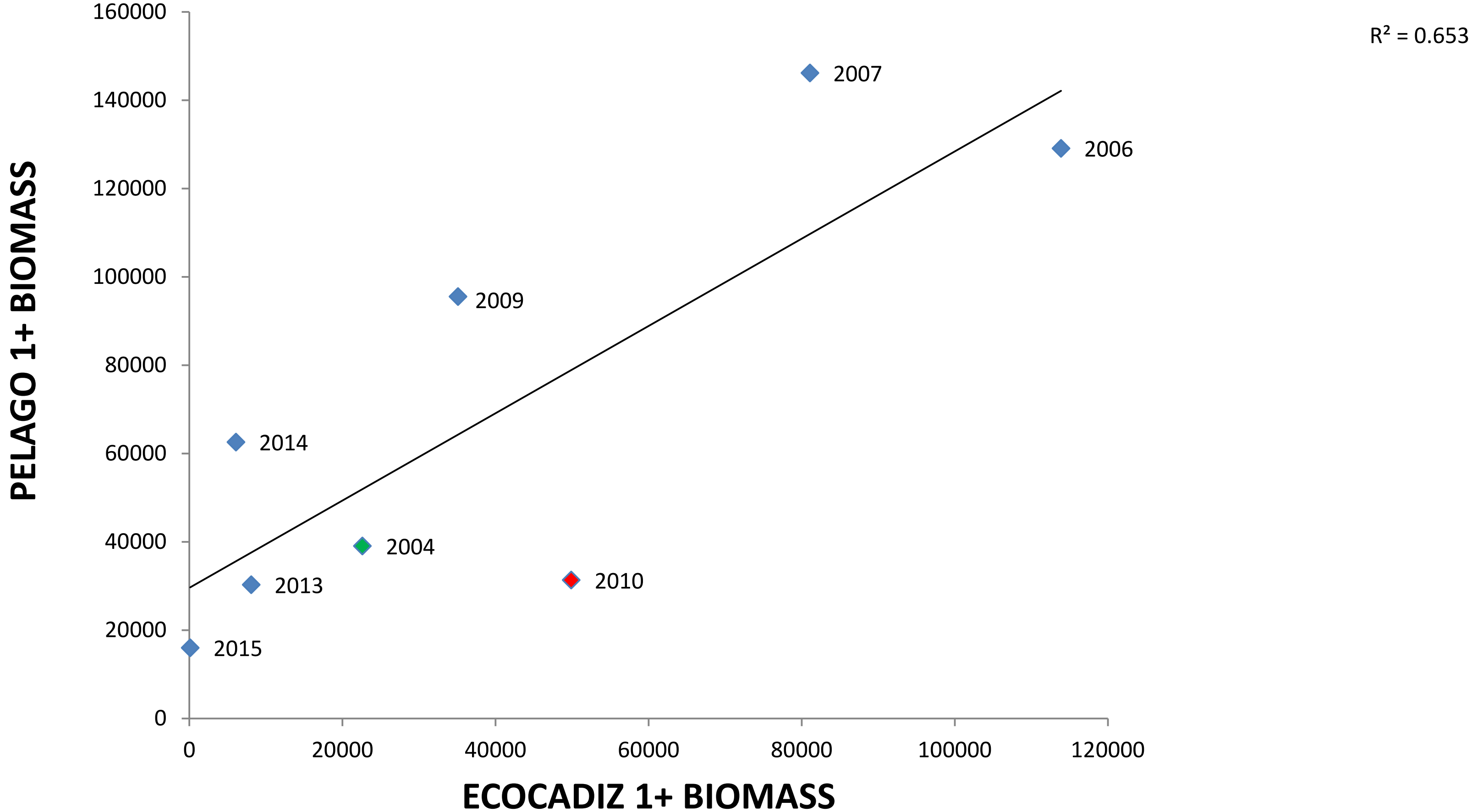
2010: ECOCADIZ did not cover all the area

PELAGO-ECOCADIZ SARDINE ESTIMATES



ABUNDANCE

PELAGO-ECOCADIZ SARDINE ESTIMATES



BIOMASS

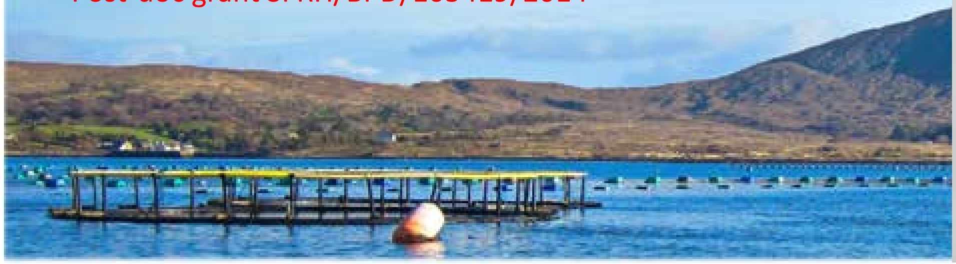
SAFI: Supporting our Aquaculture & Fisheries Industries

SAFI Meeting, Rabat, Morocco

Temperature and food-mediated variability of Atlanto-Iberian European sardine populations

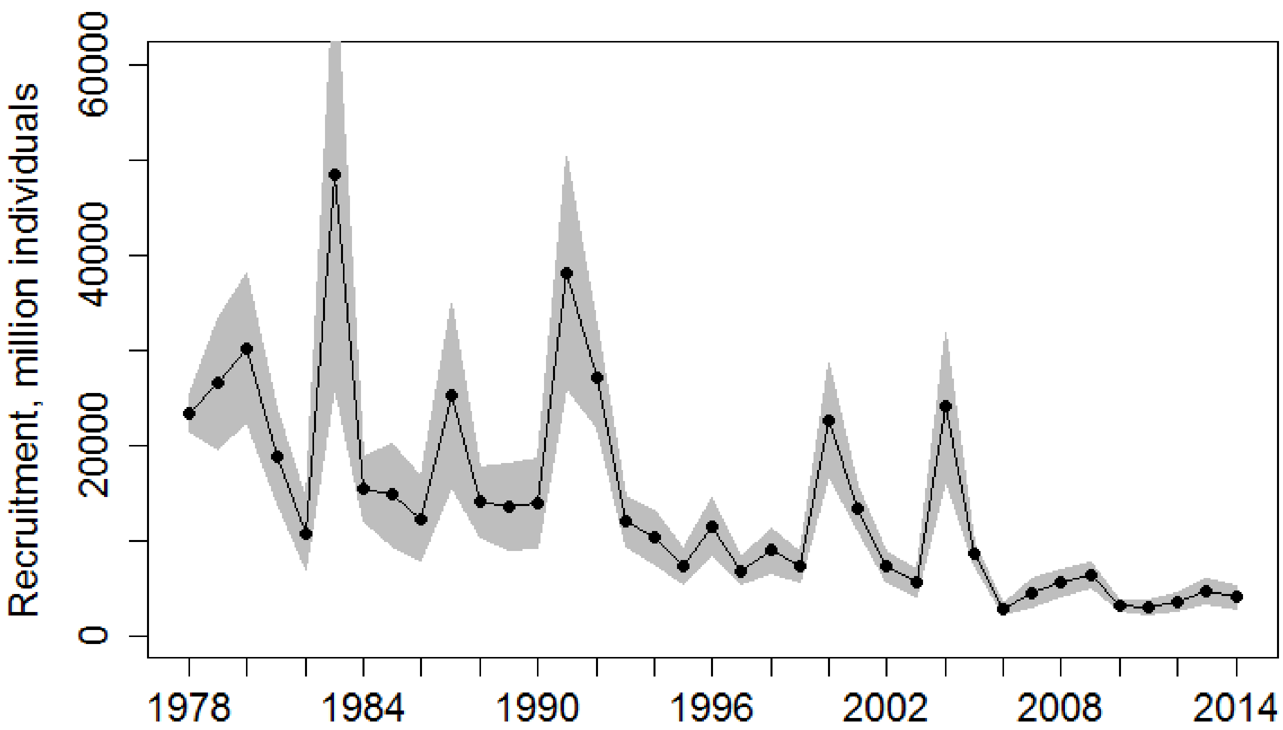
Susana Garrido, Alexandra Silva, Vitor Marques, Ivone Figueiredo, Philippe Bryère, Antoine Mangin, A Miguel P. Santos

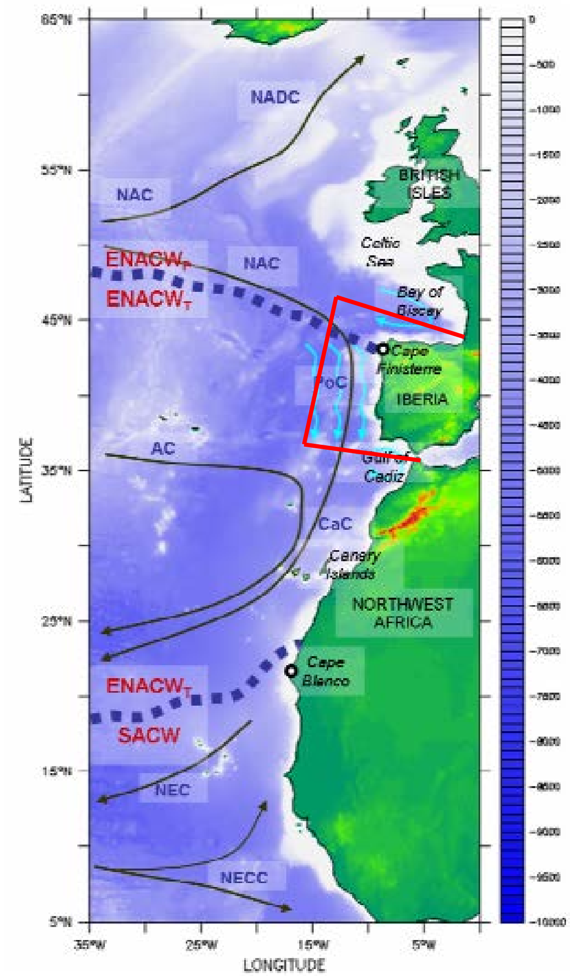
SAFI EU 7th Framework Programme ([FP7/2007-2013] – 607155)
Post-doc grant SFRH/BPD/105419/2014



Temperature and food-mediated variability of sardine populations

- **INTRODUCTION**





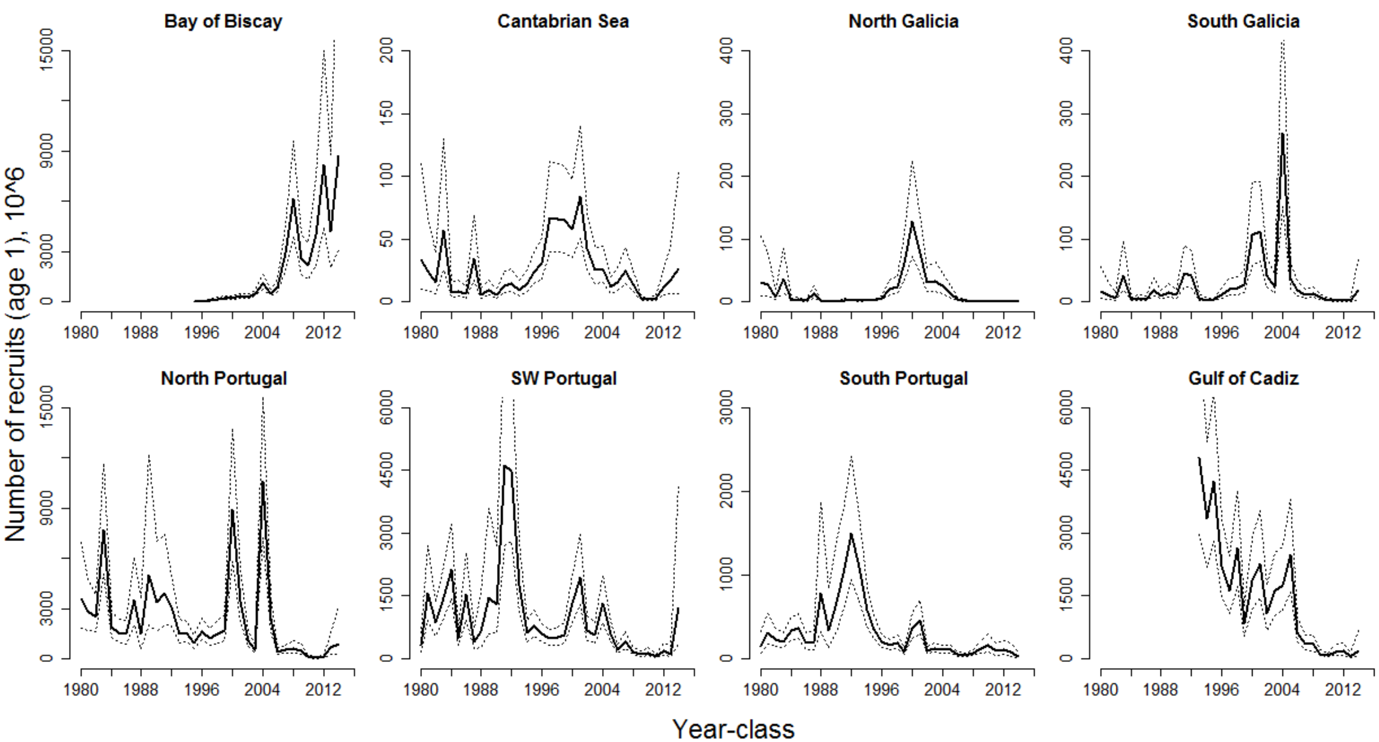
Smaller peaks, more spaced in time

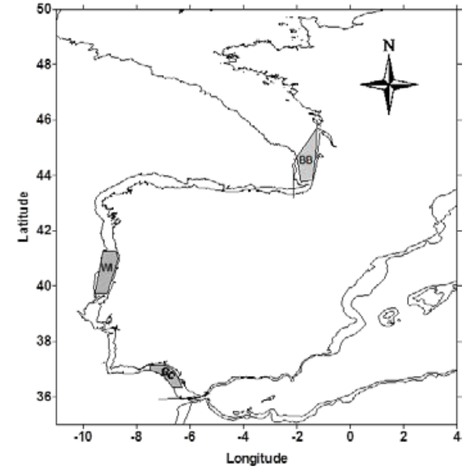
Historical minimum values last 10 years

Temperature- and food-mediated variability of sardine populations

- **INTRODUCTION**

The main recruitment areas off Iberia are at the **North-Western Iberia**, the **Gulf of Cadiz** and the **Bay of Biscay**. There are contrasting signals of recruitment strength and population dynamics (e.g., growth and maturation) between these recruitment "hotspots" (Silva et al. 2006, 2009).

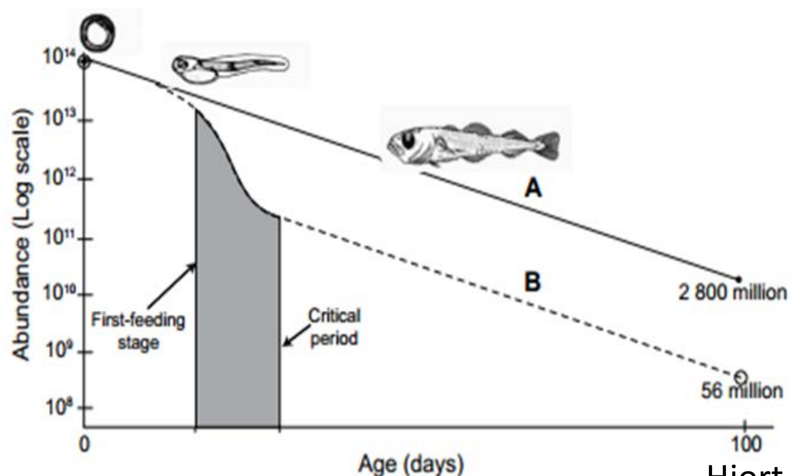




Temperature and food-mediated variability of sardine populations

- **INTRODUCTION**

Numerous studies on small pelagic fish show that the strength of the recruitment is dependent of the survival of the early-life stages.



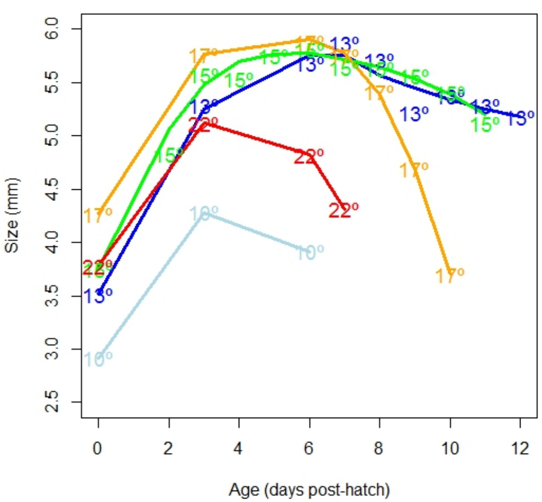
Hjort 1914

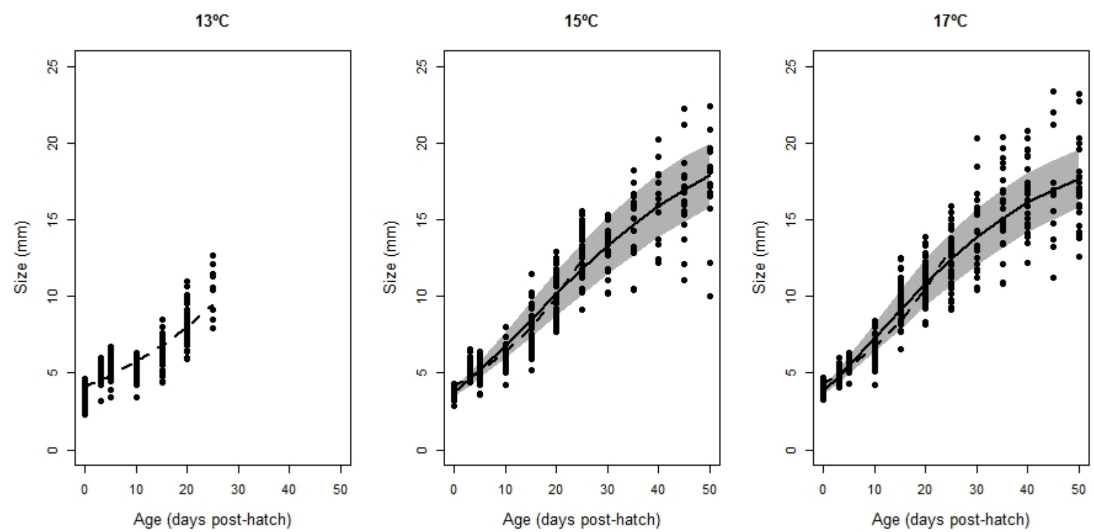
Temperature and food-mediated variability of sardine populations

- **INTRODUCTION**

Laboratory experiments showed that:

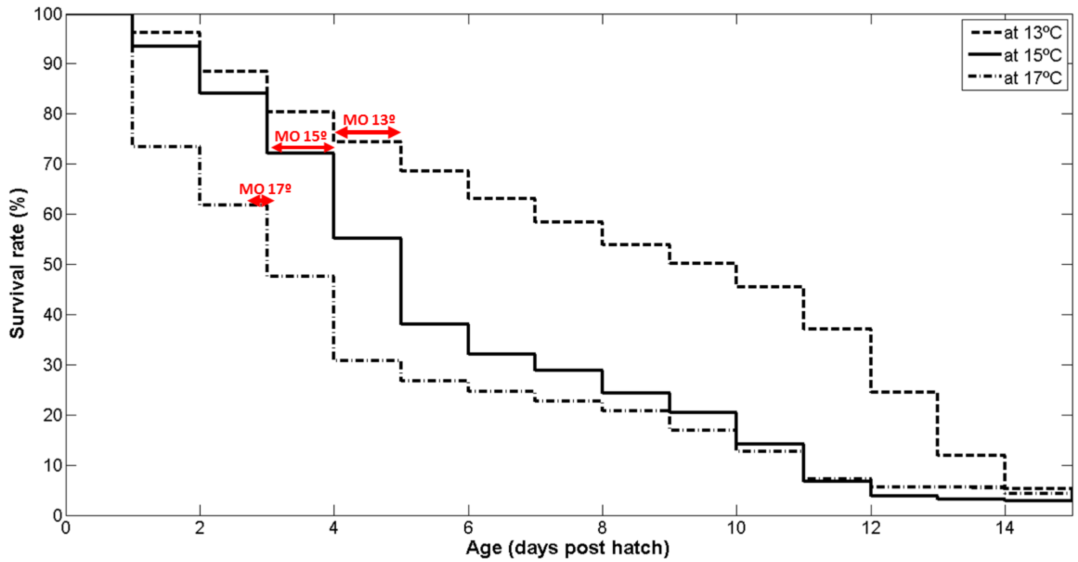
1 - There is an optimal temperature range for sardine larval survival and growth (13 - 17 °C).





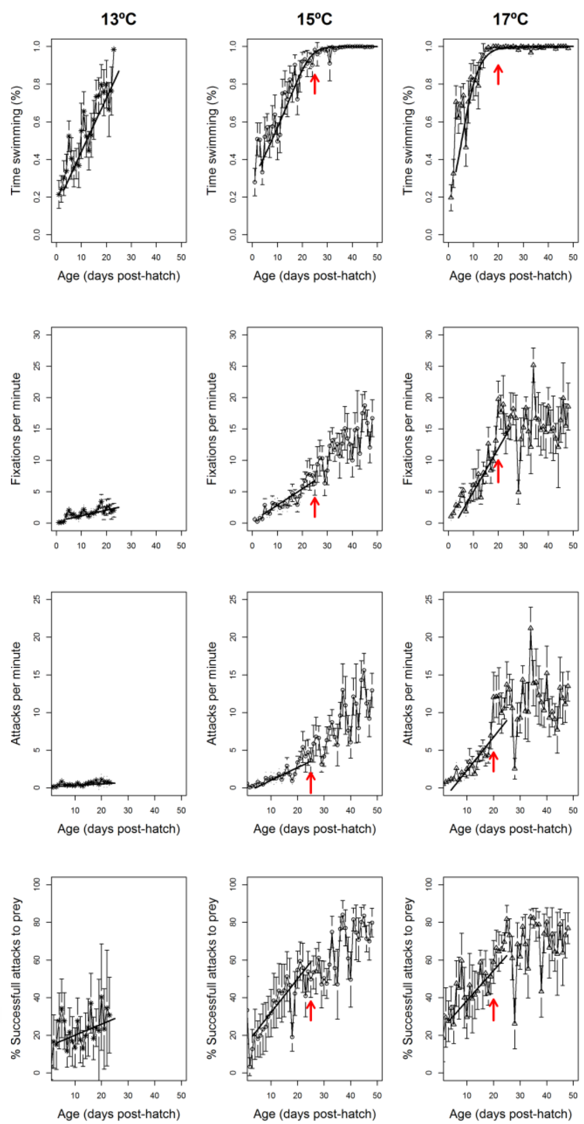
Garrido et al. MEPS *in press*

Temperature and food-mediated variability of sardine populations



Garrido et al. MEPS *in press*

Temperature and food-mediated variability of sardine populations



Morphologic characteristic		Temperature		
		13ºC	15ºC	17ºC
Hatching day, no pigmentation	Age (dph):	0	0	0
	Mean Size±SD (mm):	3.6±0.64	3.8±0.27	4.1±0.34
Pigmentation, yolk sac, mouth open	Age (dph):	4/5	3/4	3
	Mean Size±SD (mm):	5.5±0.63	5.4±0.41	5.0±0.49
Pectoral fins and beginning of caudal fin formation	Age (dph):	10	10	5
	Mean Size±SD (mm):	5.5±0.60	5.9±0.60	5.5±0.41
Beginning of notochord flexion	Age (dph):	20	15	10
	Mean Size±SD (mm):	8.1±1.32	7.7±1.29	6.3±0.92
Beginning of dorsal fin development	Age (dph):	20	20	15
	Mean Size±SD (mm):	8.1±1.32	10.0±1.41	9.7±1.26
Notochord flexion complete	Age (dph):	-	25	20
	Mean Size±SD (mm):	-	13.1±1.52	10.8±1.25
Dorsal fin complete	Age (dph):	-	30	25
	Mean Size±SD (mm):	-	13.2±1.25	12.1±1.82
Beginning of anal fin development	Age (dph):	-	35	25
	Mean Size±SD (mm):	-	14.5±2.29	12.1±1.82
Caudal fin complete	Age (dph):	-	40	30
	Mean Size (mm):	-	16.2±2.49	13.7±2.44

Garrido et al. MEPS *in press*

Temperature and food-mediated variability of sardine populations

- **INTRODUCTION**

Laboratory experiments showed that:

2 - Sardine larvae depend on high food availability to survive, particularly during the first weeks of life, when swimming and foraging abilities are low (Caldeira et al., 2014; Silva et al., 2013).

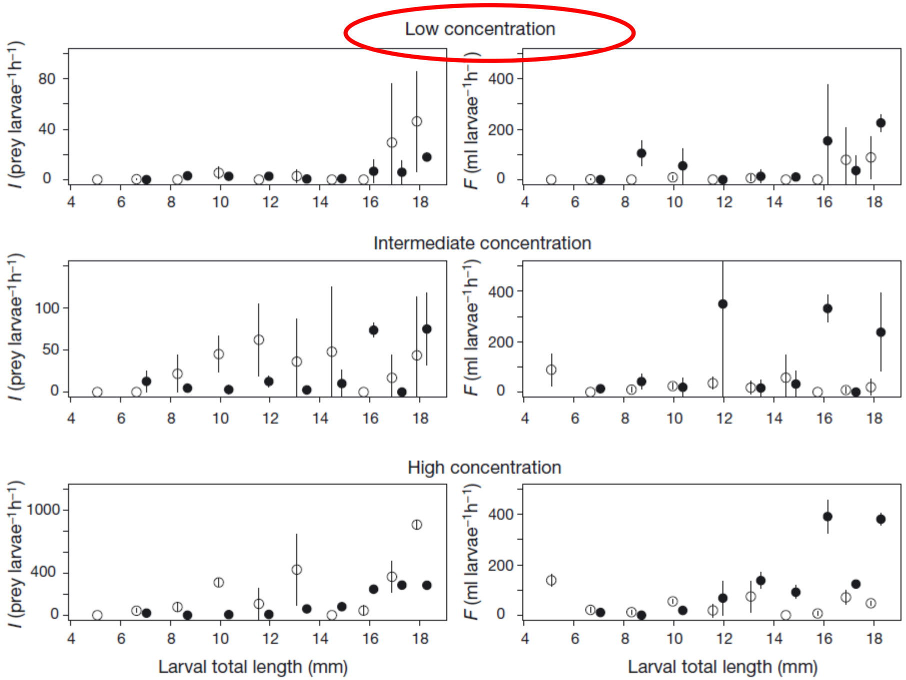


Fig. 2. Ingestion (*I*, prey larvae^{-1} h^{-1}; left panels), and clearance (*F*, ml larvae^{-1} h^{-1}; right panels) rates of sardine larvae during the ingestion experiment, offered different concentrations of nauplii (○) and copepodites (●) of the calanoid copepod *Acartia grani*. Diet concentrations are described in Table 2. Values are expressed as means and vertical lines are 95% confidence intervals. Note that the *y*-axes scales are different between the diets

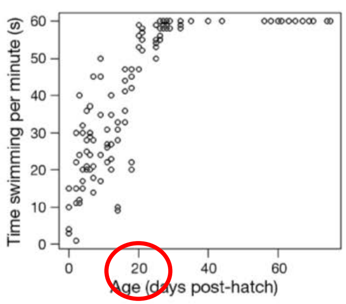


Fig. 2. Time spent swimming by sardine *Sardina pilchardus* larvae during a 60 s period of observation throughout larval ontogeny for larvae reared with high prey concentrations (Diet C)

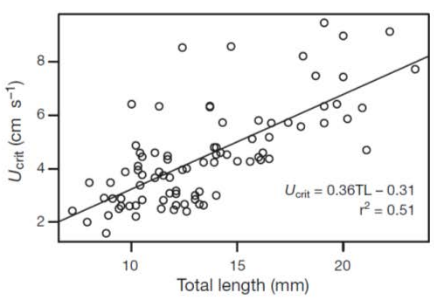


Fig. 4. Critical swimming speed (U_{crit}) of sardine *Sardina pilchardus* larvae throughout ontogeny for larvae from all feeding treatments. Each symbol represents the U_{crit} for an individual larva

Temperature and food-mediated variability of sardine populations

- **HYPOTHESIS**

Water temperature and food availability experienced by larvae during the spawning season of a given year will influence the strength of the recruitment of the following year. The environmental stressors that mostly affect recruitment strength are area-specific.

- **OBJECTIVE**

Develop an indicator of recruitment strength for Iberian sardines based on environmental information (SST and Chla)

Temperature and food-mediated variability of sardine populations

- **DATA USED TO TEST THE HYPOTHESIS**

Spring acoustic surveys carried out by IPMA since 1986 (some gaps) in the Western Iberian coast, since 1995 in the Gulf of Cadiz, and since 2003 in the Bay of Biscay (IFREMER).
Abundance of recruits (<16 cm TL) and Spawning stock biomass (>16 cm TL) in the three recruitment ”hotspots”.

ICES recruitment index of the Atlanto-Iberian stock based in fisheries data and using an age-structured model to estimate spawning stock biomass and recruitment index (not area-specific).

Satellite-derived SST and Chla (mean values for the three recruitment areas) of the following periods:
i. Spawning season in the beginning of the previous year (January to March; SST1 & Chla1) resulting in fish large enough to be recruited to the fishery (>10 cm);
ii. Spawning season in the end of the previous year (October to December) SST2 & Chla2) resulting in recruits (<16 cm)

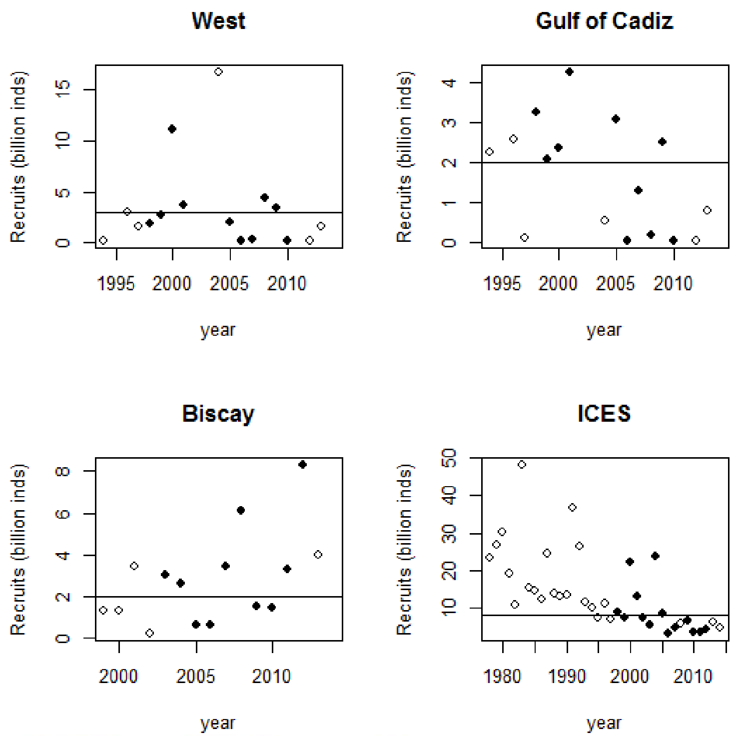
Earth Observation (EO): SST PATHFINDER, GHRSST and CHL-1_ _GSM, GlobColour).

Temperature and food-mediated variability of sardine populations

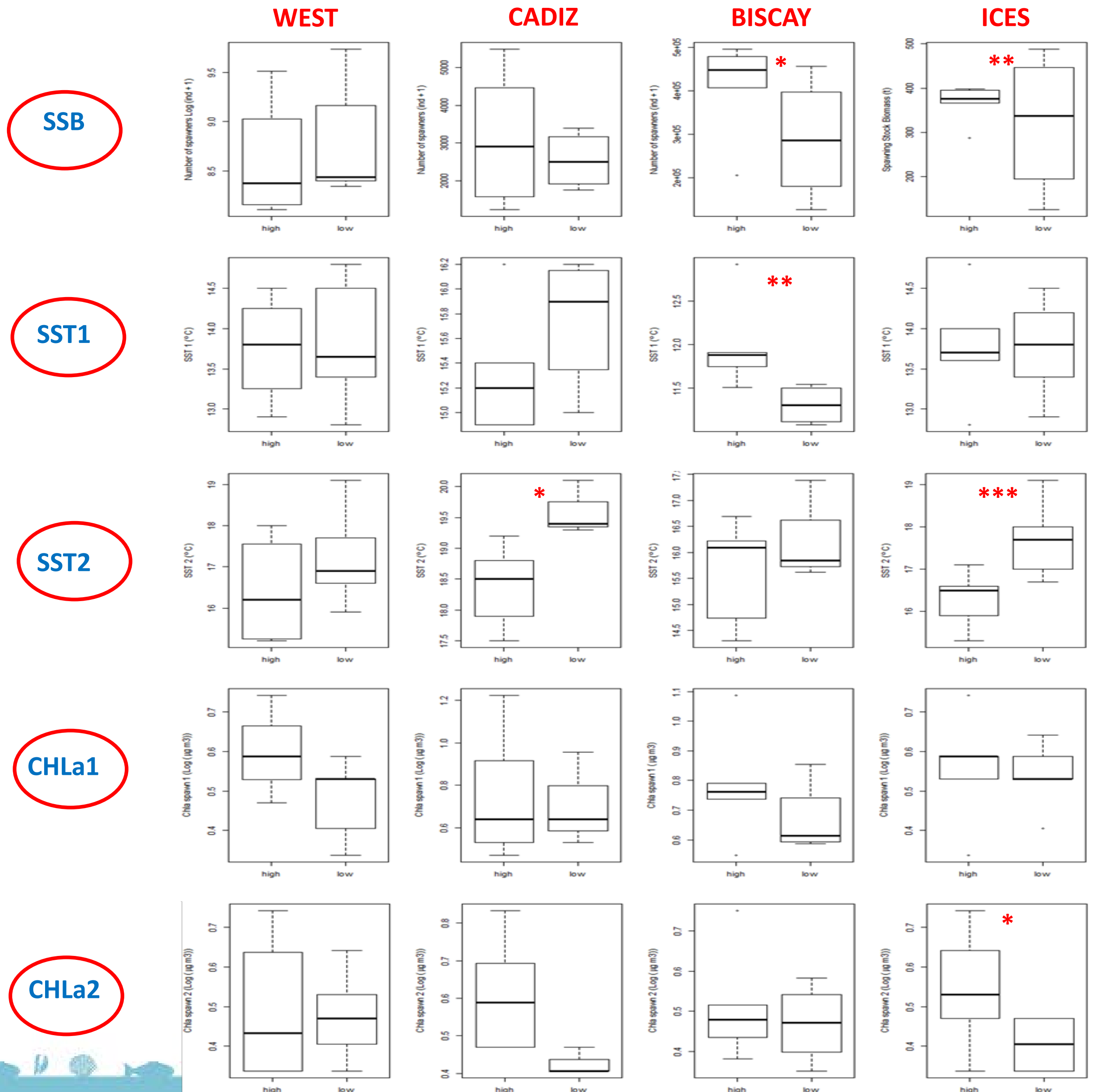
- **DATA ANALYSIS**

Linear Discriminant Analysis (LDA), a data classification and dimensionality reduction technique was applied to investigate the ability of satellite-derived SST and Chl-a data, and abundance of spawners from previous spawning season (<u>5 predictor variables</u>), in discriminating between **high** and **low** recruitment years.

Cut-off level: largest difference + balanced number of years between the 2 groups



Temperature and food-mediated variability of sardine populations



Temperature and food-mediated variability of sardine populations

AREA	N	GROUP	GROUP MEANS					% CORRECT CROSS VALIDATION
			ADULTS YEAR BEFORE	SST SPAWN 1	SST SPAWN 2	CHLA SPAWN 1	CHLA SPAWN 2	
A. Abundance of adult sardines and satellite-derived SST and Chla combined								
WEST	10	HIGH	-	13.75	16.40	0.59*	-	100
		LOW	-	13.80	17.18	0.48*	-	75
		coefficients	-	1.90	1.40	-15.81	-	TOTAL: 80
SOUTH	10	HIGH	3097	15.30	18.61	0.73*	0.60*	83
		LOW	2541	15.75	19.55	0.69*	0.42*	75
		coefficients	0.001	3.74	2.16	8.05	-35.9	TOTAL:80
BISCAY	10	HIGH	4.14	11.97	-	-	0.50*	83
		LOW	2.88	11.30	-	-	0.46*	75
		coefficients	$-6.76x10^{-6}$	-4.50	-	-	1.48	TOTAL: 80
ICES	16	HIGH	364	-	16.28	-	0.54*	67
		LOW	320	-	17.23	-	0.40*	88
		coefficients	-0.004	-	1.04	-	-3.54	TOTAL:79

Linear discriminant analysis was able to correctly classify **79-80%**.

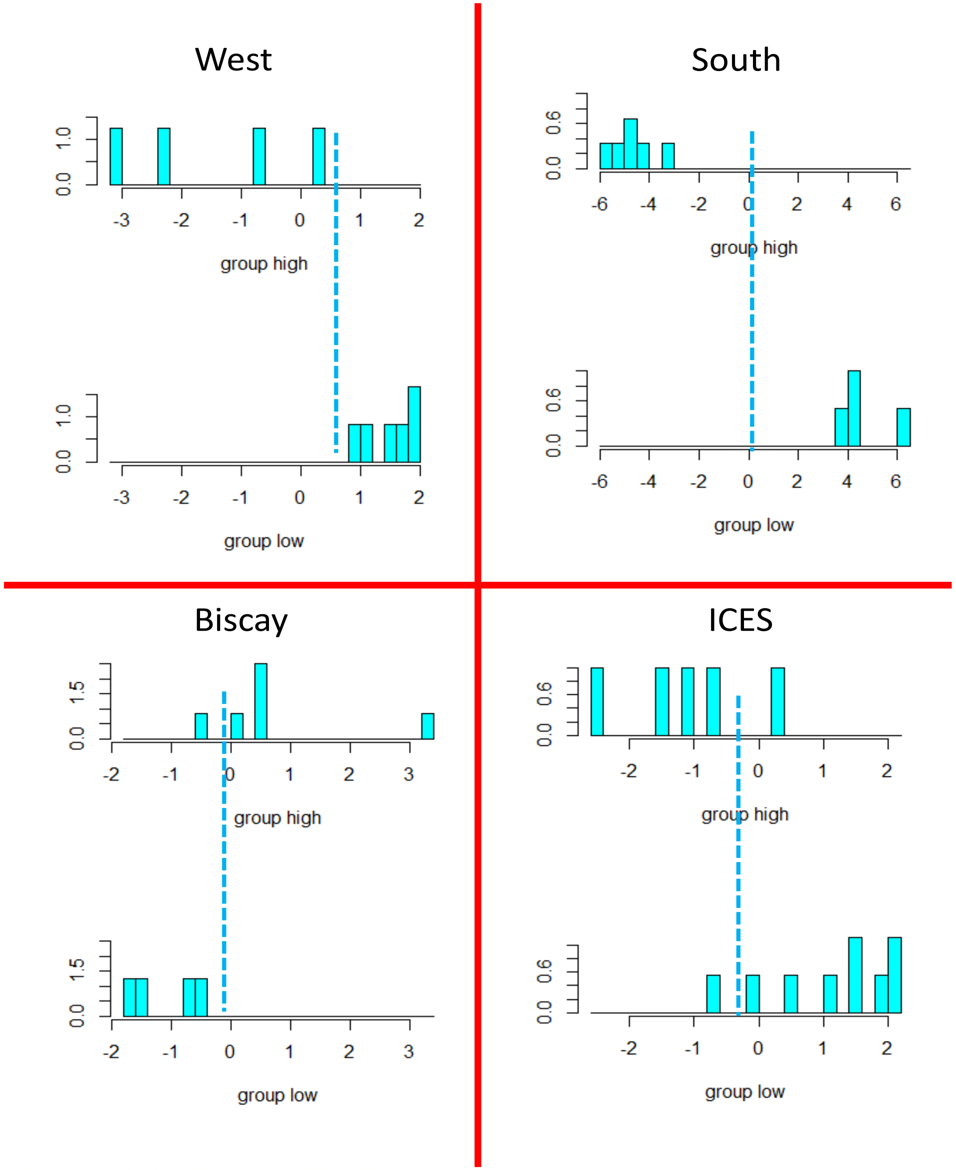
In general, high recruitment years were associated to high food availability and to low SST, although there were differences of the most important variables according to the areas under study.

Temperature and food-mediated variability of sardine populations

AREA	N	GROUP	GROUP MEANS					% CORRECT CROSS VALIDATION
			ADULTS YEAR BEFORE	SST SPAWN 1	SST SPAWN 2	CHLA SPAWN 1	CHLA SPAWN 2	
B. Satellite-derived SST and Chla only								
WEST	12	HIGH	X	13.74	16.42	0.59*	0.48*	100
		LOW	X	13.80	17.25	0.49*	0.47*	88
		coefficients	X	3.33	3.09	-18.88	12.61	TOTAL:92
SOUTH	12	HIGH	X	-	18.40	-	0.60*	75
		LOW	X	-	19.25	-	0.45*	63
		coefficients	X	-	-1.07	-	-5.57	TOTAL:67
BISCAY	10	HIGH	X	11.97	15.68	0.78*	0.65*	83
		LOW	X	11.30	16.17	0.66*	0.53*	75
		coefficients	X	-3.98	1.73	-5.52	8.53	TOTAL:80
ICES	16	HIGH	X	-	16.28	-	0.54*	75
		LOW	X	-	17.63	-	0.40*	80
		coefficients	X	-	1.12	-	-2.19	TOTAL:79
C. Satellite-derived SST only								
WEST	15	HIGH	X	13.85	16.25	X	X	57
		LOW	X	13.87	17.36	X	X	71
		coefficients	X	0.86	1.05	X	X	TOTAL:64
SOUTH	12	HIGH	X	15.25	18.50	X	X	60
		LOW	X	15.60	19.10	X	X	60
		coefficients	X	1.07	0.52	X	X	TOTAL:60
BISCAY	14	HIGH	X	11.97	-	X	X	75
		LOW	X	11.41	-	X	X	83
		coefficients	X	-3.15	-	X	X	TOTAL:78
ICES	30	HIGH	X	13.63	16.25	X	X	75
		LOW	X	13.93	17.44	X	X	70
		coefficients	X	0.75	1.06	X	X	TOTAL:73

Even if SSB was not known, LDA was still able to correctly classify **80-90%** except for the Gulf of Cadiz (classification decreased to 60%). SST alone only worked for Biscay (**78%**).

Temperature and food-mediated variability of sardine populations



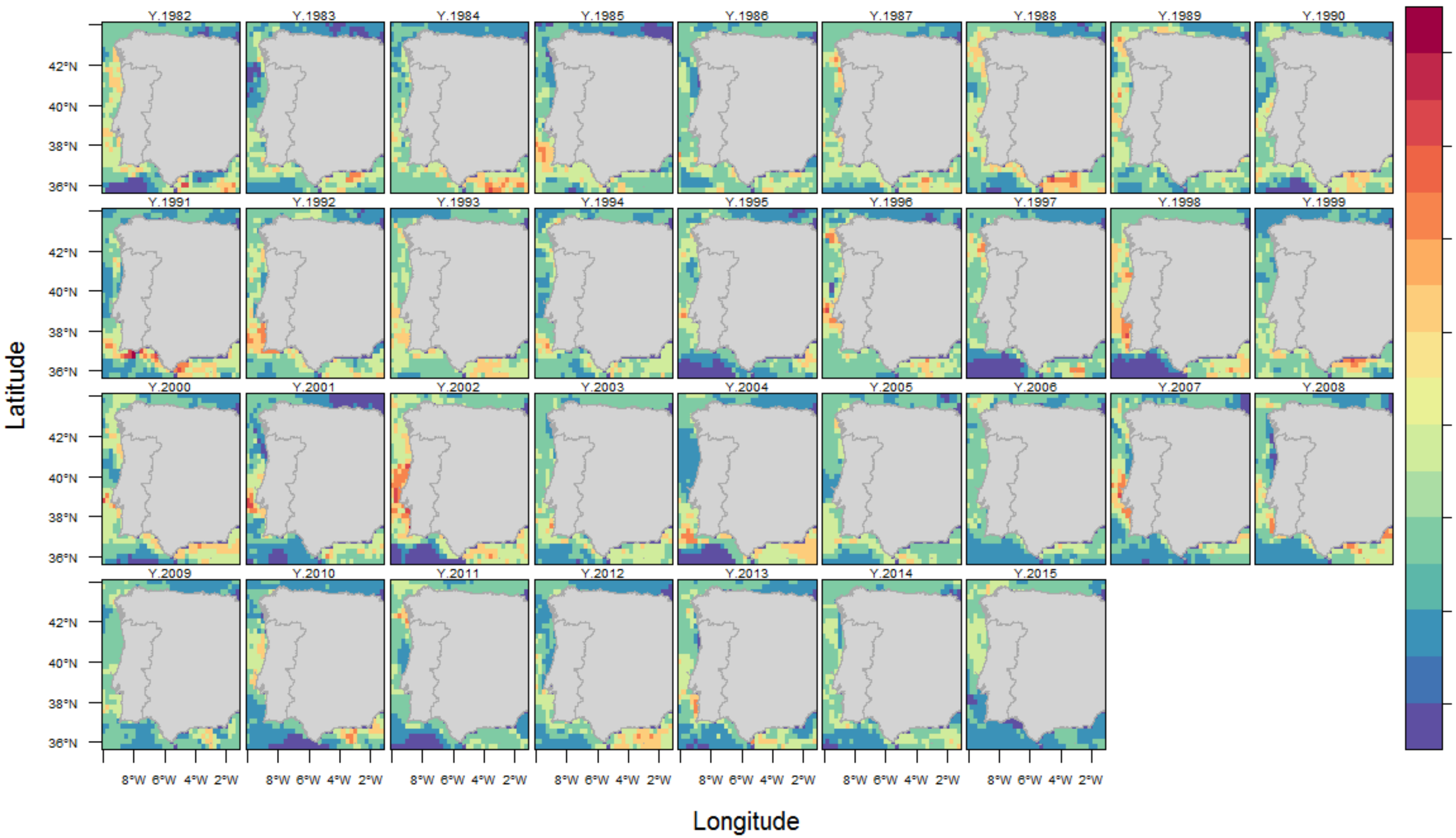
Temperature and food-mediated variability of sardine populations

Results of the Wilk's Lambda to evaluate the overall significance of the discriminant function analyses.

AREA	N	Wilk's Lambda
A. Abundance of adult sardines and satellite-derived SST and Chla combined		
WEST	10	Wilks=0.279 approx F=5.167 p=0.004
SOUTH	10	Wilks=0.03 approx F=21.256 p=0.005
BISCAY	10	Wilks=0.234 approx F=6.519 p=0.02
ICES	15	Wilks=0.455 approx F=3.983 p=0.041
B. Satellite-derived SST and Chla combined		
WEST	12	Wilks=0.138 approx F=10.847 p=0.004
SOUTH	12	Wilks=0.521 approx F=4.135 p=0.05
BISCAY	10	Wilks=0.173 approx F=5.944 p=0.038
ICES	16	Wilks=0.527 approx F=4.933 p=0.02
A. Satellite-derived SST only		
WEST	15	Wilks=0.708 approx F=2.262 p=0.150
SOUTH	12	Wilks=0.879 approx F= 0.823 p=0.462
BISCAY	14	ANOVA F=7.817 p=0.016
ICES	30	Wilks=0.644 approx F= 7.455 p=0.002

Temperature and food-mediated variability of sardine populations

10-15 consecutive days with SST between 13-17ºC and Chla >0.49mg m^{-3}



Work in progress, collaboration with Marta Rufino

Temperature and food-mediated variability of sardine populations

CONCLUSIONS

- SST and Chla were able to discriminate years of high and low recruitment based on spawners abundance and satellite-derived environmental data with an accuracy of ≥79%. This means that we can compute an indicator of recruitment strength for the Atlanto-Iberian waters.
- Although the time-series of available data are still small, these relationships should be further investigated in the following years to evaluate if these relationships can be used to construct a reliable indicator that allows the prediction of the level of recruitment and abundance with sufficient advance to help in the management of this important fishing resource.
- The underlying hypothesis and method can also be tested for different areas/ populations.

Temperature and food-mediated variability of sardine populations

Acknowledgments

- EU 7th Framework
- FCT – Portuguese Foundation of Science and Technology
- IPMA – colleagues collecting data onboard and analyzing samples in the lab

SARDINE GROWTH by areas from surveys and catches

A. Uriarte, L. Citores, Silva A., Duhamel, …. etc

Data: Survey Wa

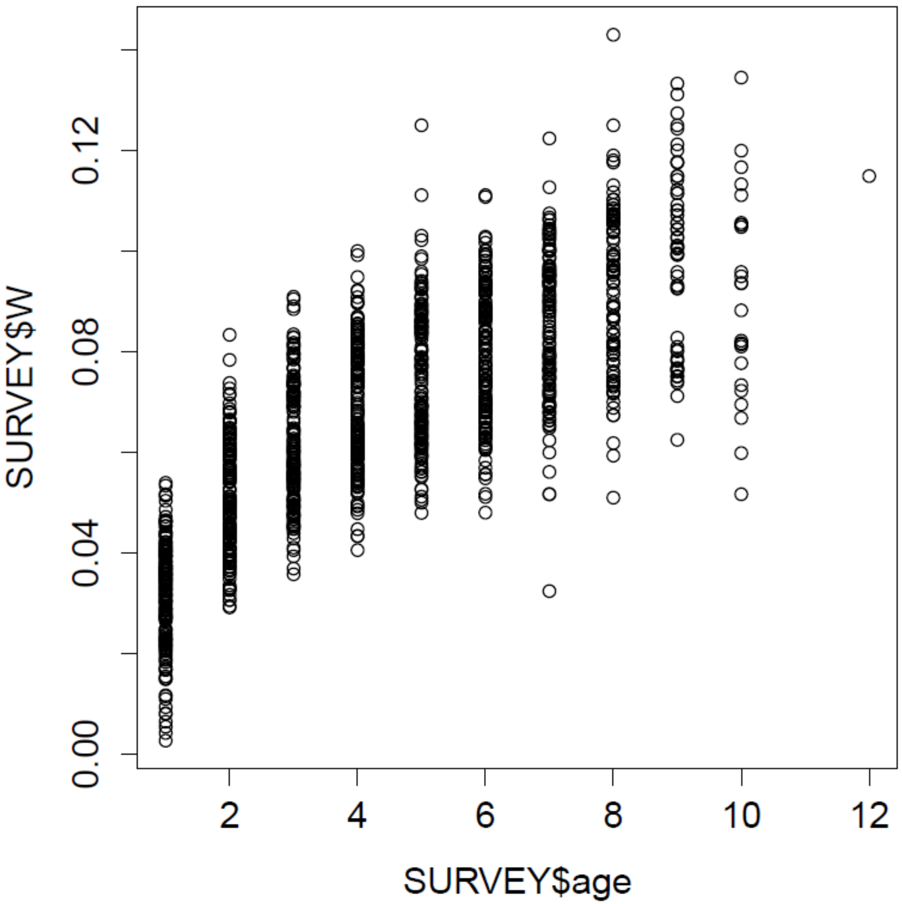
- Survey data (after removing NAs and 0 values)
- summary(SURVEY)

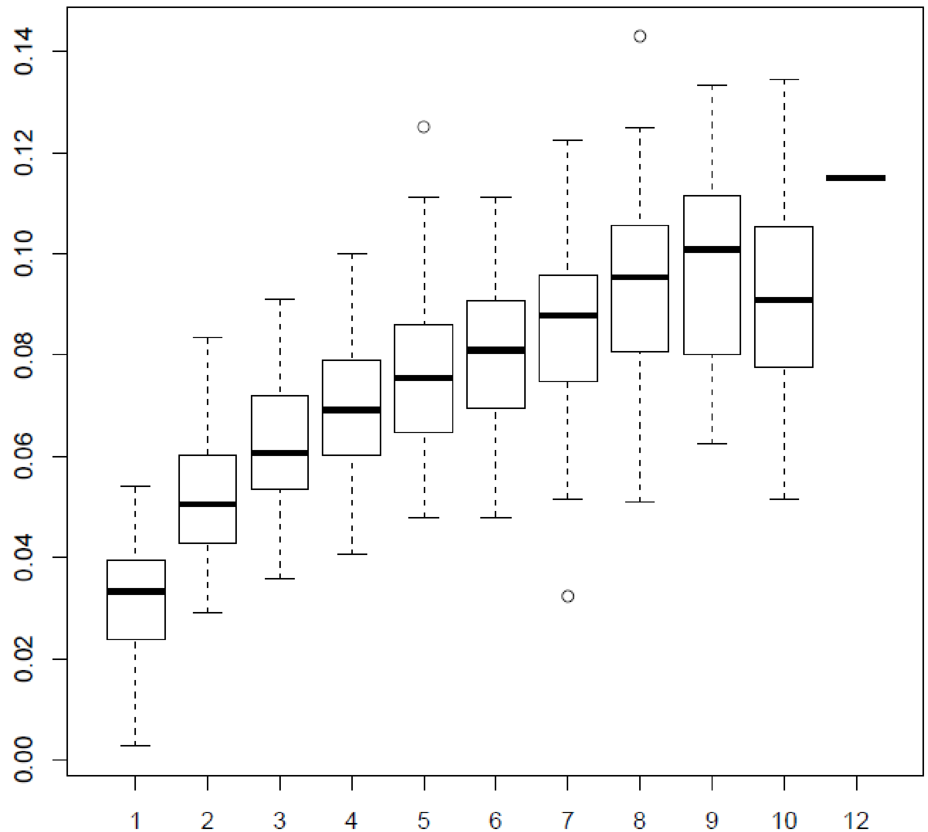
```
•      year         quarter       country          area             age              cohort
•   Min.   :1996   Min.   :1   france  :136   spor    :150   Min.    : 1.000   Min.   :1986
•   1st Qu.:2001   1st Qu.:1   portugal:557   swpor   :149   1st Qu.: 2.000   1st Qu.:1996
•   Median :2006   Median :1   spain   :604   wcan    :149   Median : 4.000   Median :2001
•   Mean   :2006   Mean   :1                  ecan    :141   Mean    : 4.579   Mean   :2001
•   3rd Qu.:2011   3rd Qu.:1                  sgal    :138   3rd Qu.: 6.000   3rd Qu.:2006
•   Max.   :2016   Max.   :1                  bisc    :136   Max.    :12.000   Max.   :2015
•                                             (Other):434
•        n                  b                  W
•   Min.   :       1   Min.   :     0.1   Min.   :0.00263
•   1st Qu.:    4846   1st Qu.:   366.0   1st Qu.:0.05404
•   Median :   29071   Median :  1951.0   Median :0.06935
•   Mean   :  272932   Mean   : 10967.8   Mean   :0.06876
•   3rd Qu.:  153973   3rd Qu.:  9168.1   3rd Qu.:0.08488
•   Max.   :16868108   Max.   :301274.0   Max.   :0.14300
```

Data

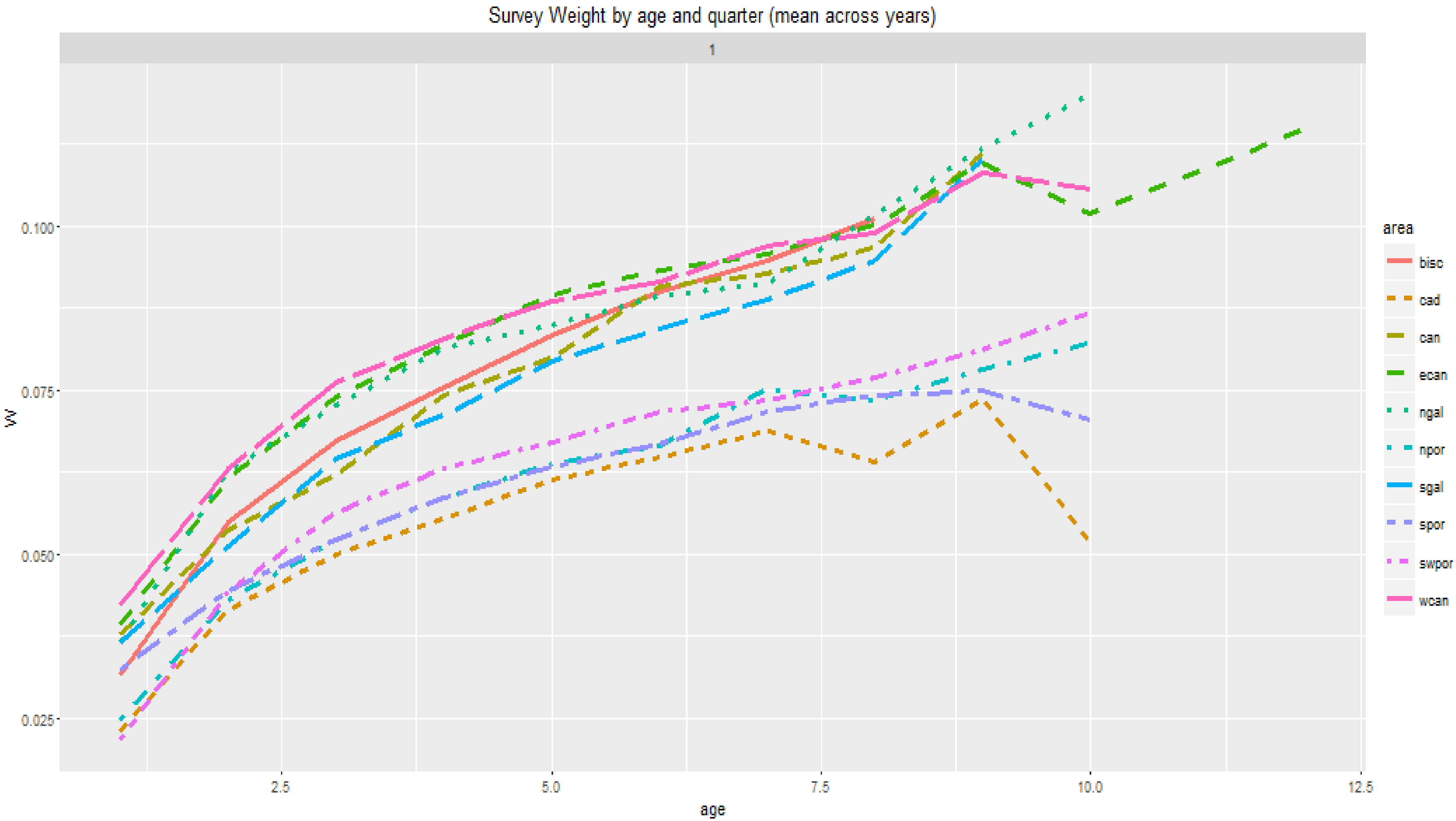
	Ages	Pesos	SdDev	CV	LOG_SdDev	sumN	sumRel
1	1	0.03163379	0.01089216	2.904272	0.4826177	176940716.49	4.998436e-01
2	2	0.05148171	0.01117180	4.608183	0.2245902	80991870.15	2.287956e-01
3	3	0.06234259	0.01215479	5.129055	0.1991802	41223729.84	1.164538e-01
4	4	0.06961991	0.01235715	5.633978	0.1828545	26236184.26	7.411515e-02
5	5	0.07536532	0.01342794	5.612573	0.1788142	14948499.40	4.222833e-02
6	6	0.07999980	0.01330135	6.014410	0.1721727	8139723.30	2.299408e-02
7	7	0.08526136	0.01439170	5.924342	0.1845334	3443137.73	9.726593e-03
8	8	0.09251435	0.01596541	5.794675	0.1789377	1869431.26	5.280996e-03
9	9	0.09838925	0.01785010	5.511973	0.1869216	152125.91	4.297437e-04
10	10	0.09081576	0.02001303	4.537833	0.2282317	46629.66	1.317251e-04
12	12	0.11490224	NA	NA	NA	133.00	3.757145e-07

Data Wa


SURVEY$W
0.00
0.04
0.08
0.12
2
4
6
8
10
12
SURVEY$age


0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
1
2
3
4
5
6
7
8
9
10
12

Survey data

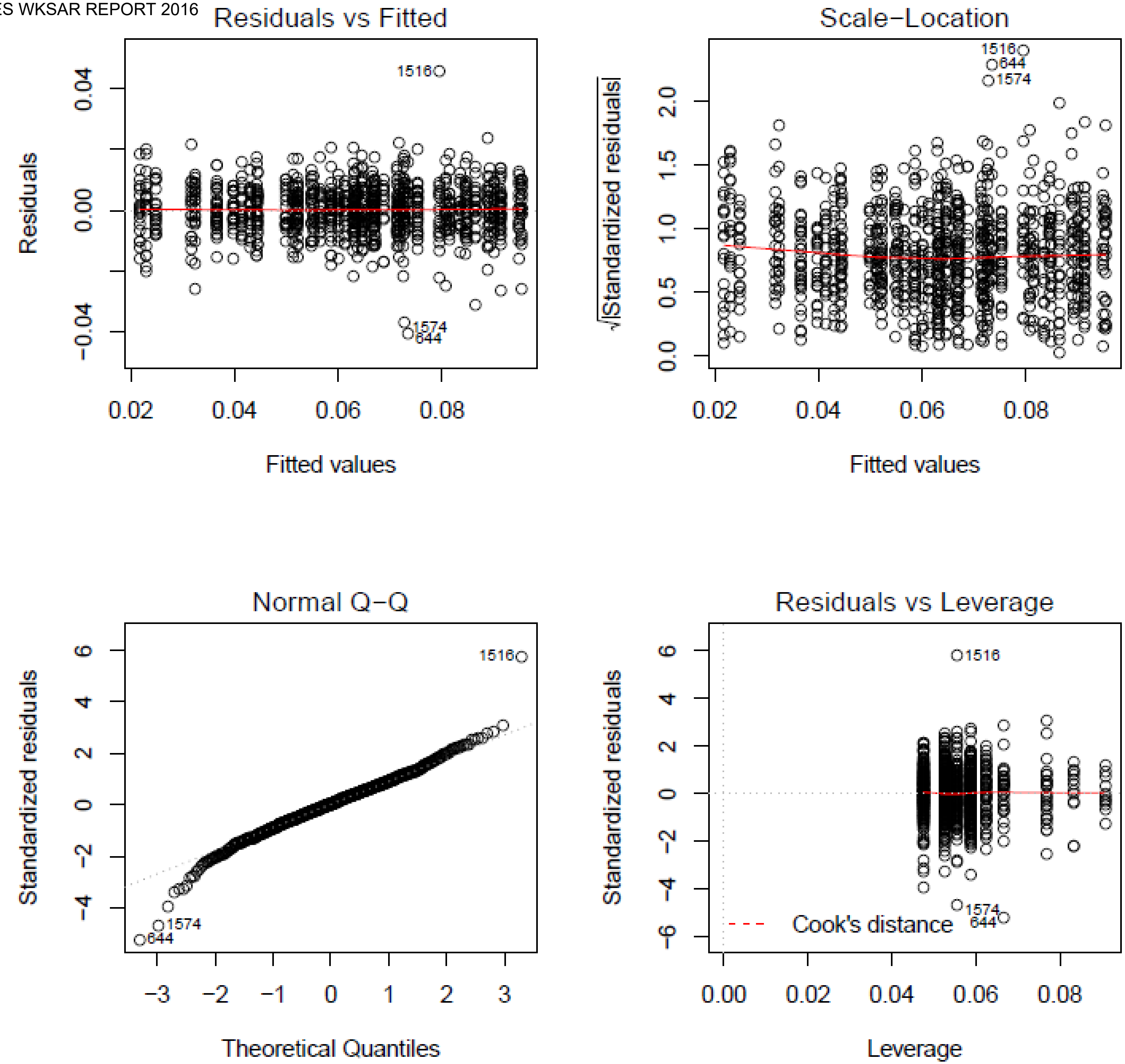

Survey Weight by age and quarter (mean across years)
1
0.100
0.075
0.050
0.025
W
2.5
5.0
7.5
10.0
12.5
age
area
bisc
cad
can
ecan
ngal
npor
sgal
spor
swpor
wcan

Analysis Wa 10 areas

```
•  area.levels
•  [1] "cad"   "spor"  "swpor" "npor"  "sgal"  "ngal"  "can"   "wcan"  "ecan"  "bisc"
•  Call:
•  aov(formula = W ~ area * as.factor(age), data = SURVEY, subset = age < 8)

•  Terms:
•                        area as.factor(age) area:as.factor(age)  Residuals
•  Sum of Squares  0.11678602     0.30445182          0.00745722 0.06728768
•  Deg. of Freedom          9              6                  54       1045

•  Residual standard error: 0.008024345
•  Estimated effects may be unbalanced
•                        Df  Sum Sq Mean Sq F value   Pr(>F)
•  area                   9 0.11679 0.01298 201.525  < 2e-16 ***
•  as.factor(age)         6 0.30445 0.05074 788.040  < 2e-16 ***
•  area:as.factor(age)   54 0.00746 0.00014   2.145 5.29e-06 ***
•  Residuals           1045 0.06729 0.00006
```

Analysis Wa: 8 areas

```
• area.levels
• [1] "cad"   "spor"  "swpor" "npor"  "sgal"  "ngal"  "can"   "bisc"
• Call:
• aov(formula = W ~ as.factor(age) * area, data = SURVEYCAN, subset = age < 8)
• Terms:
•                 as.factor(age)       area as.factor(age):area  Residuals
• Sum of Squares      0.28491694 0.08005475          0.00665307 0.06287643
• Deg. of Freedom              6          7                  42        950

• Residual standard error: 0.00813546
• Estimated effects may be unbalanced
•                      Df  Sum Sq Mean Sq F value   Pr(>F)
• as.factor(age)        6 0.28492 0.04749 717.468  < 2e-16 ***
• area                  7 0.08005 0.01144 172.792  < 2e-16 ***
• as.factor(age):area  42 0.00665 0.00016   2.393 2.61e-06 ***
• Residuals           950 0.06288 0.00007
```


Residuals vs Fitted
Residuals
Fitted values
1516
1574
644
Scale−Location
√|Standardized residuals|
Fitted values
Normal Q−Q
Standardized residuals
Theoretical Quantiles
Residuals vs Leverage
Standardized residuals
Leverage
Cook's distance

Analysis Wa

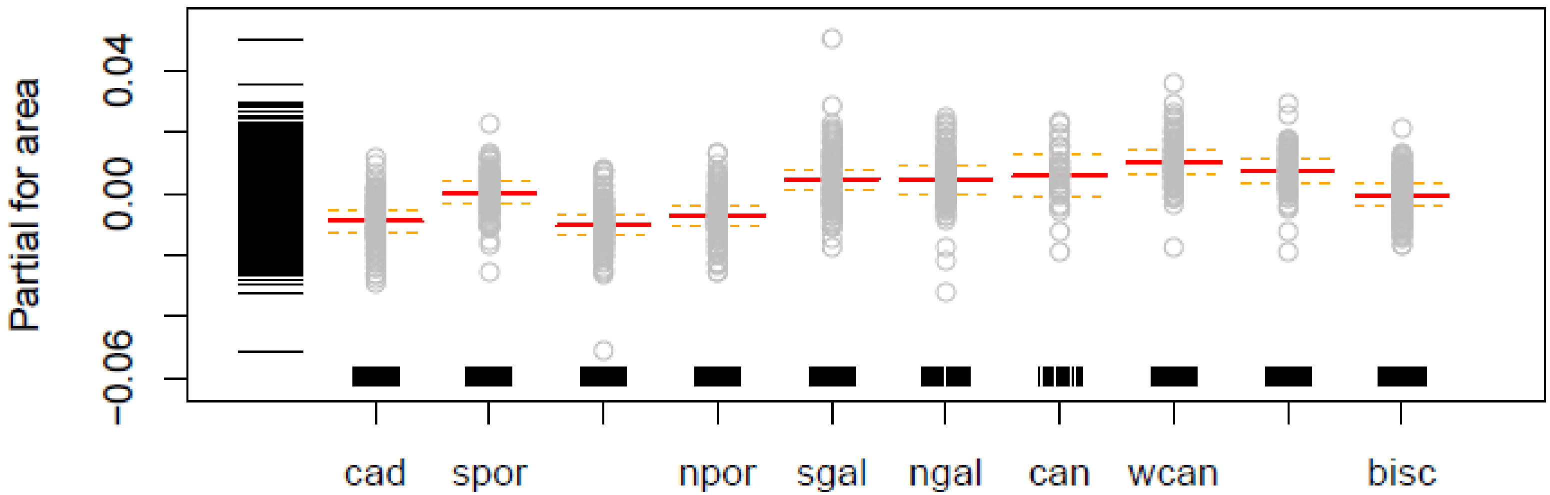
Tukey multiple comparisons of means

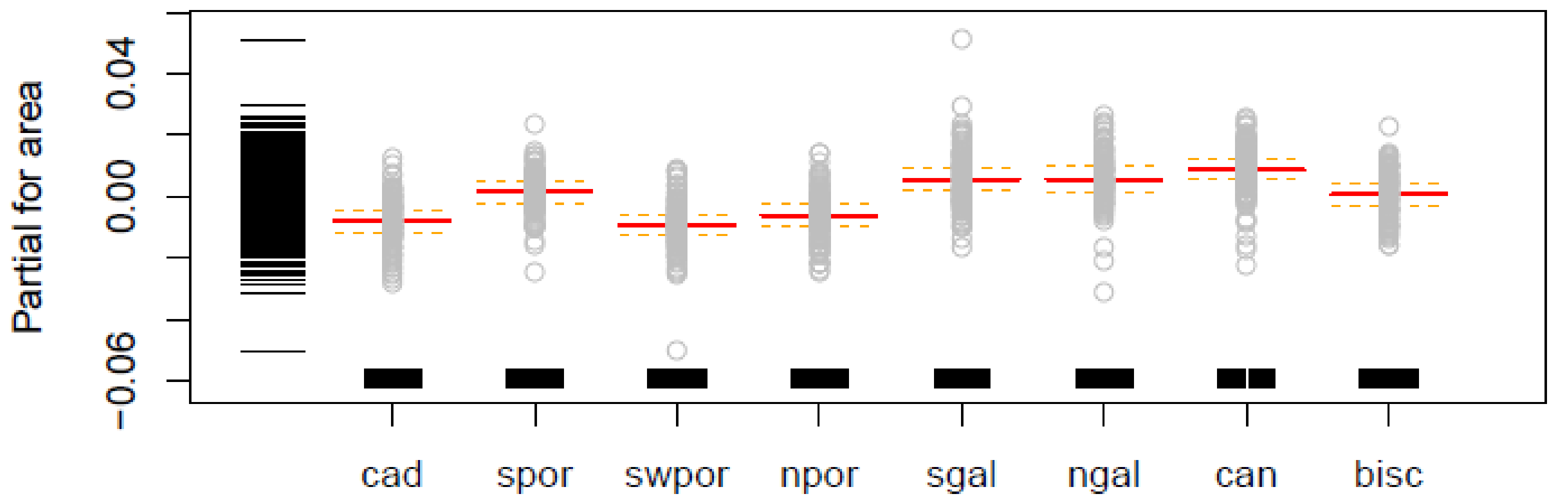
95% family-wise confidence level

	spor	swpor	npor	sgal	ngal	can	wcan	ecan	bisc
cad	0.0007344	0.0000014	0.2123823	0	0	0	0	0	0
spor		0.9598634	0.8252524	0	0	0	0	0	0
swpor			0.1078292	0	0	0	0	0	0
npor				0	0	0	0	0	0
sgal					0	0.1293437	0	0	0.0000194
ngal						0.0060636	0.9595035	0.938338	0.0000913
can							0.0001624	0.0001271	0.9999146
wcan								1	0.0000001
ecan									0.0000001

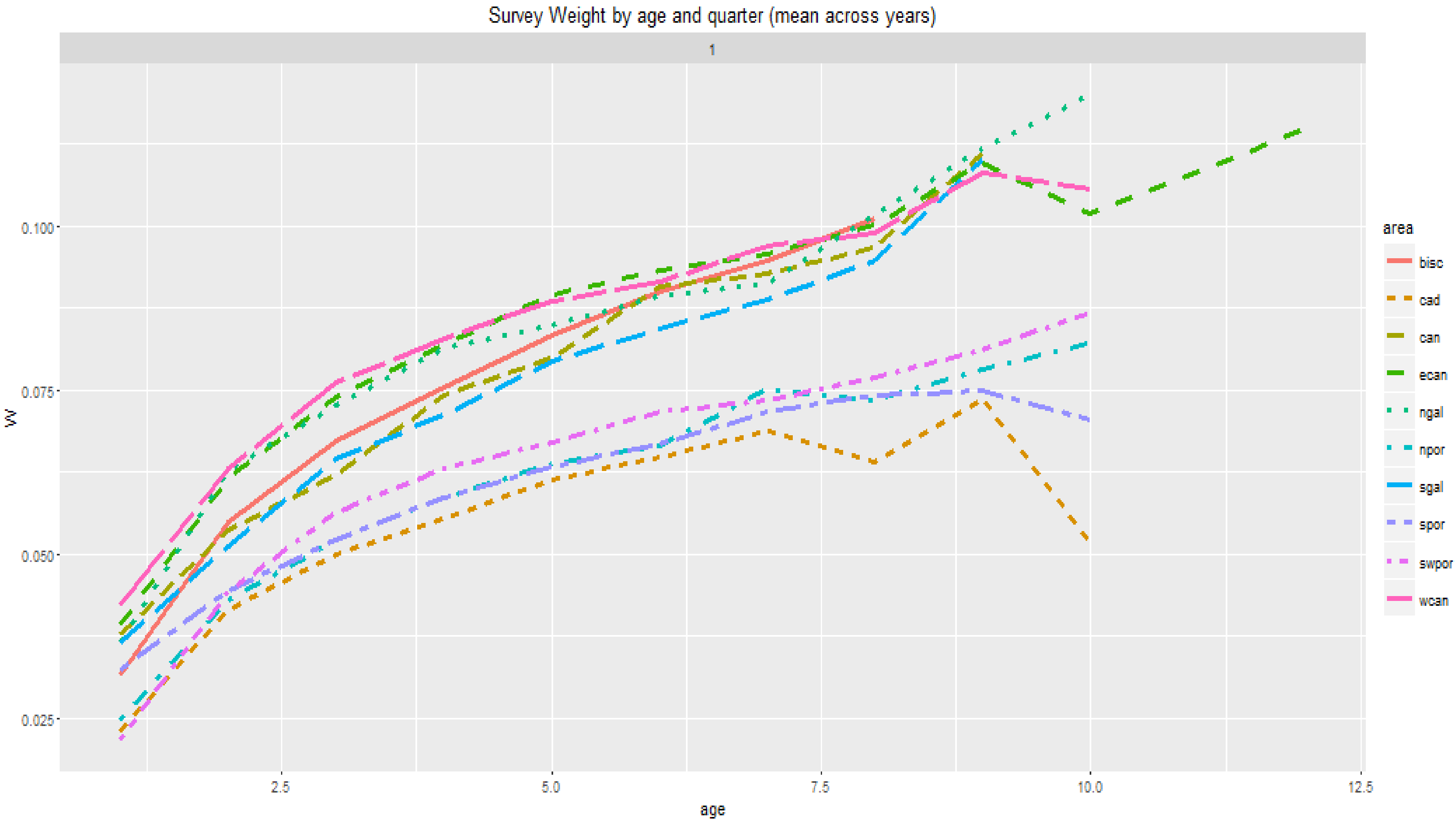
	spor	swpor	npor	sgal	ngal	can	bisc
cad	0.0006046	0.0000014	0.1652358	0	0	0	0
spor		0.9153191	0.7362677	0	0	0	0
swpor			0.0828295	0	0	0	0
npor				0	0	0	0
sgal					0	0	0.0000175
ngal						0.9855637	0.0000792
can							0.0013348

Analysis Wa


Partial for area
0.04
0.00
−0.06
cad
spor
npor
sgal
ngal
can
wcan
bisc


Partial for area
0.04
0.00
−0.06
cad
spor
swpor
npor
sgal
ngal
can
bisc

Survey data


Survey Weight by age and quarter (mean across years)
1
W
0.025
0.050
0.075
0.100
2.5
5.0
7.5
10.0
12.5
age
area
bisc
cad
can
ecan
ngal
npor
sgal
spor
swpor
wcan

Survey Analysis Wa Conclusions

- Latitudinal Gradient: Increasing South-North
- Statistically different groups:
  - Cadiz
  - SouthPort + <u>SW + North Portugal</u>
  - S.Galicia(?)
  - <u>North Galicia+ Cantabria</u>
  - Bay of Biscay

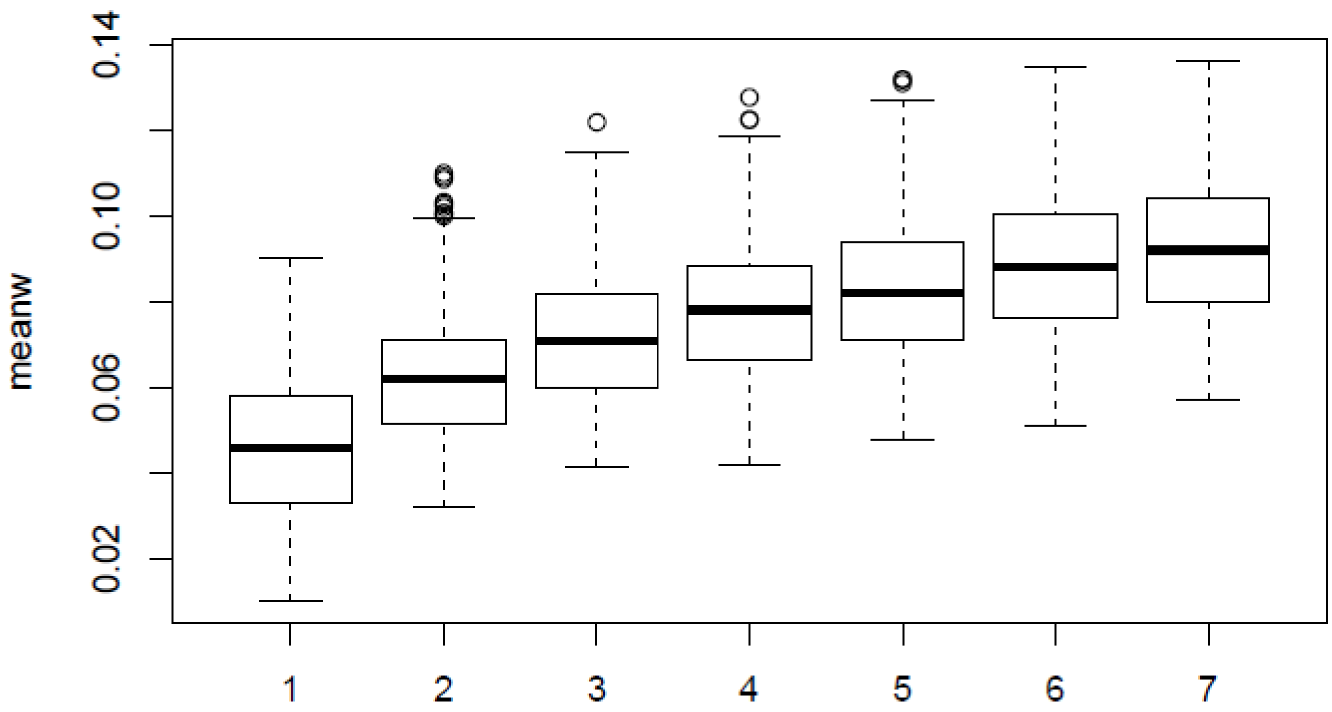
Data: Catches Wa

- Catch data (after removing NAs and 0 values)

```
## [1] "bisc"  "cad"   "can"   "ngal"  "npor"  "sgal"  "spor"  "swpor"

##        area          year         age      quarter         N
##  ngal    :666   Min.   :1991   1:679   1:1174   Min.   :     0
##  can     :656   1st Qu.:1998   2:690   2:1165   1st Qu.:   863
##  swpor   :640   Median :2004   3:690   3:1154   Median :  2781
##  sgal    :639   Mean   :2003   4:686   4:1136   Mean   :  8625
##  npor    :636   3rd Qu.:2009   5:676            3rd Qu.:  8311
##  spor    :620   Max.   :2014   6:642            Max.   :244652
##  (Other):772                   7:566
##      meanw              meanl
##  Min.   :0.01000   Min.   :10.90
##  1st Qu.:0.06000   1st Qu.:19.45
##  Median :0.07400   Median :20.74
##  Mean   :0.07427   Mean   :20.43
##  3rd Qu.:0.08900   3rd Qu.:21.80
##  Max.   :0.13620   Max.   :24.70
##
```

Catch Data (Age <8)

##	Ages	Pesos	SdDev	CV	LOG_SdDev	sumN	sumRel
## 1	1	0.04656786	0.01644701	2.831388	0.3796936	11185099.9	0.28015035
## 2	2	0.06243879	0.01480578	4.217189	0.2390587	10302594.3	0.25804646
## 3	3	0.07161892	0.01491682	4.801220	0.2098958	8654942.6	0.21677815
## 4	4	0.07822315	0.01500628	5.212693	0.1939464	5494875.0	0.13762874
## 5	5	0.08321246	0.01538083	5.410142	0.1857574	2603184.3	0.06520130
## 6	6	0.08874681	0.01640384	5.410125	0.1860875	1207184.4	0.03023604
## 7	7	0.09325817	0.01741905	5.353804	0.1876574	477466.1	0.01195897



Catch Data (Age <8)

Catch Data Analysis Wa: 8 areas

All quarters (No Interaction)
AnalisisW2Q

```
## Call:
##    aov(formula = meanw ~ area + as.factor(age) + as.factor(quarter),
##     data = Ca)
##
## Terms:
##                      area as.factor(age) as.factor(quarter) Residuals
## Sum of Squares  0.4193479      0.9801617          0.3033549 0.4686447
## Deg. of Freedom         7              6                  3      4612
##
## Residual standard error: 0.01008039
## Estimated effects may be unbalanced
```

```
##                      Df Sum Sq Mean Sq F value Pr(>F)
## area                  7 0.4193 0.05991   589.6 <2e-16 ***
## as.factor(age)        6 0.9802 0.16336  1607.7 <2e-16 ***
## as.factor(quarter)    3 0.3034 0.10112   995.1 <2e-16 ***
## Residuals          4612 0.4686 0.00010
```

All quarters (With Interactions)
AnalisisW3Q

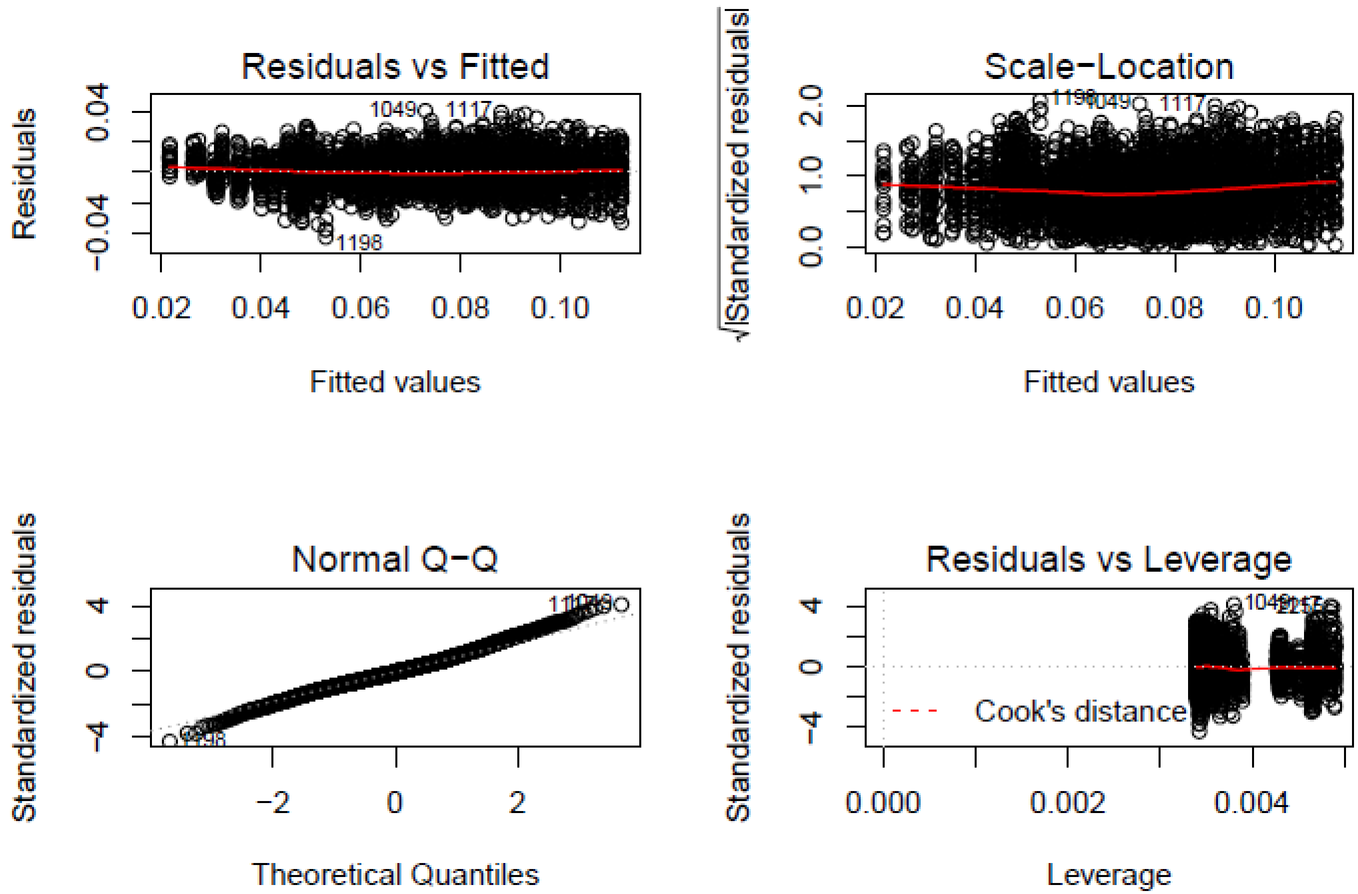
```
## Call:
##    aov(formula = meanw ~ area * age + as.factor(quarter) * age +
##     as.factor(quarter) * area, data = Ca)
##
## Terms:
##                      area       age as.factor(quarter)  area:age
## Sum of Squares  0.4193479 0.9801617          0.3033549 0.0369622
## Deg. of Freedom         7         6                  3        42
##                 age:as.factor(quarter) area:as.factor(quarter) Residuals
## Sum of Squares               0.0096214               0.0225453 0.3995159
## Deg. of Freedom                     18                      21      4531
##
## Residual standard error: 0.009390095
## Estimated effects may be unbalanced
```

```
##                           Df Sum Sq Mean Sq  F value   Pr(>F)
## area                       7 0.4193 0.05991  679.417  < 2e-16 ***
## age                        6 0.9802 0.16336 1852.706  < 2e-16 ***
## as.factor(quarter)         3 0.3034 0.10112 1146.806  < 2e-16 ***
## area:age                  42 0.0370 0.00088    9.981  < 2e-16 ***
## age:as.factor(quarter)    18 0.0096 0.00053    6.062 7.36e-15 ***
## area:as.factor(quarter)   21 0.0225 0.00107   12.176  < 2e-16 ***
## Residuals               4531 0.3995 0.00009
```

```
##            df        AIC
## AnalisW    57 -27249.078
## AnalisW2   57 -27249.078
## AnalisW2Q  18 -29405.039
## AnalisW3Q  99 -29981.788
## AnalisWq2  57  -7607.426
```

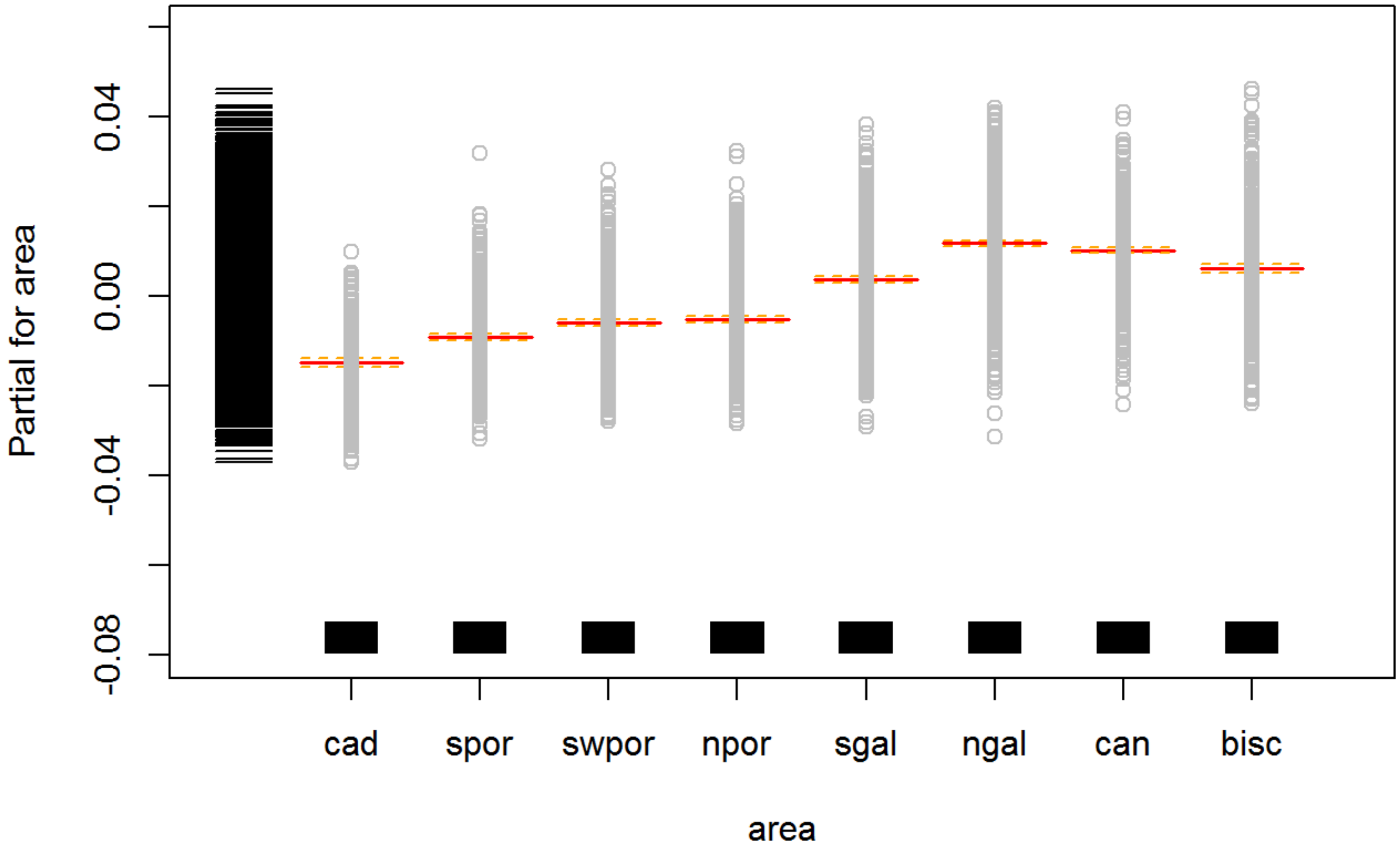
Catch Data Analysis Wa: 8 areas

All quarters (no Interactions)



Catch Data Analysis Wa: 8 areas

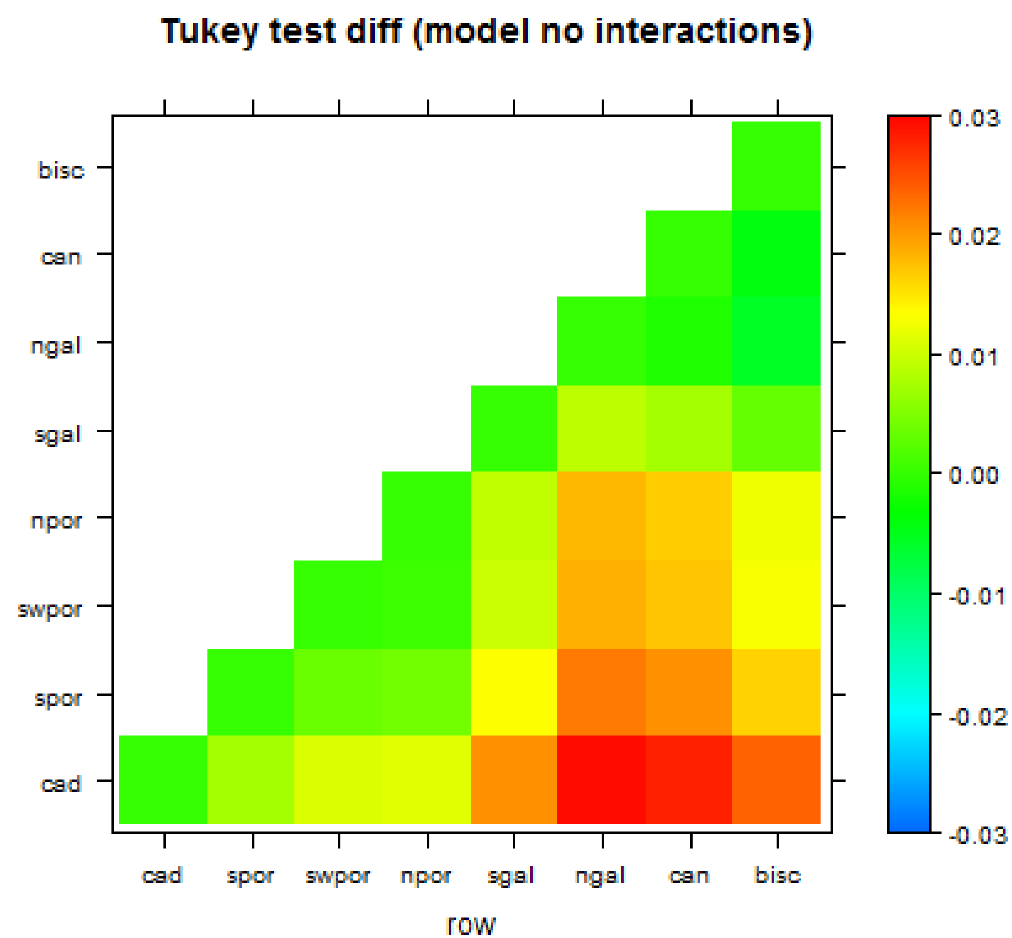
All quarters (No Interaction)



Tukey test for catch weights

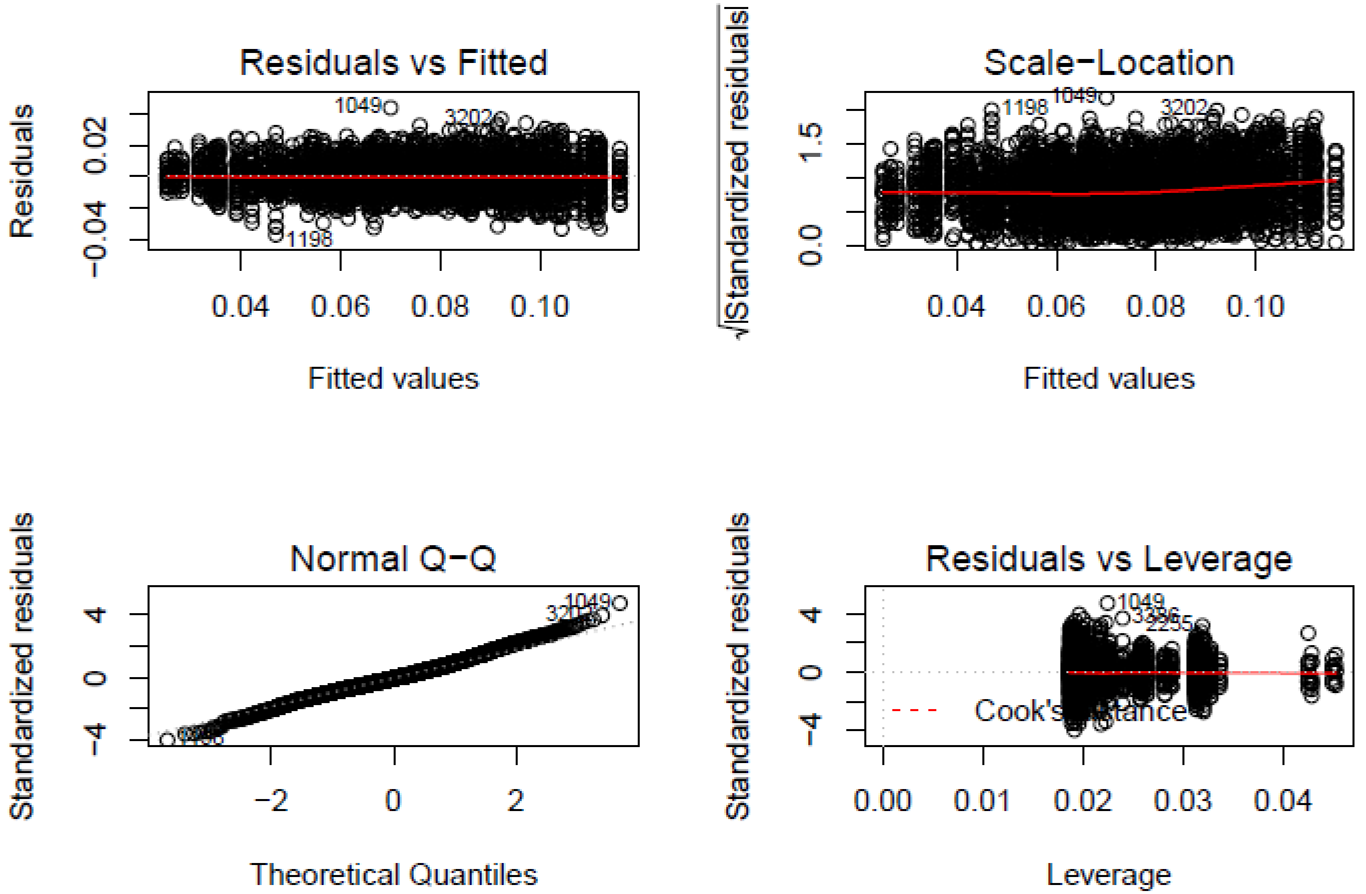
Model with no interactions

	cad	spor	swpor	npor	sgal	ngal	can	bisc
cad	NA	NA	NA	NA	NA	NA	NA	NA
spor	0	NA	NA	NA	NA	NA	NA	NA
swpor	0	0	NA	NA	NA	NA	NA	NA
npor	0	0	0.9842	NA	NA	NA	NA	NA
sgal	0	0	0.0000	0	NA	NA	NA	NA
ngal	0	0	0.0000	0	0e+00	NA	NA	NA
can	0	0	0.0000	0	0e+00	0.173	NA	NA
bisc	0	0	0.0000	0	1e-04	0.000	0	NA



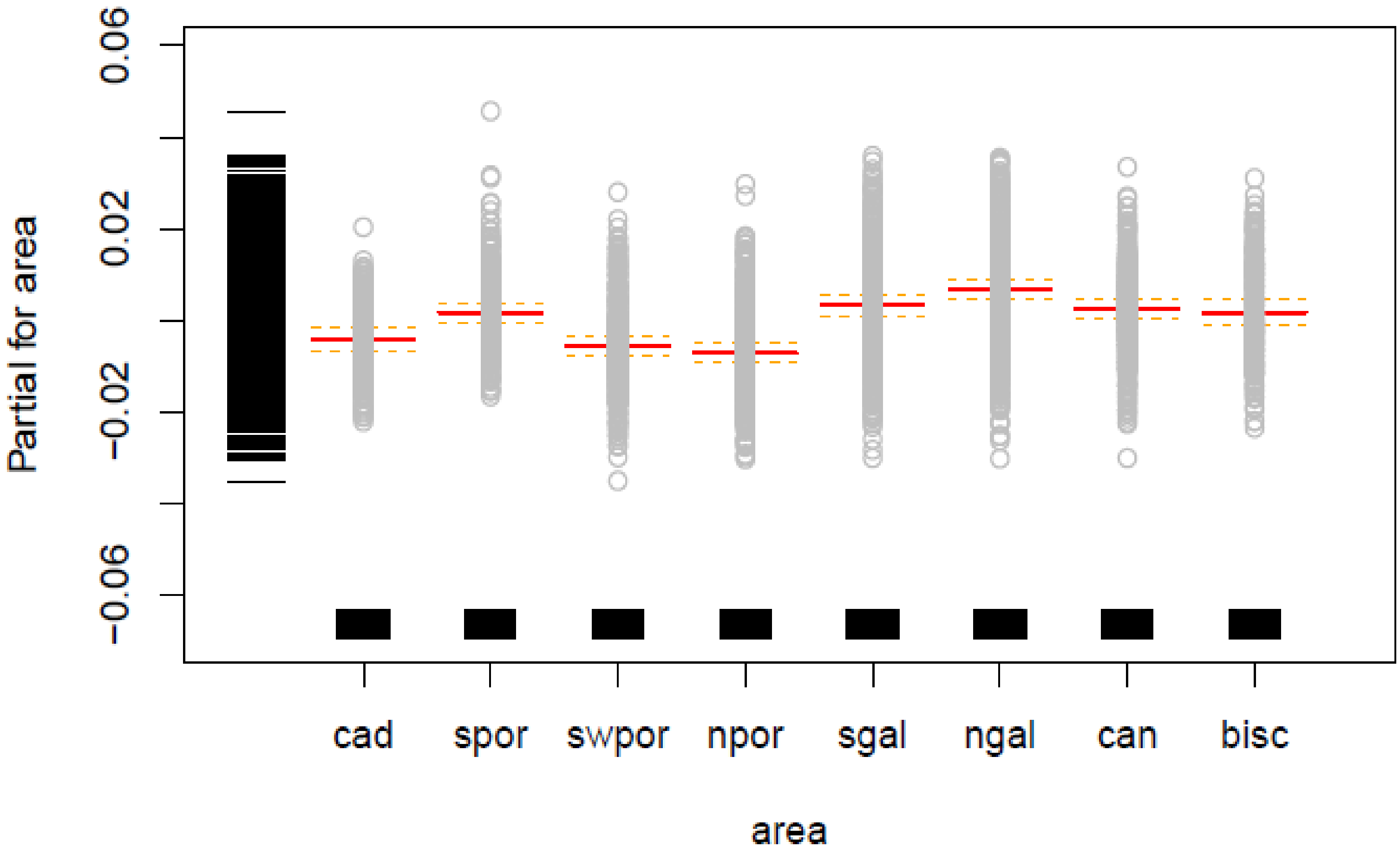
Catch Data Analysis Wa: 8 areas

All quarters (with Interactions)



Catch Data Analysis Wa: 8 areas

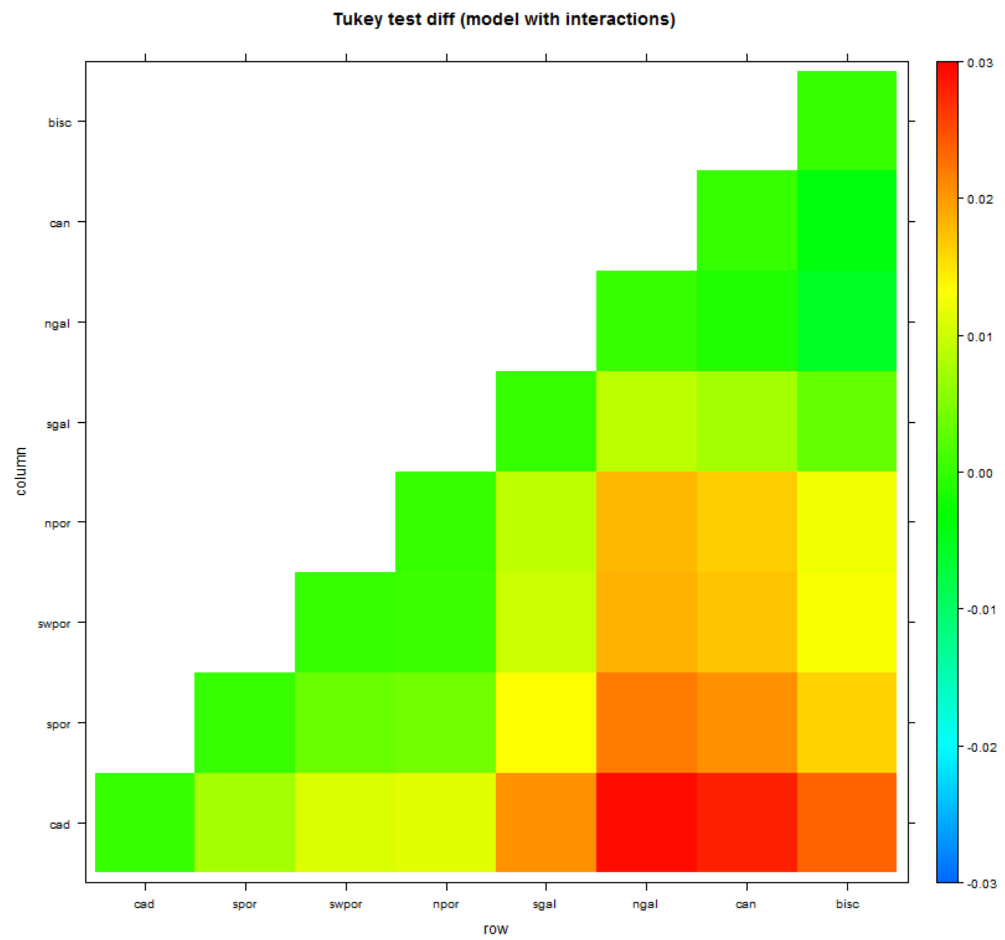
All quarters (with Interactions)



Tukey test for catch weights

Model with interactions

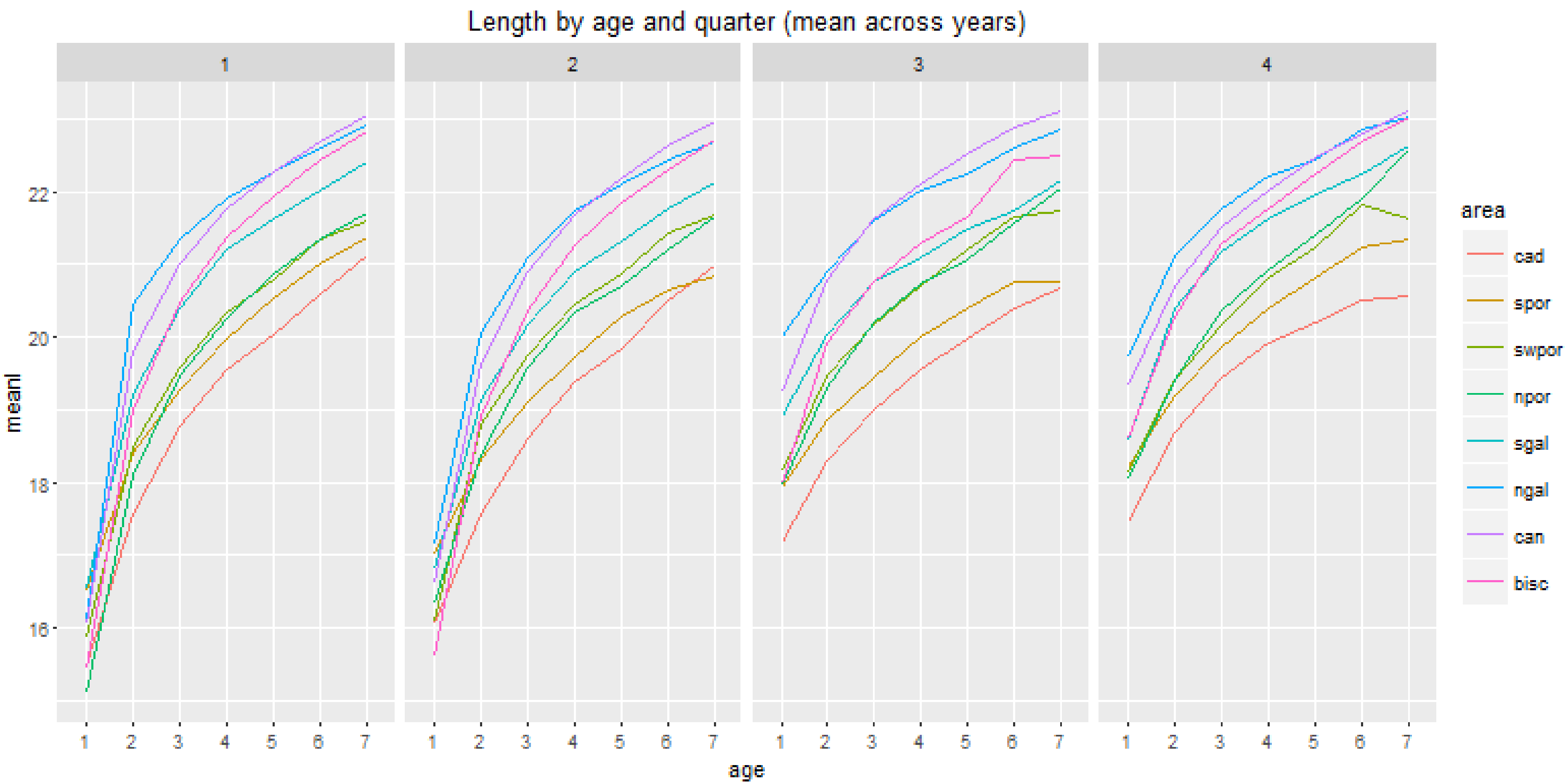
	cad	spor	swpor	npor	sgal	ngal	can	bisc
cad	NA	NA	NA	NA	NA	NA	NA	NA
spor	0	NA	NA	NA	NA	NA	NA	NA
swpor	0	0	NA	NA	NA	NA	NA	NA
npor	0	0	0.9762	NA	NA	NA	NA	NA
sgal	0	0	0.0000	0	NA	NA	NA	NA
ngal	0	0	0.0000	0	0	NA	NA	NA
can	0	0	0.0000	0	0	0.1102	NA	NA
bisc	0	0	0.0000	0	0	0.0000	0	NA



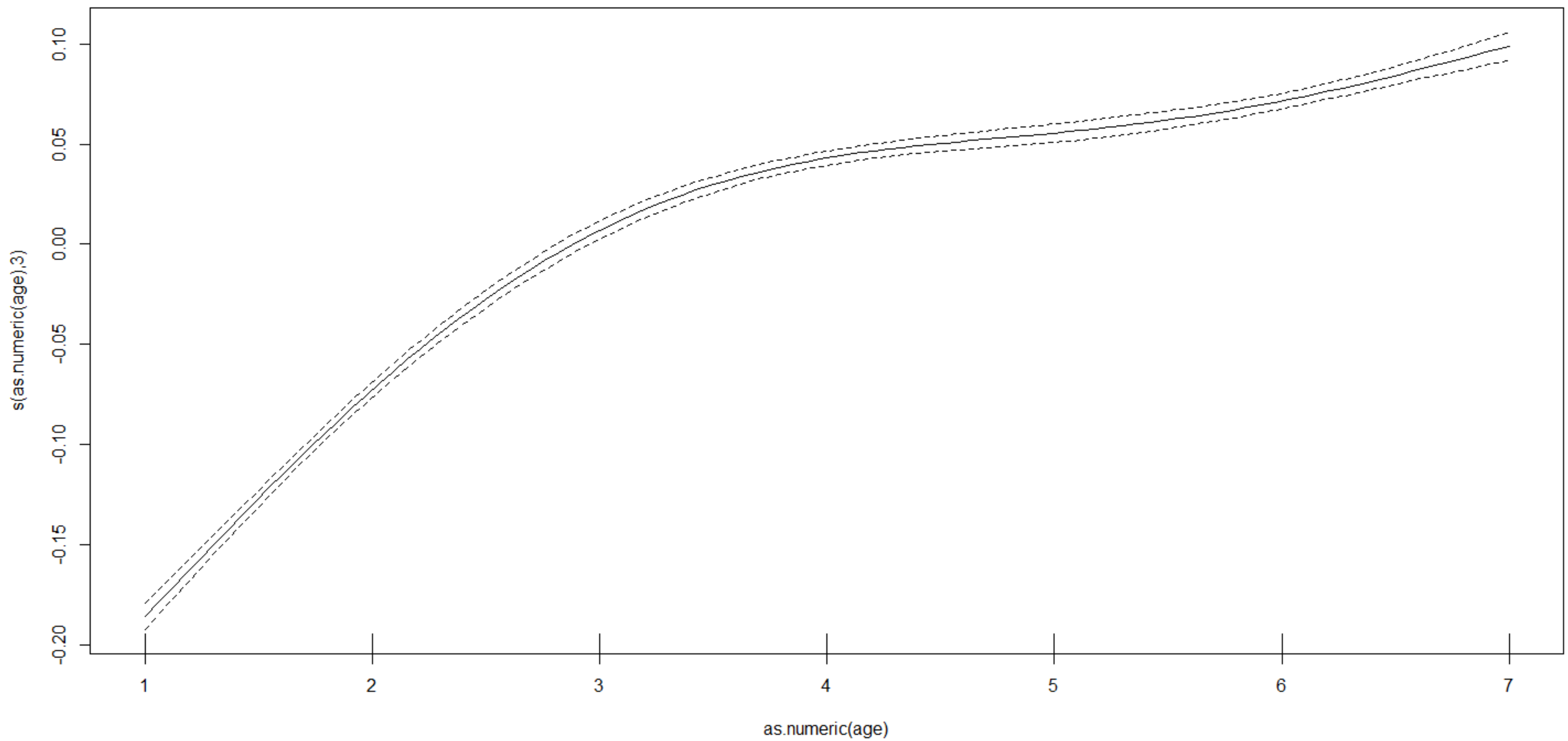
Catch Analysis Wa Conclusions

- Latitudinal Gradient: Increasing South-North
- Statistically different groups:
  - Cadiz
  - South Portugal
  - SW + North Portugal
  - S.Galicia(?)
  - North Galicia+ Cantabria
  - Bay of Biscay

LENGTH AT AGE IN CATCHES



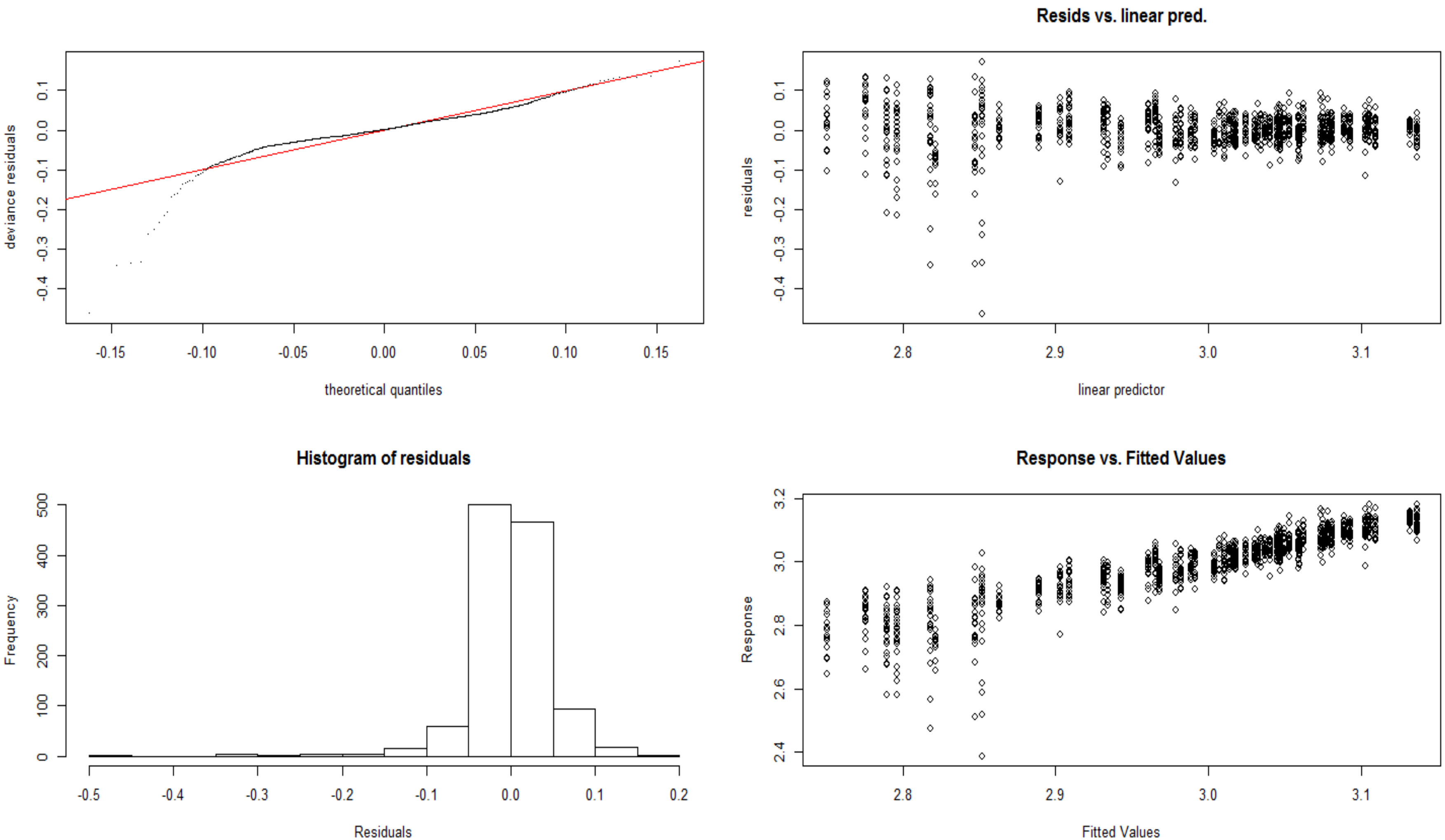
Mean Length at age in Catches



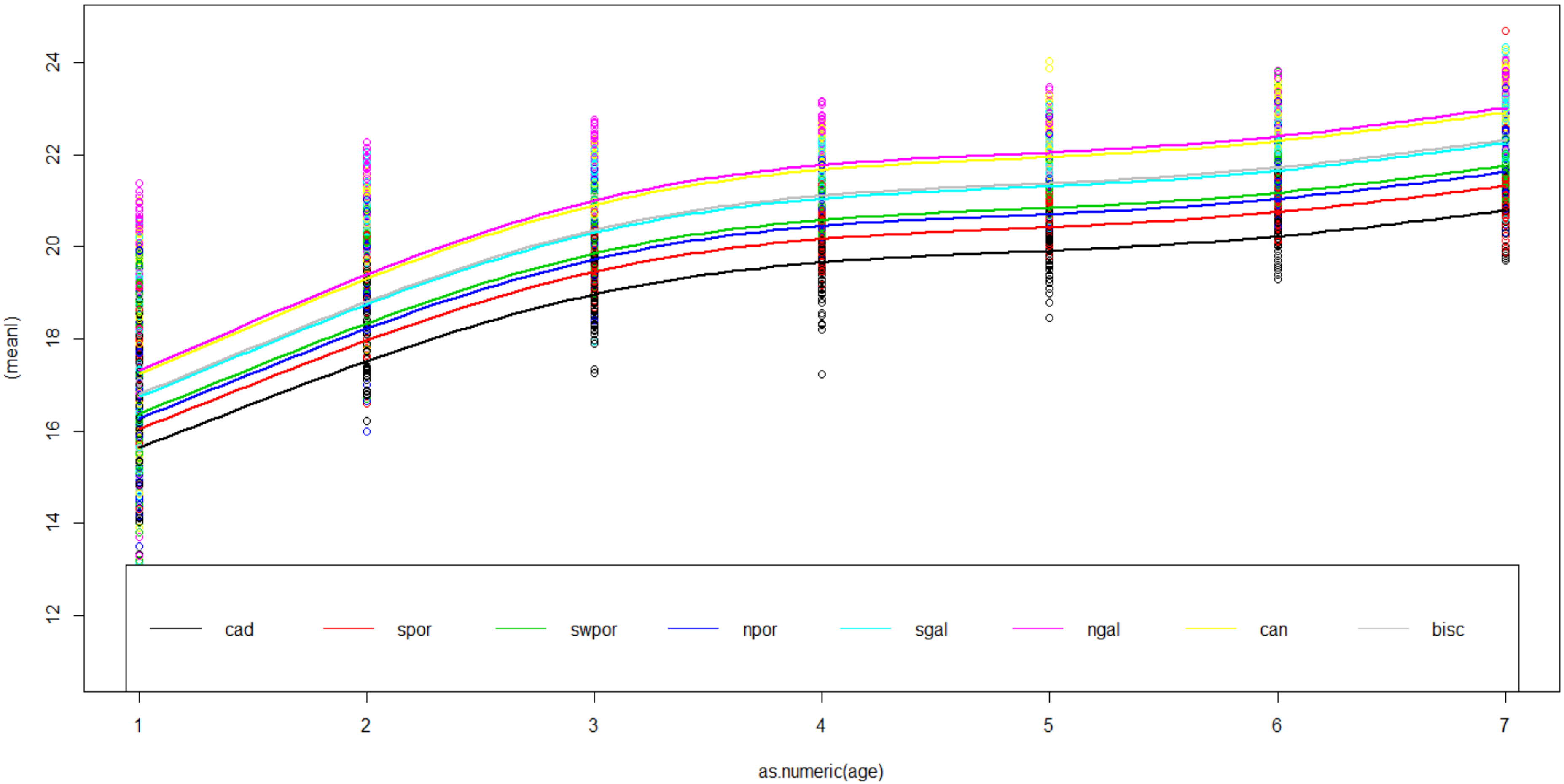
Length at age
log(meanl)~s(age)+area

```
Family: gaussian
Link function: identity

Formula:
log(meanl) ~ s(as.numeric(age), k = 4) + area

Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 2.935781   0.004832 607.530  < 2e-16 ***
areaspor    0.025531   0.006194   4.122 4.03e-05 ***
areaswpor   0.045826   0.006165   7.434 2.05e-13 ***
areanpor    0.039474   0.006158   6.410 2.11e-10 ***
areasgal    0.068111   0.006164  11.050  < 2e-16 ***
areangal    0.102092   0.006140  16.627  < 2e-16 ***
areacan     0.097493   0.006177  15.784  < 2e-16 ***
areabisc    0.071222   0.007035  10.124  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate significance of smooth terms:
                     edf Ref.df    F p-value
s(as.numeric(age)) 2.997      3 1377  <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =  0.802   Deviance explained = 80.4%
GCV = 0.0023966  Scale est. = 0.002374  n = 1165
```

Fitted GAM for Length at age by area



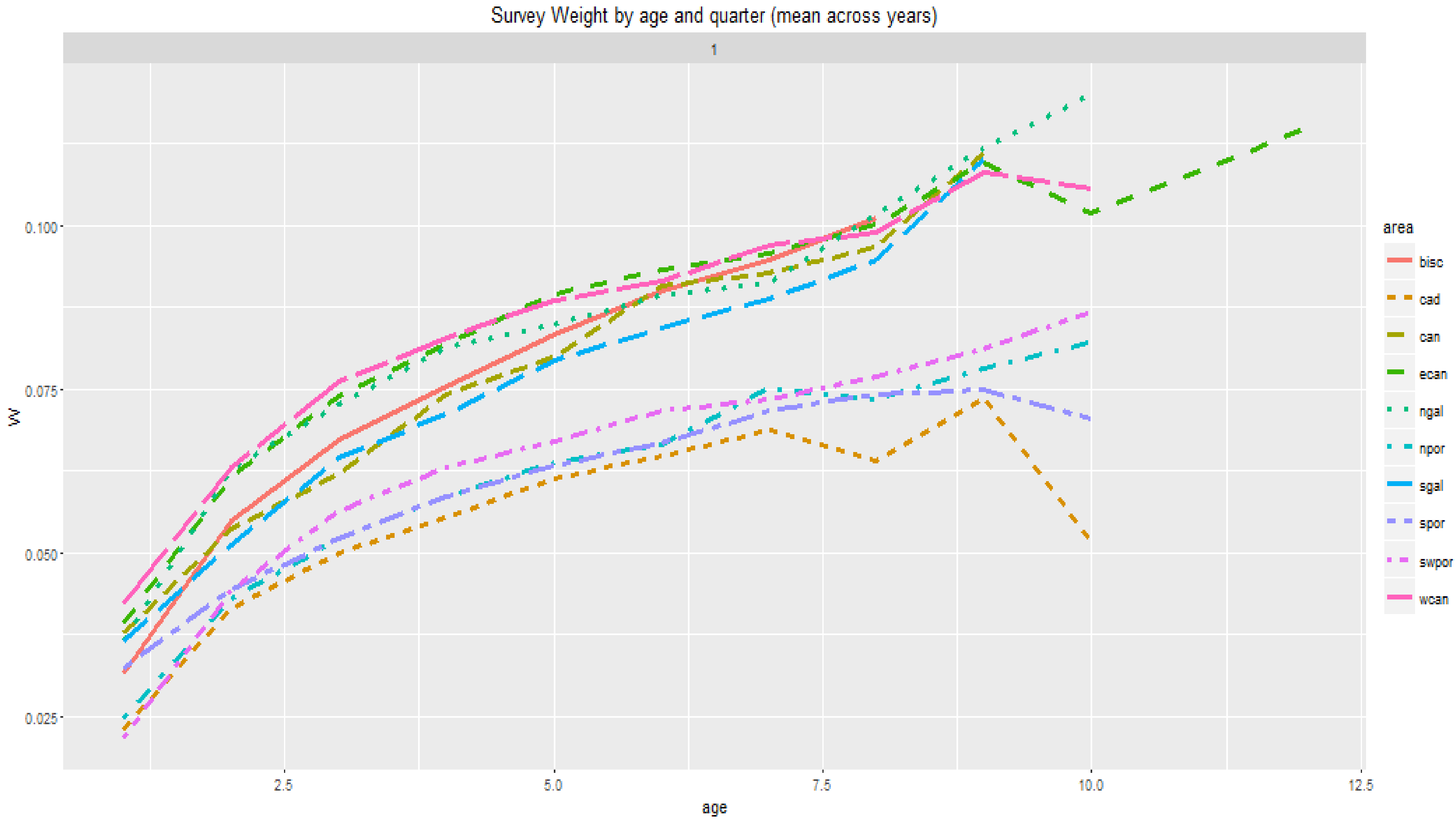
Length at age by area



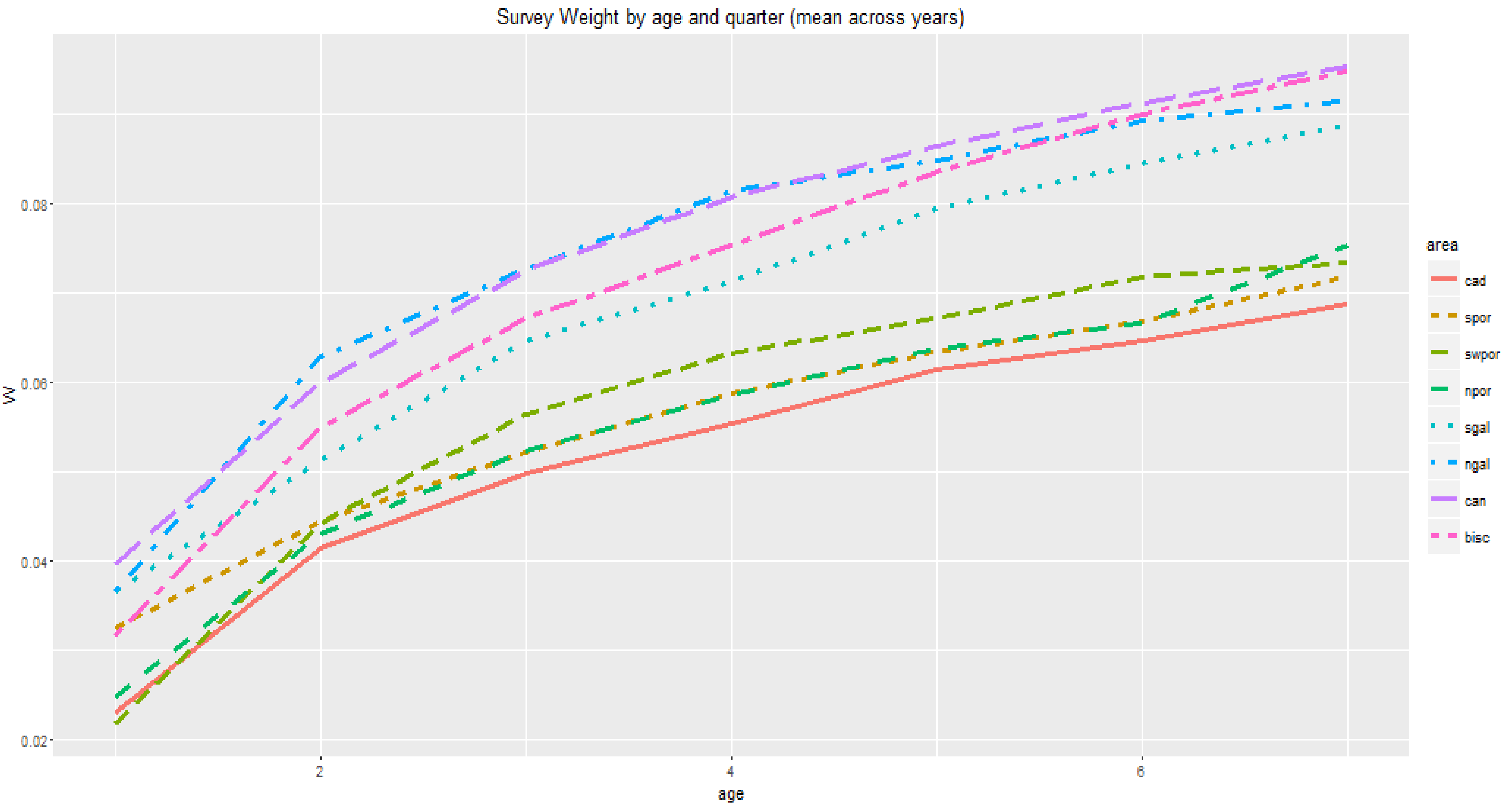
Catch Analysis La Conclusions

- Latitudinal Gradient: Increasing South-North
- Visual groups:
  - Cadiz
  - South Portugal
  - <u>SW + North Portugal</u>
  - S.Galicia(?)
  - <u>North Galicia+ Cantabria</u>
  - Bay of Biscay

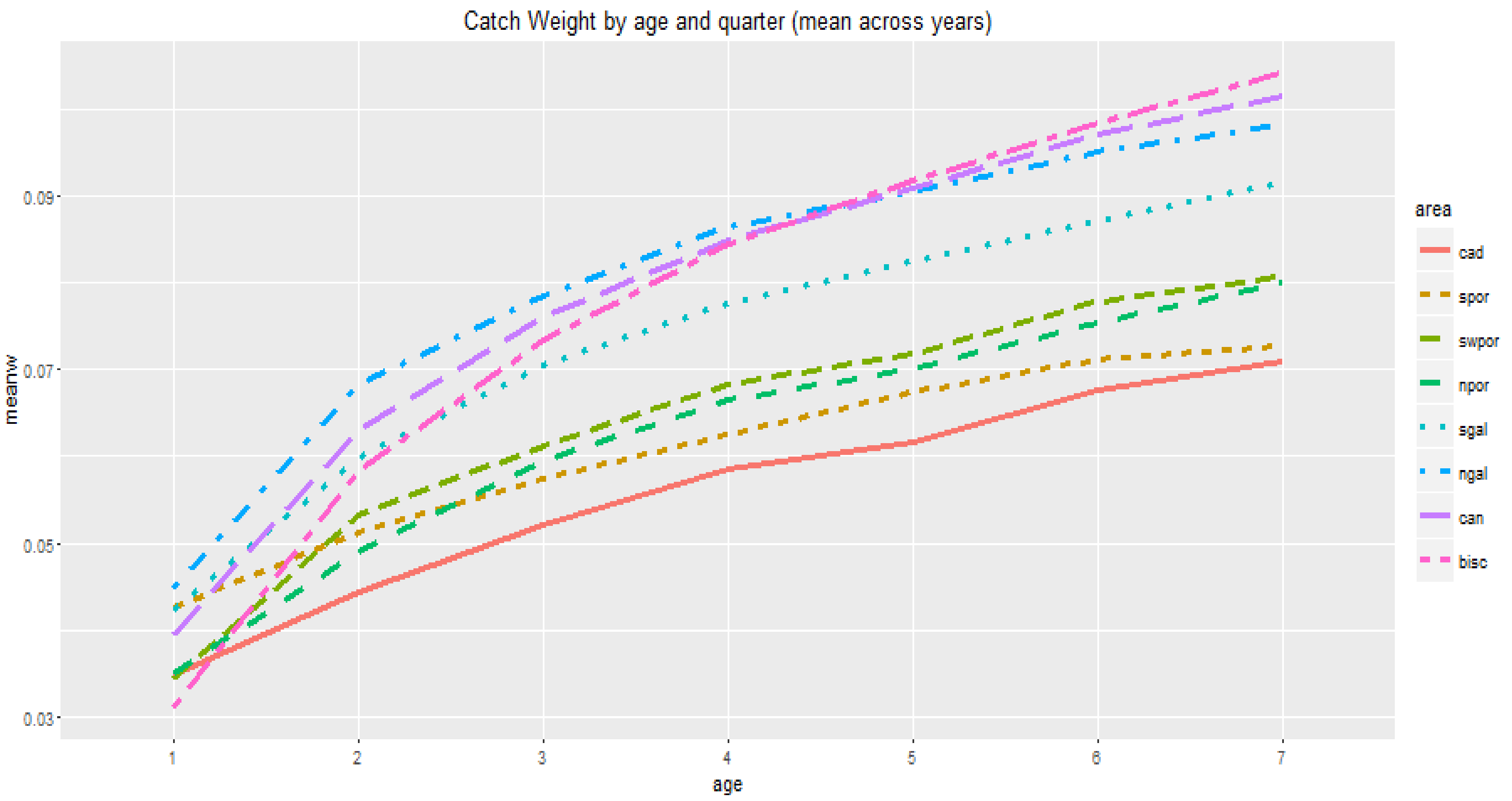
Survey data

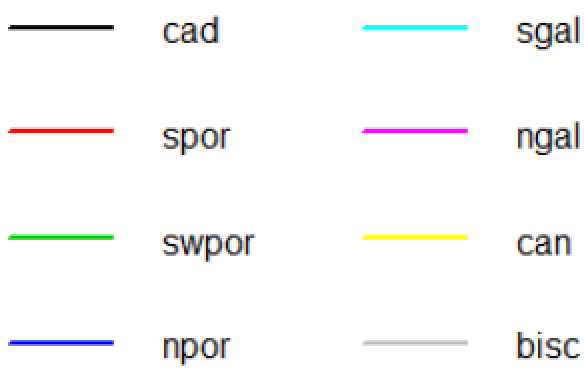

Survey Weight by age and quarter (mean across years)
1
0.100
0.075
0.050
0.025
W
2.5
5.0
7.5
10.0
12.5
age
area
bisc
cad
can
ecan
ngal
npor
sgal
spor
swpor
wcan

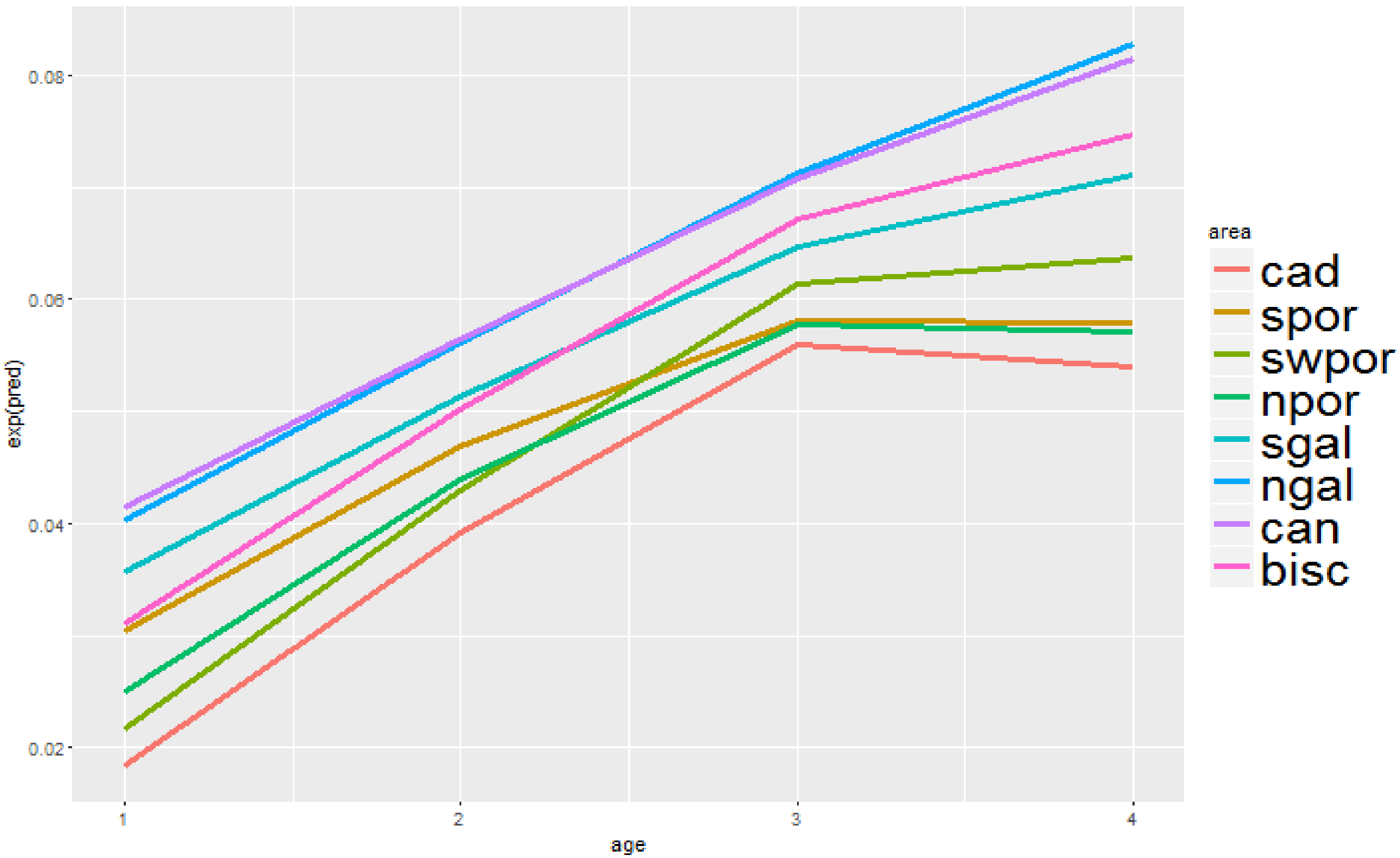
Survey data joined can



Catch data W

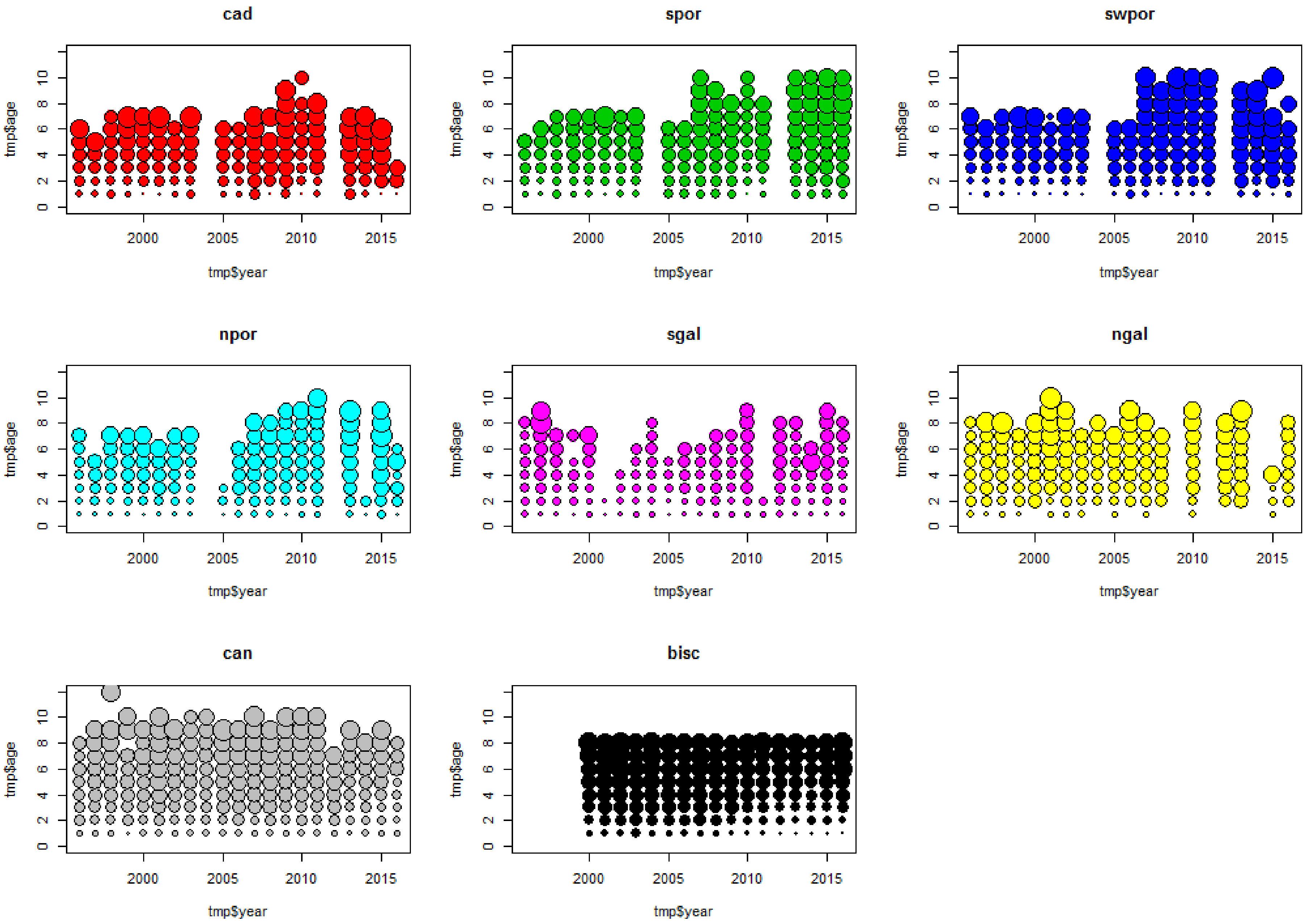

Catch Weight by age and quarter (mean across years)
meanw
0.03
0.05
0.07
0.09
age
1
2
3
4
5
6
7
area
cad
spor
swpor
npor
sgal
ngal
can
bisc


cad
spor
swpor
npor
sgal
ngal
can
bisc

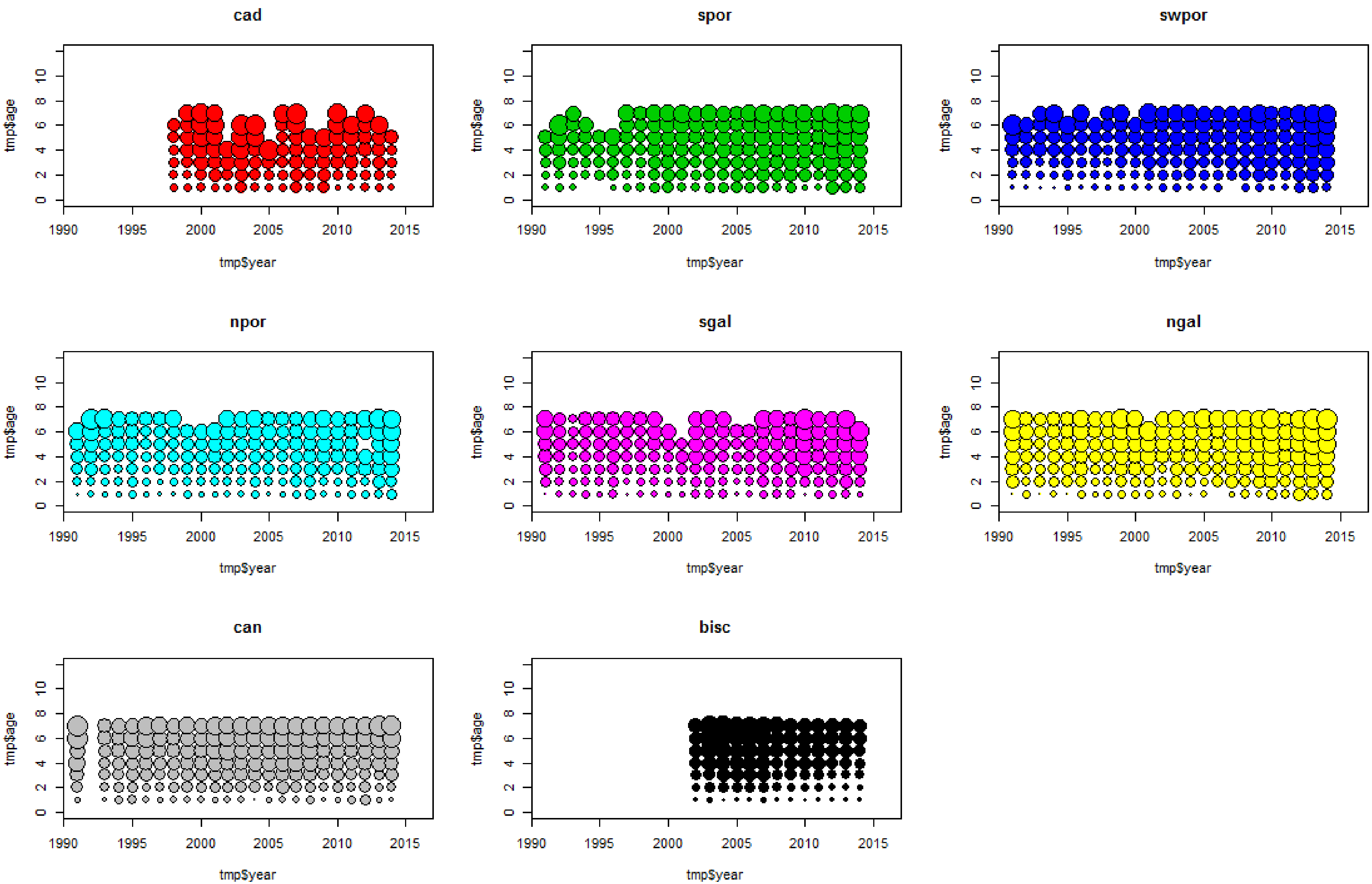


0.08
0.06
0.04
0.02
exp(pred)
1
2
3
4
age
area
cad
spor
swpor
npor
sgal
ngal
can
bisc

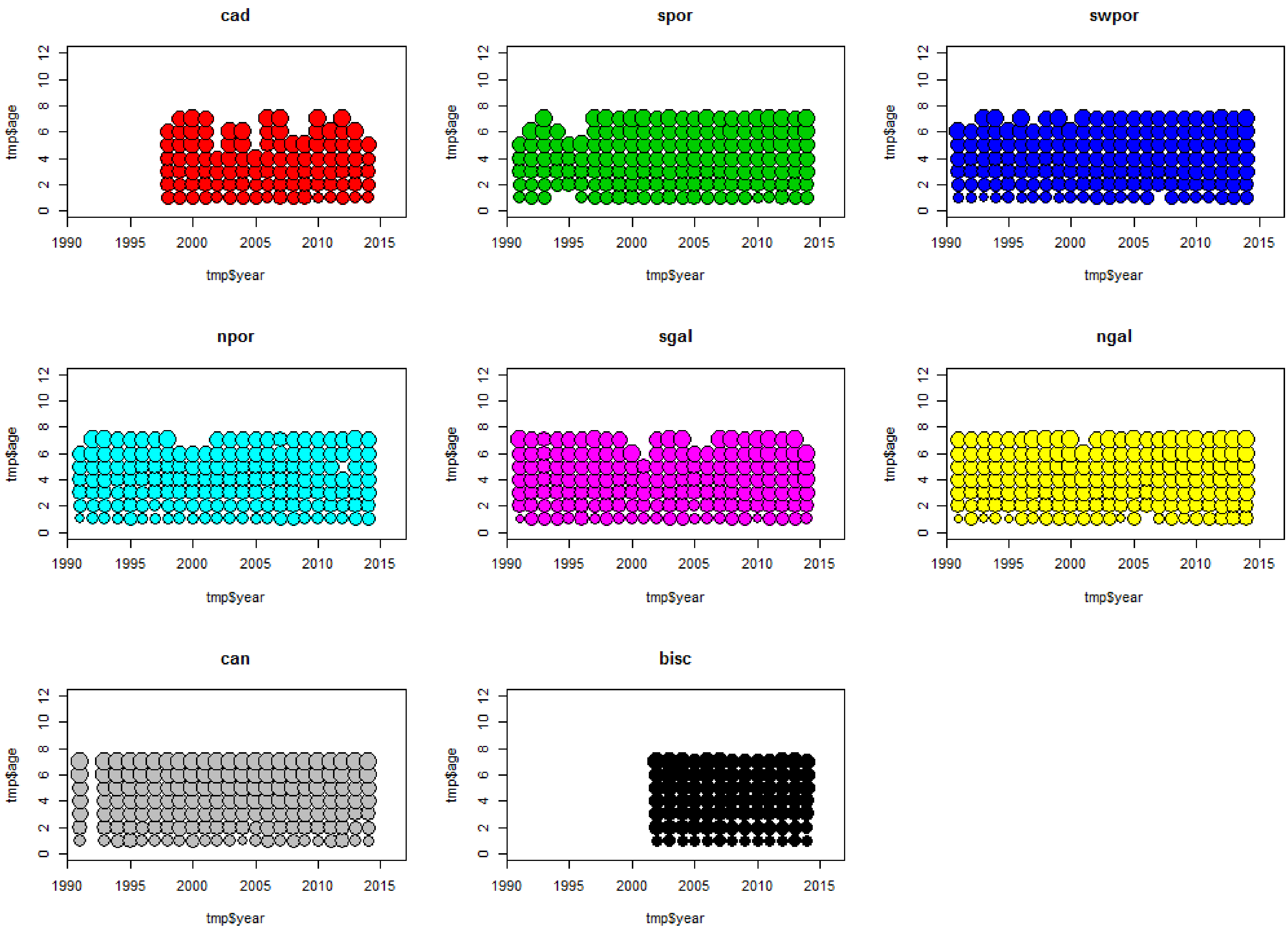
Survey W row data



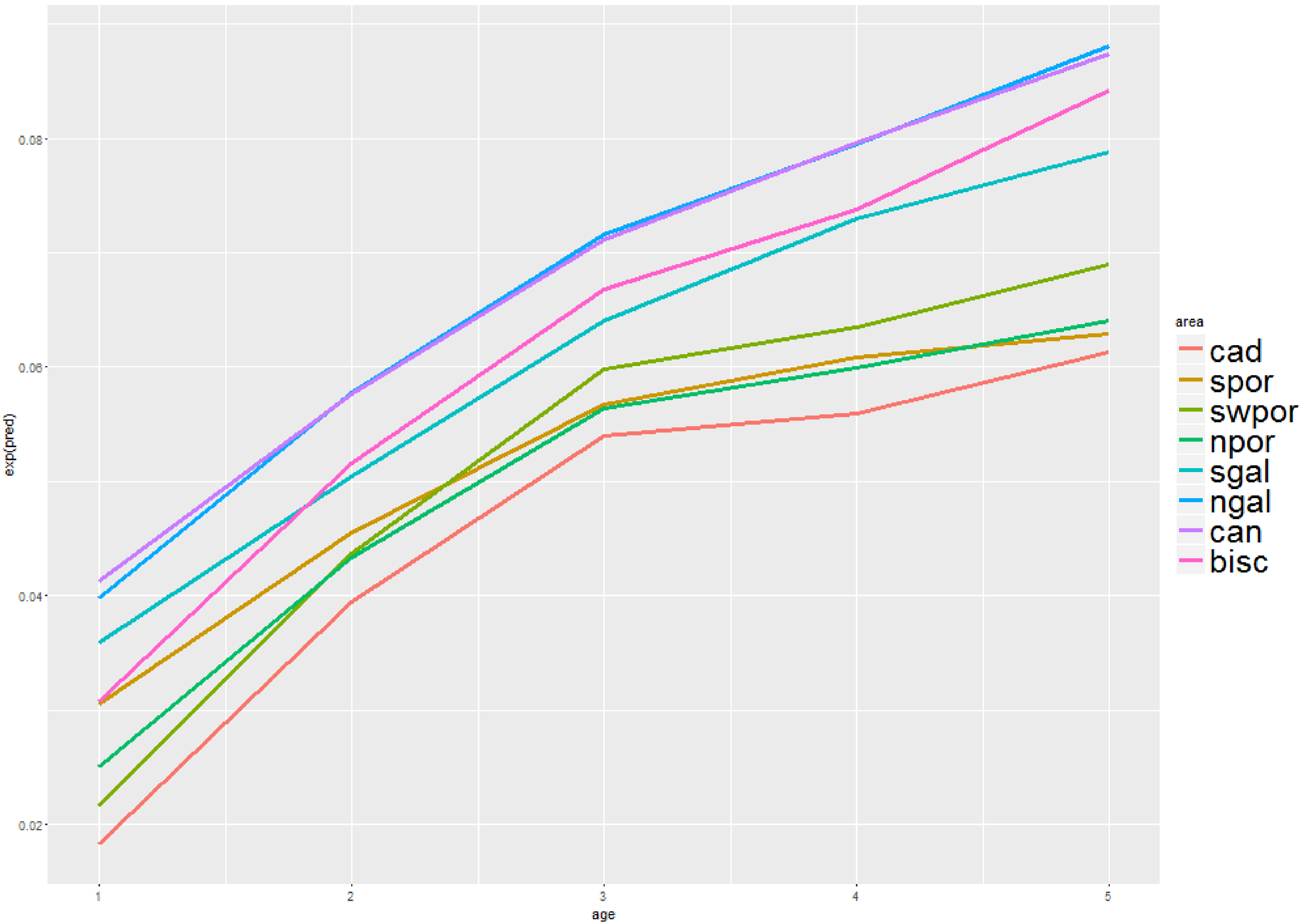
Catch W row data (quarter 2)



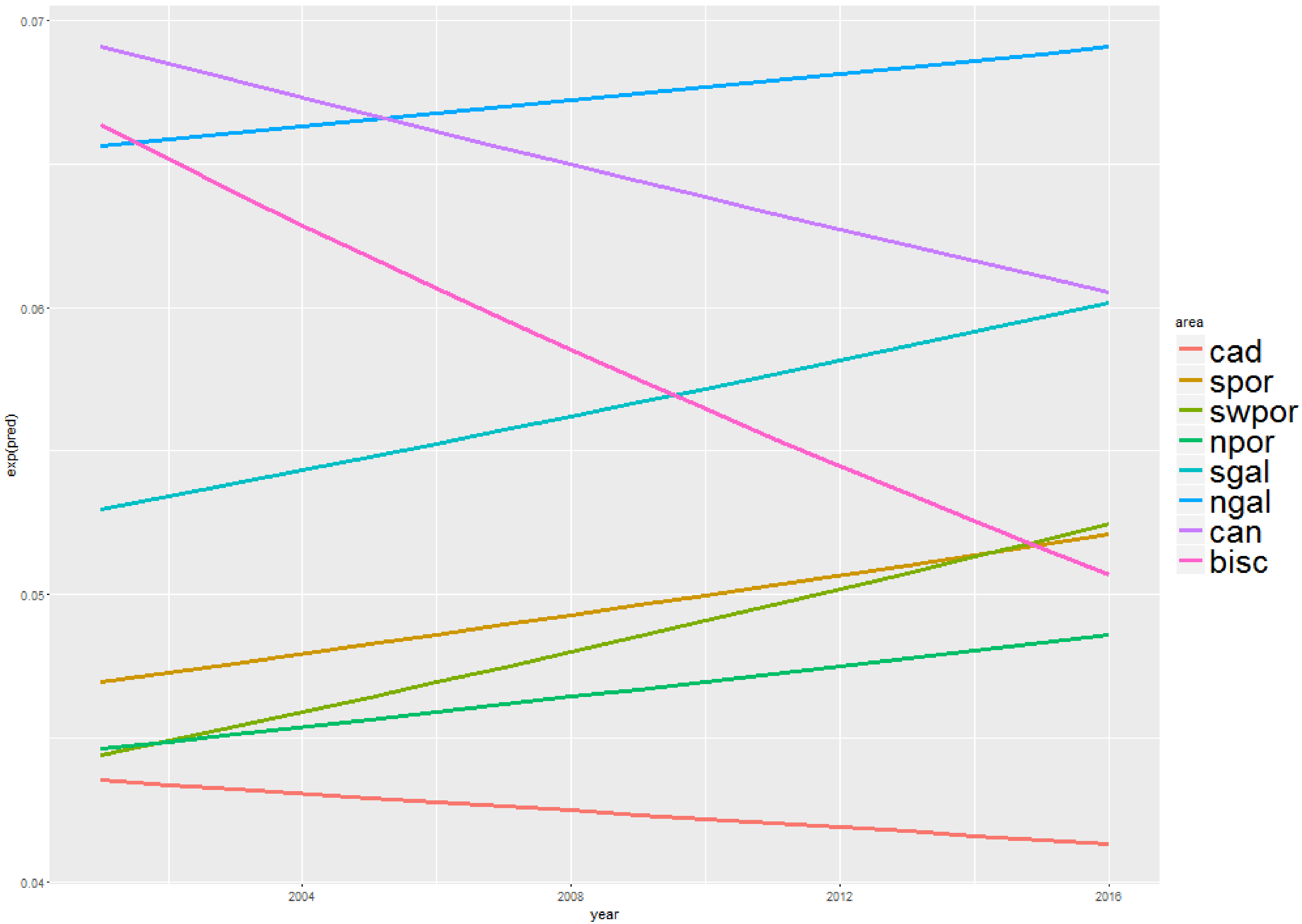
Catch Len row data (quarter 2)



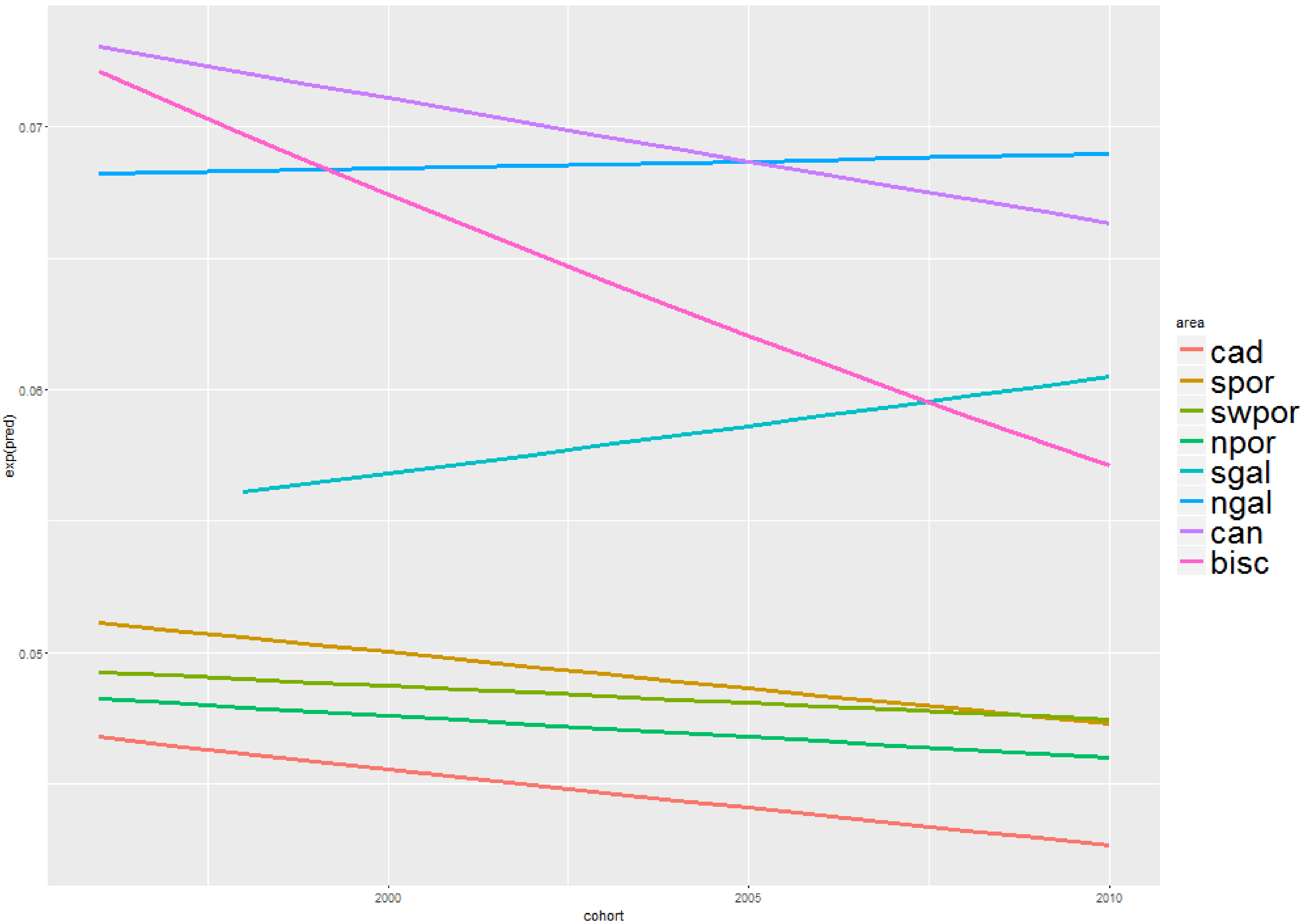
Survey W~age*area



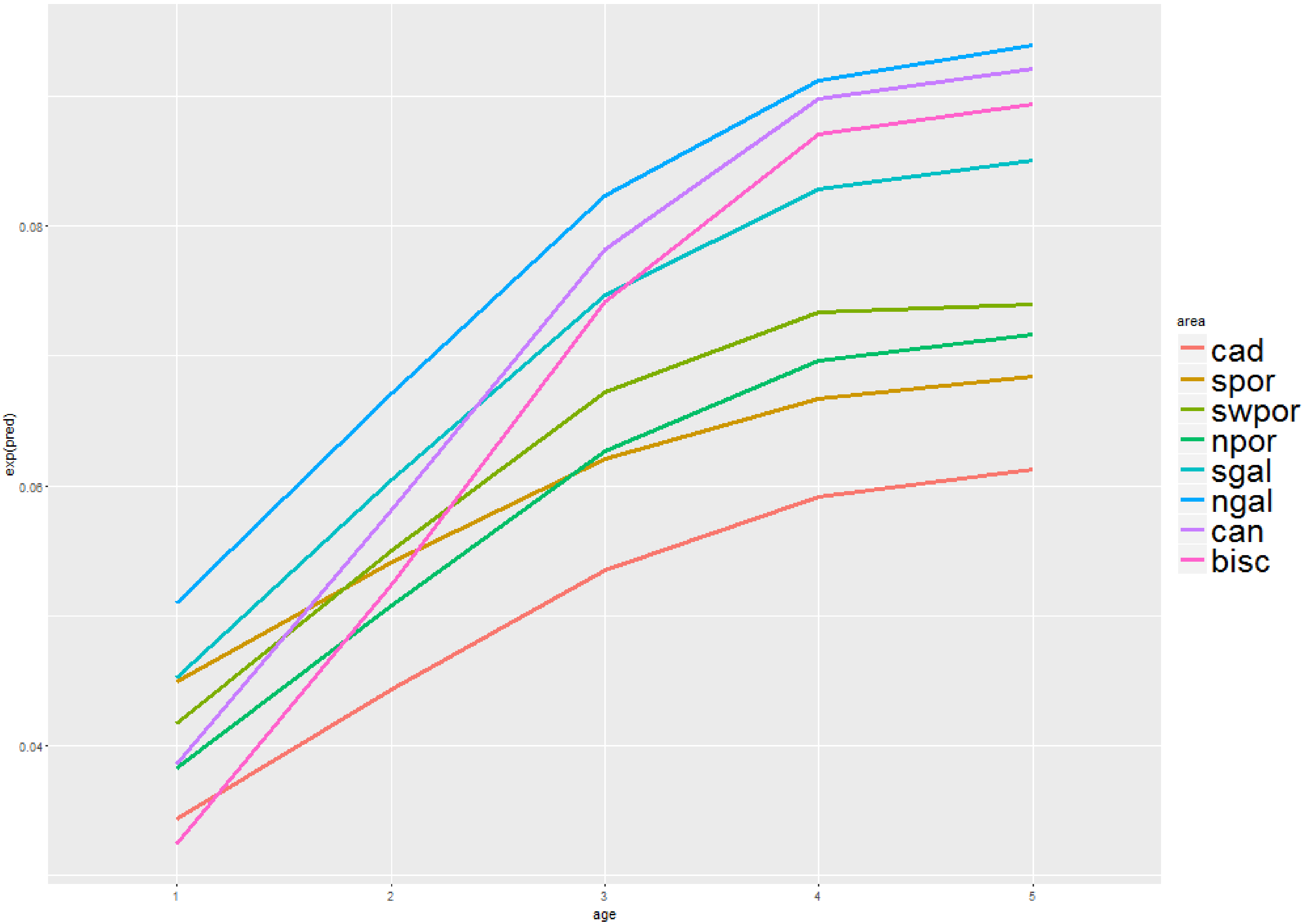
Survey W~year*area



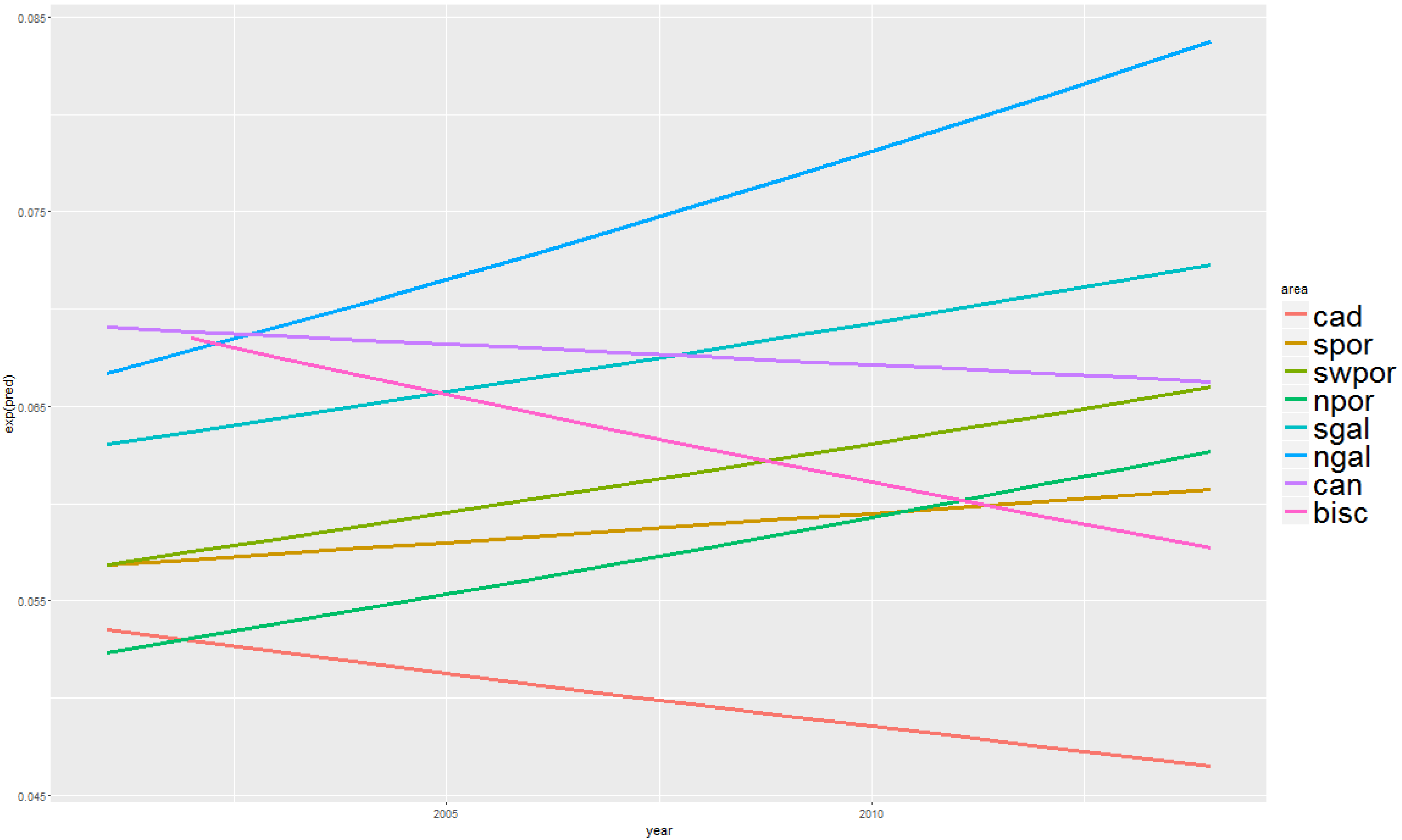
Survey W~cohort*area



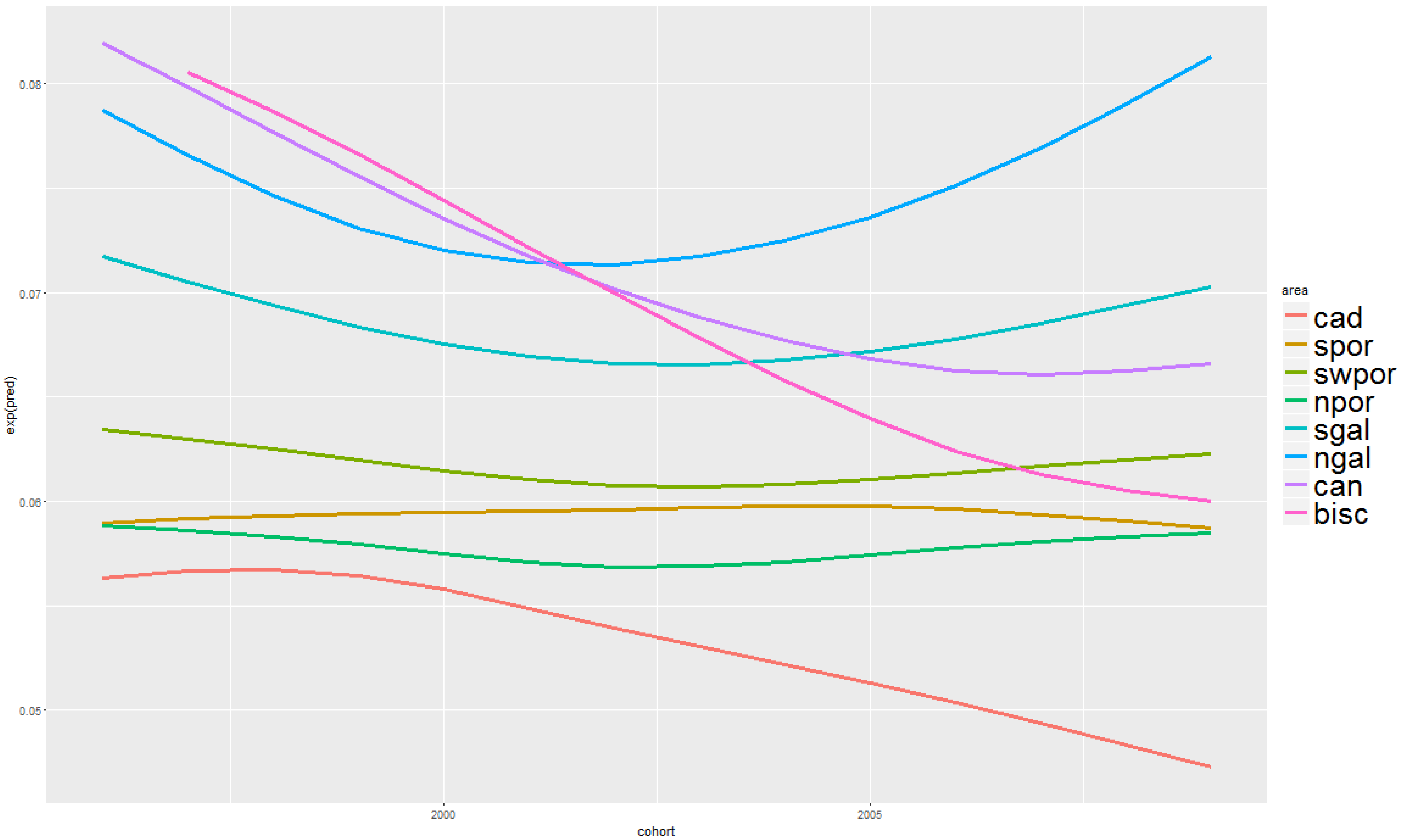
Catch W~age*area



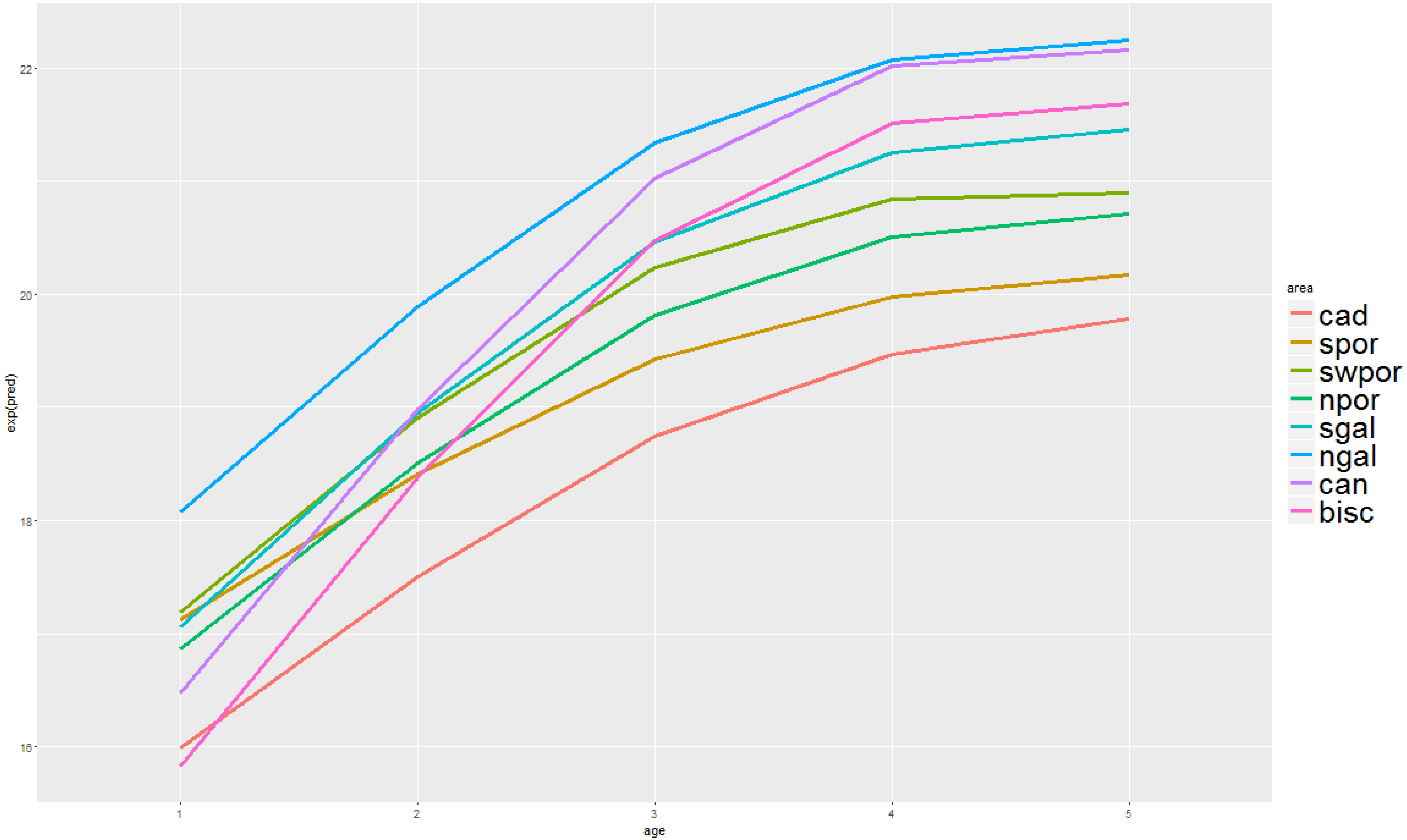
Catch W~year*area



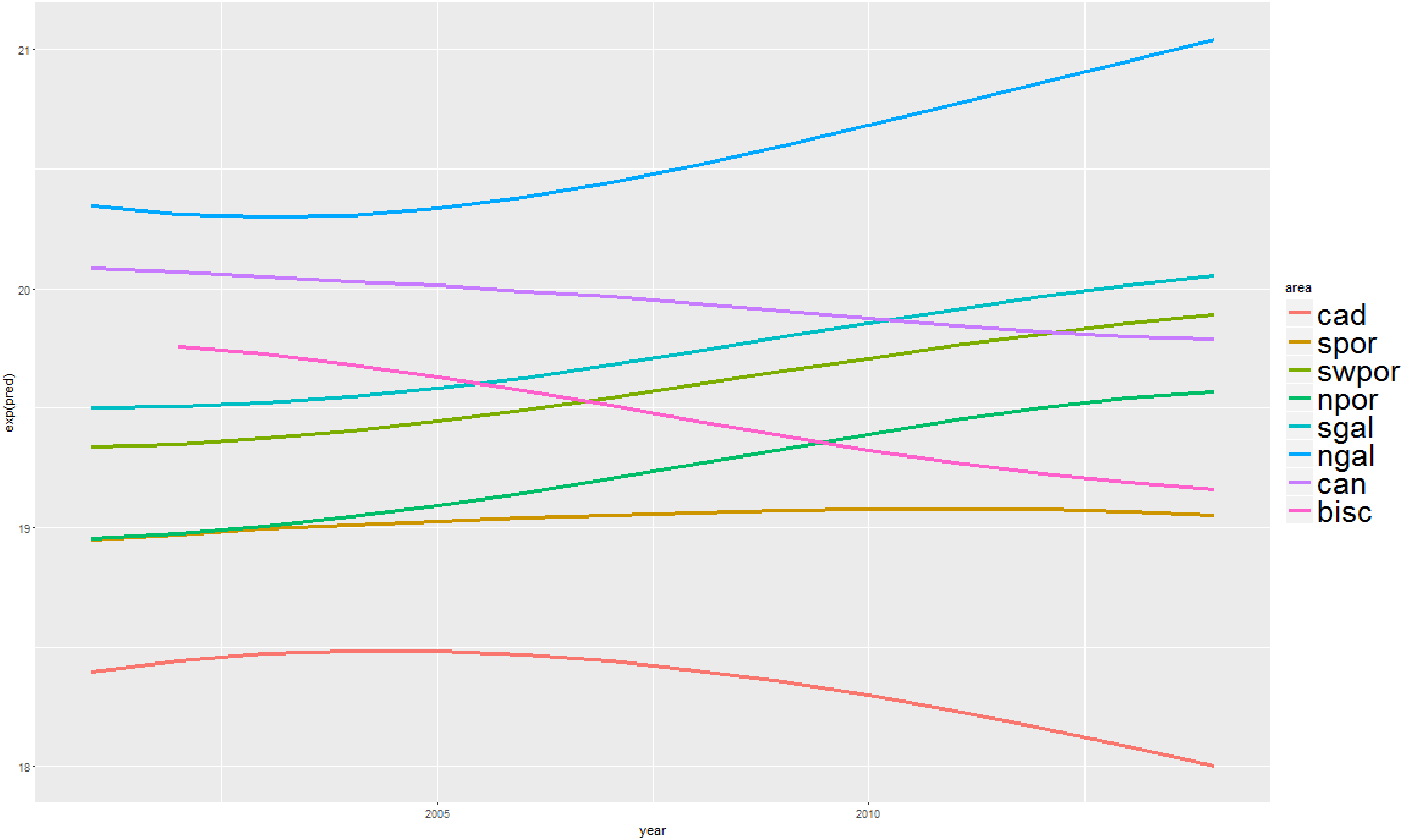
Catch W~cohort*area



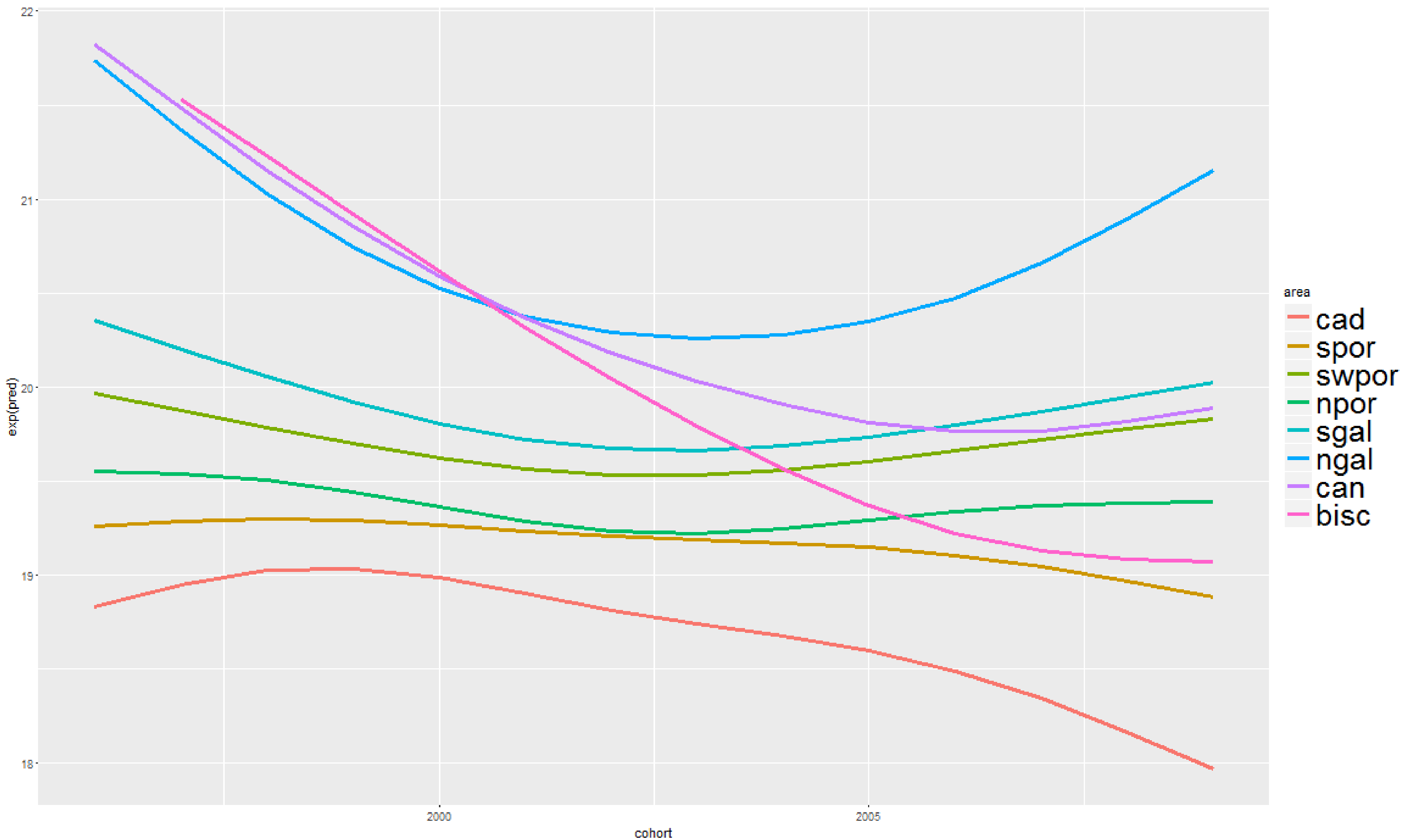
Catch L~age*area



Catch L~year*area



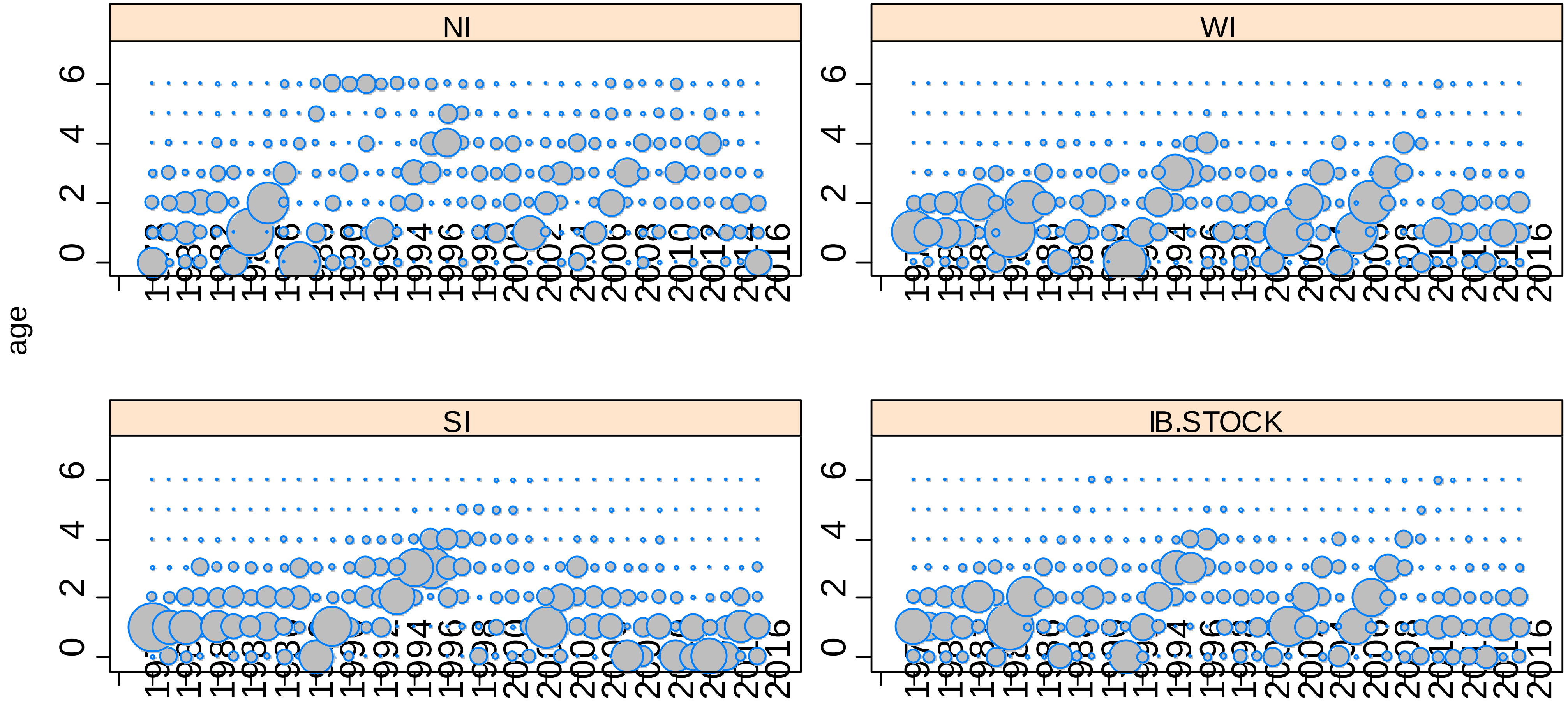
Catch L~cohort*area



WKSAR, 26-30 SEP 2016

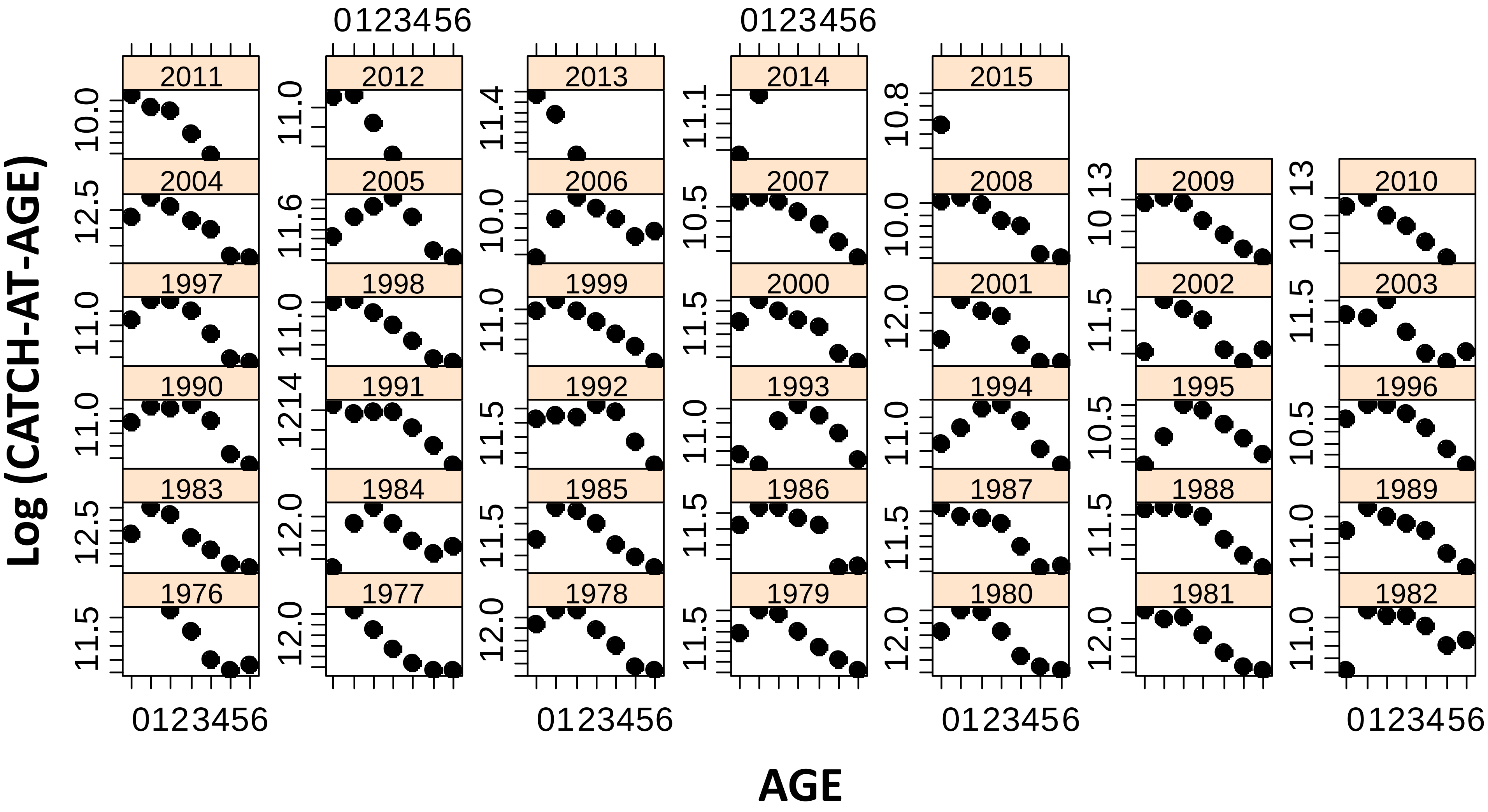
CATCH-AT-AGE DATA

IBERIAN SARDINE STOCK

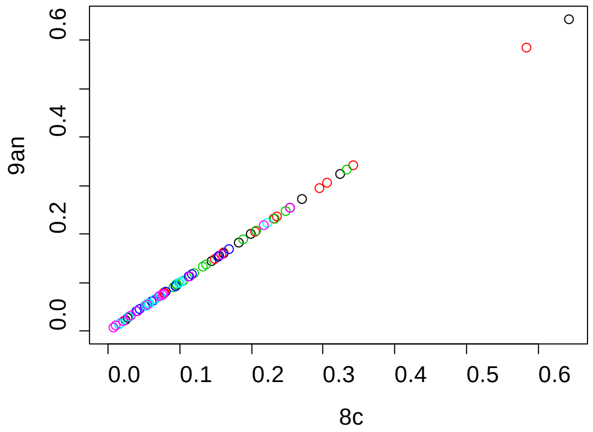


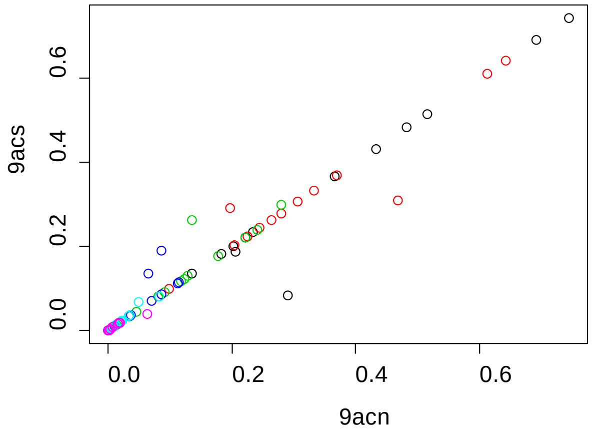
- NI-North Iberia= Cantabrian+North Galicia
- WI- South Galicia + West Portugal
- SI-Algarve + Cadiz

YEAR-CLASS CURVES – IBERIAN STOCK CATCHES-AT-AGE



AGE COMPOSITION OF CATCHES 1978 - 1990





(1) Length sampling started in 1986 and ALK sampling in 1990 in VIIIc-E

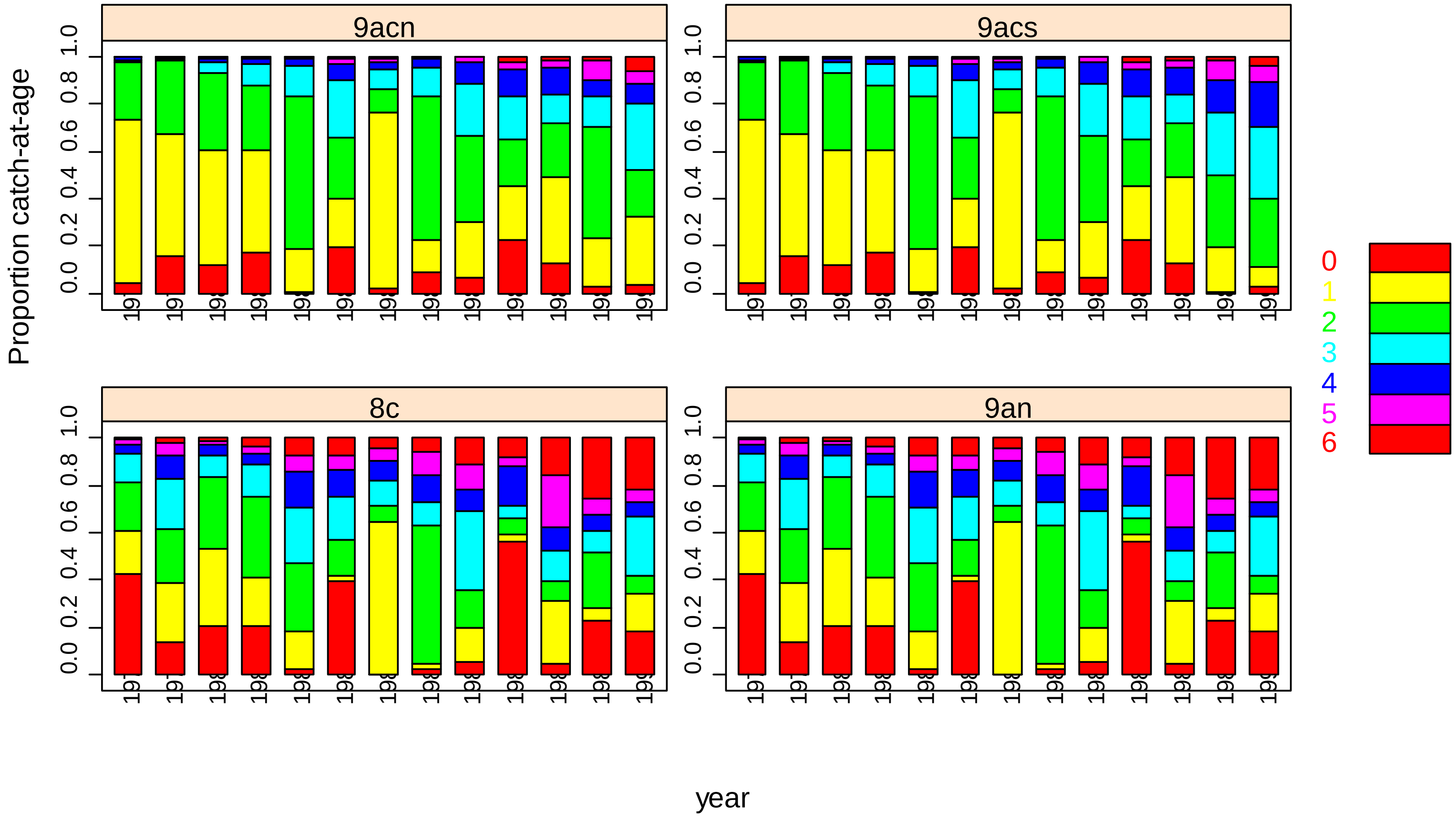
(2) Pooled ALK and Length Frequency for IXa-N and VIIIcW in 1978 – 1990

(3) Pooled ALK and Length Frequency for IXa-CN and IXa-CS in 1978 – 1990

(4) Catch sampling off Algarve moved from Olhão (close to the Gulf of Cadiz) to Portimão, a port on the western part of the area, in 1991; smaller sardine are generally distributed closer to the Gulf of Cadiz while larger sardine predominate in the western part of the area.

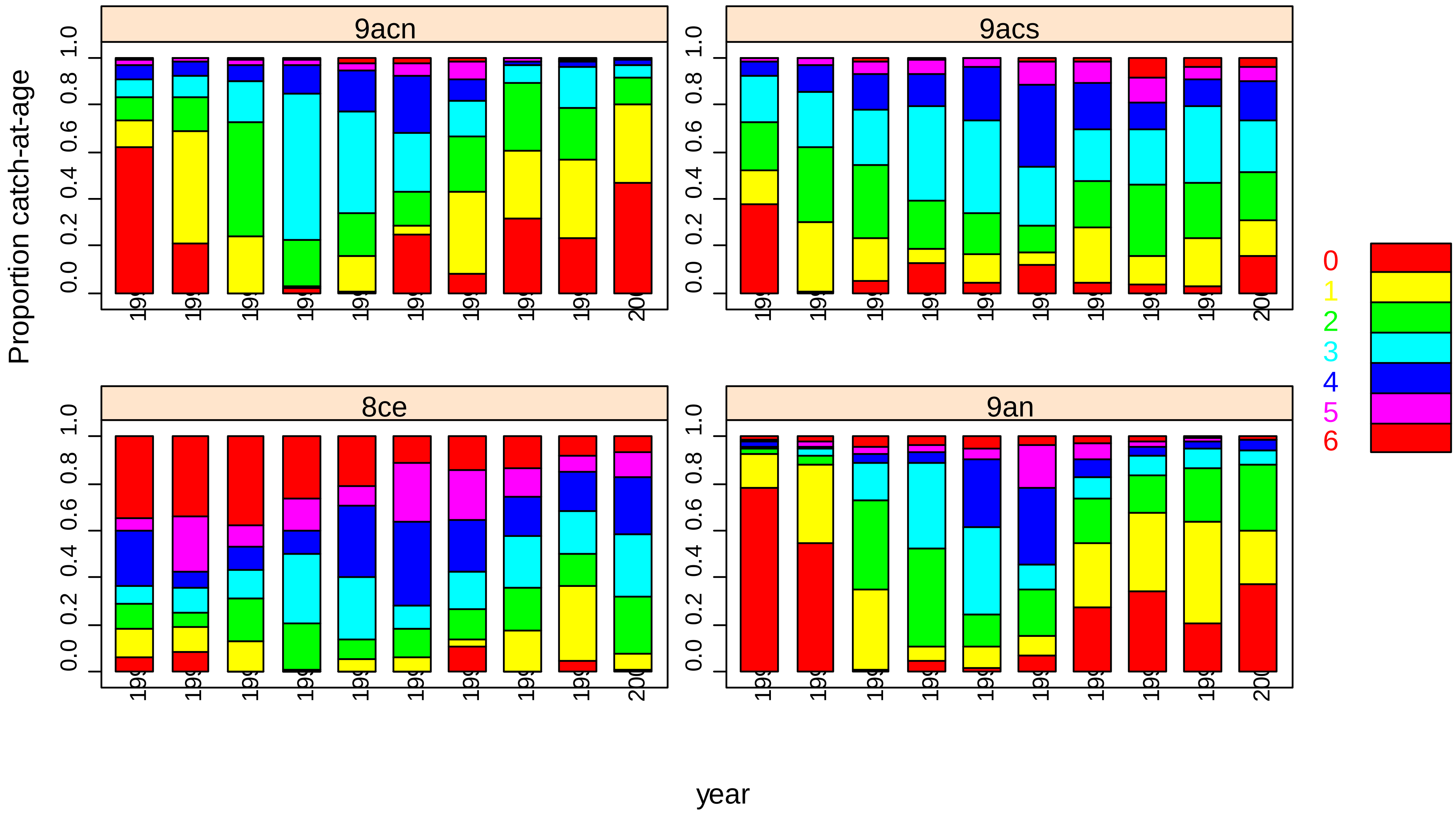
ICES, 1980. Rapport du Groupe de Travail pour l' évaluation des stocks de sardines dans les Divisions VIIIc et IXa. ICES Document C.M. 1980/H: 53, 41 pp.
ICES, 1992. Report of the Working Group on the assessment of Mackerel, Horse Mackerel, Sardine, and Anchovy. ICES Document C.M. 1992/Assess: 2, 204 pp.

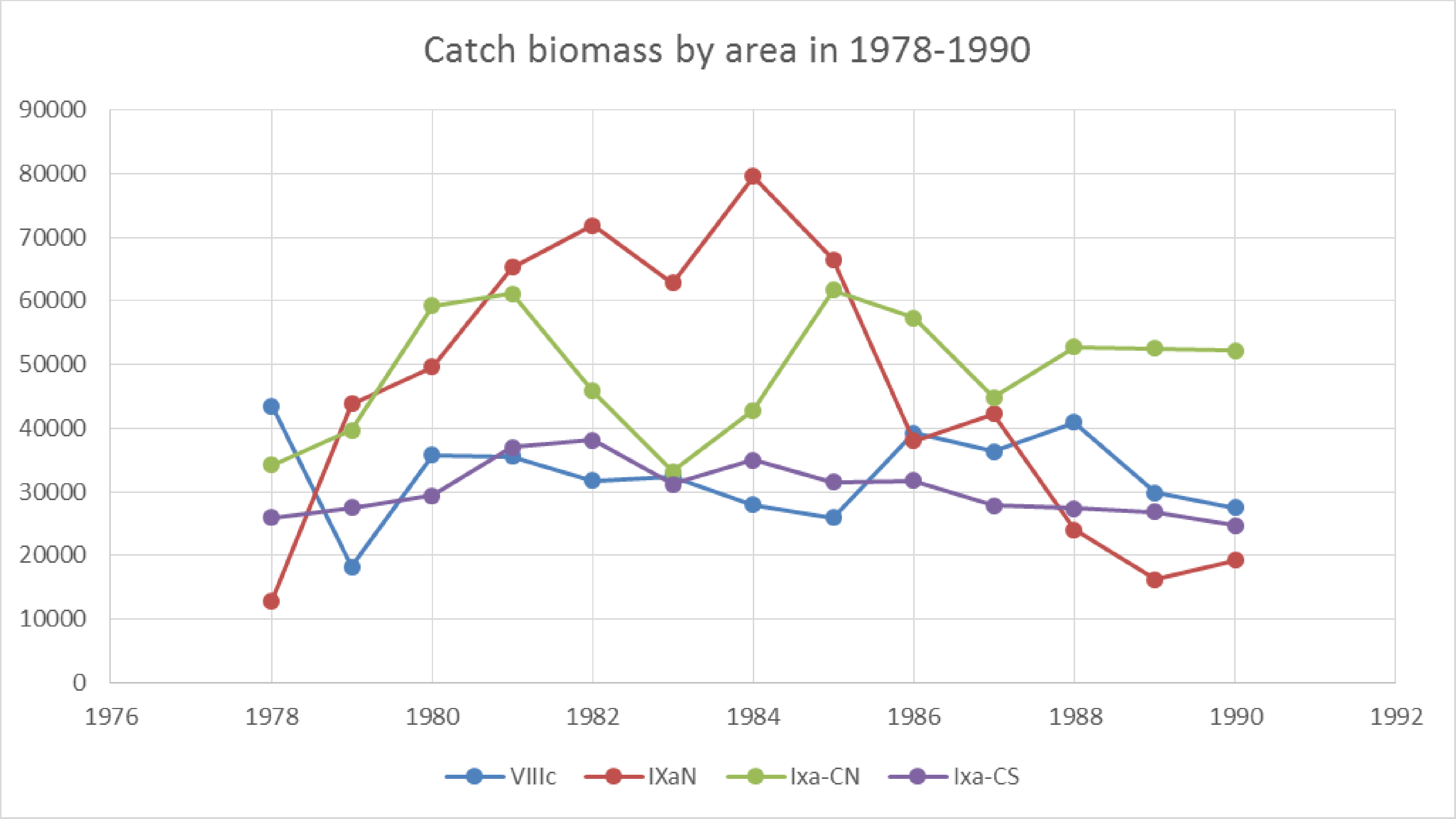
AGE COMPOSITION OF CATCHES 1978 - 1990



The same age composition in:
9acn and 9acs
8c and 9an

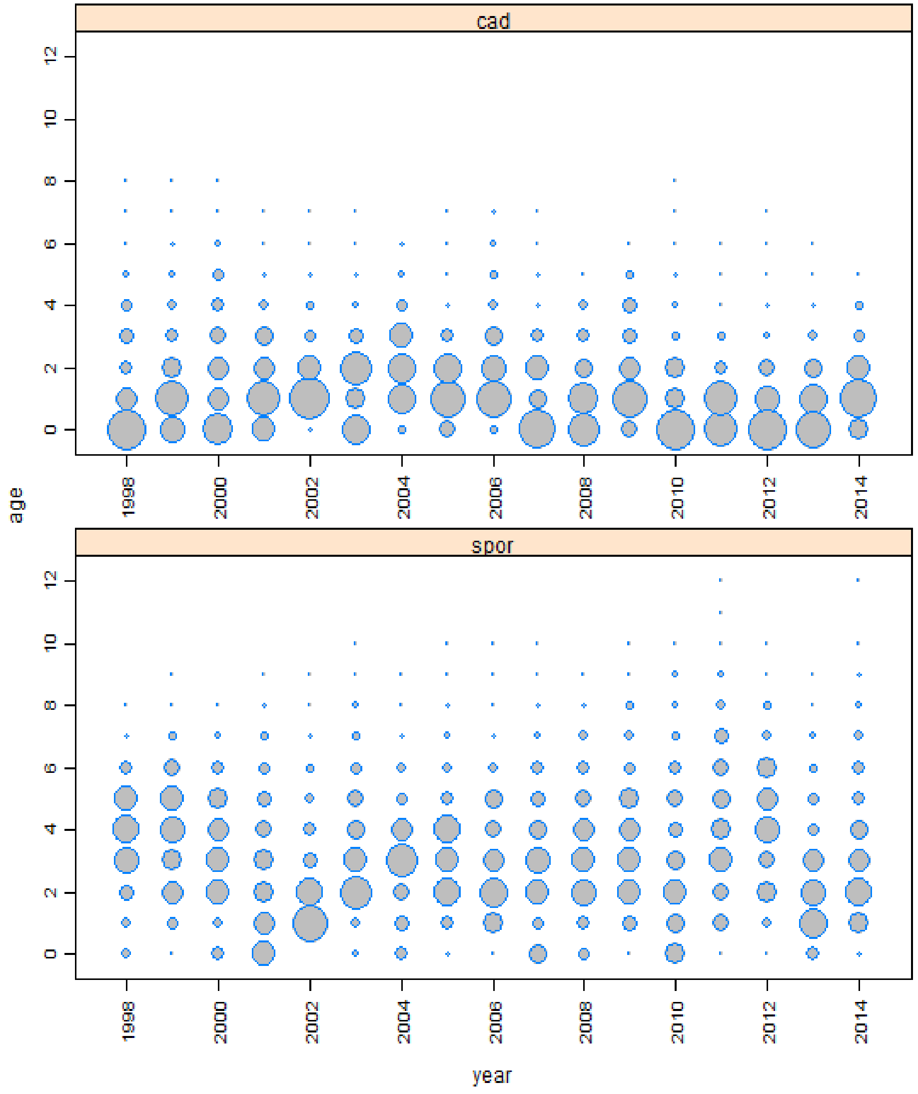
AGE COMPOSITION OF CATCHES 1991 - 2000

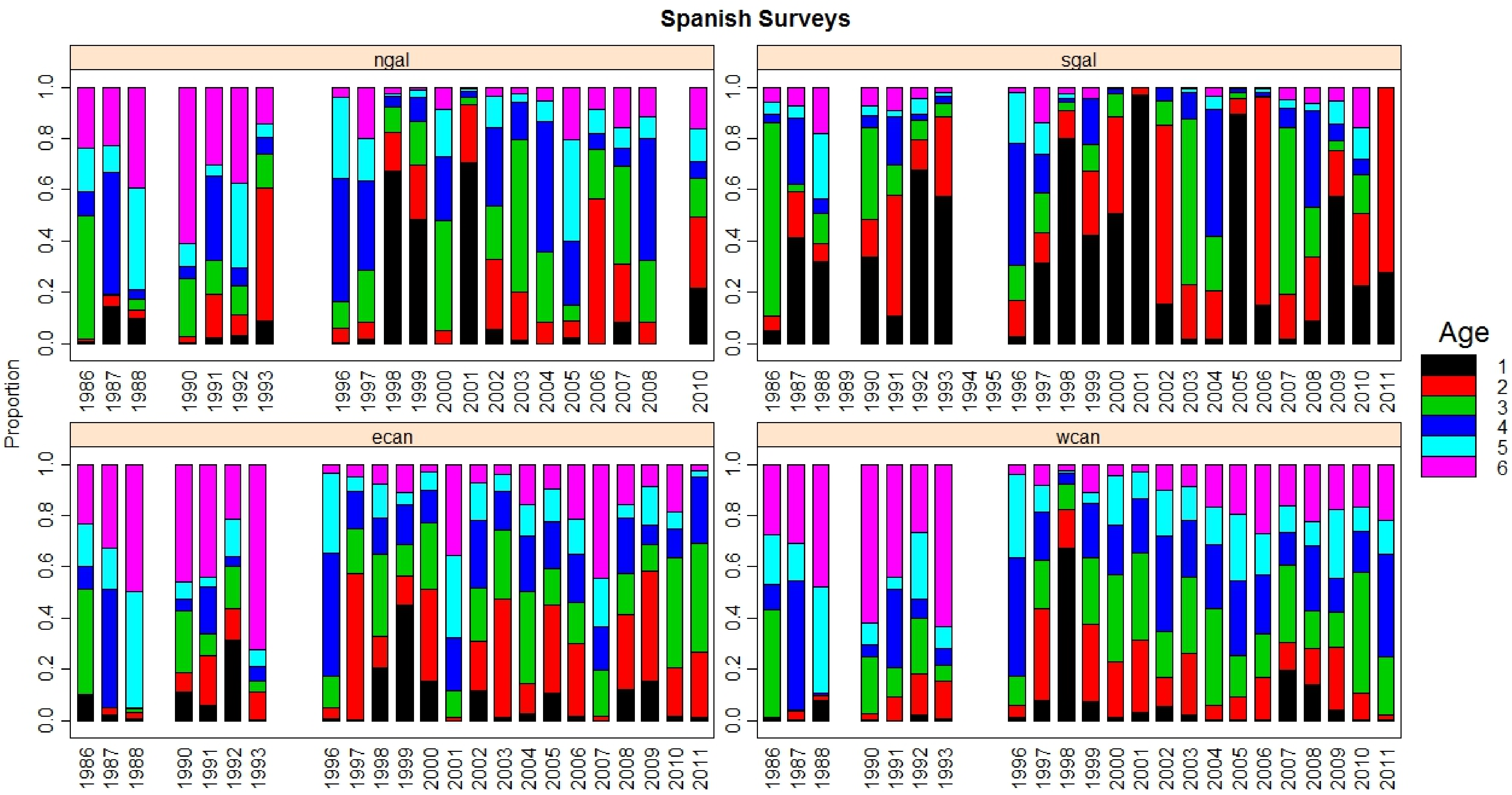



Catch biomass by area in 1978-1990
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1976
1978
1980
1982
1984
1986
1988
1990
1992
VIIIc
IXaN
Ixa-CN
Ixa-CS

CATCH SAMPLING IN CADIZ

- Length and age sampling started in 1998
- For 1991-1997 and before Cadiz landings were converted to catch-at-age using Algarve samples
- From 1991 to 1997, Cadiz landings were around 6% of total Iberian stock landings
- Algarve and Cadiz show substantially different age compositions
- No impact in stock assessment
- Could be improved with another type of “cooking”
- Could be excluded; increase catch-at-age uncertainty in the model for the period up to 1997?




Spanish Surveys
ngal
sgal
ecan
wcan
Proportion
Age
1
2
3
4
5
6

CONCLUSIONS

The age composition of catches is the only data used in the assessment to estimate the stock up to 1995 (surveys start in 1996)

The use of pooled length and age samples to estimate the age composition of catches jointly in recruitment and non-recruitment areas is biasing the assessment in 1978-1990

This bias is uncertain; to have a better perception of bias build a table with number of length samples and number of otoliths by region and year

The bias in age composition of catches due to Cadiz lack of sampling up to 1997 is small at the stock level

Weight-at-age and maturity-at-age data values are fixed in 1978 – 1989/1990

Suggestion: keep the start of the assessment in 1978 until we have a better

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Life history data

- Proportion of mature fish at age (maturity ogives)
- Mean weight at age

Sardine

Southern stock

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- **Spring acoustic surveys:**

Period 1996 – 2016 for areas 9a and 8c, 3 strata (N, W, S), annual
Individual data of length, weight, sex, macroscopic maturity stage, age (all fish for stratum N, not all fish with otoliths information and use of an ALK per survey for strata W and S)
Random sampling for stratum N, stratified sampling per length class for strata W and S,

- **DEPM surveys:**

Period 1997 – 2014 for areas 9a and 8c, 3 strata (N, W, S), triennial
Individual data of length, weight, sex, macroscopic maturity stage, microscopic maturity stage (only first 25-30 females per haul), age (not all fish with otoliths information, depending on the surveys)
Random sampling

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programa nacional de amostragem biológica

1914-2014 CENTENARIO INSTITUTO ESPAÑOL DE OCEANOGRAFÍA

DEPM data:

Males

Year	Stratum	Nind_WL	Nind_age	Nind_Mat
1997	N	142	88	142
1997	S	232	NA	232
1997	W	298	NA	298
1999	N	532	307	532
1999	S	536	296	536
1999	W	1125	300	1115
2002	N	1019	733	1019
2002	S	894	5	894
2002	W	1144	NA	1144
2005	N	721	418	721
2005	S	751	2	751
2005	W	1323	NA	1323
2008	N	759	541	759
2008	S	758	1	758
2008	W	1428	NA	1418
2011	N	334	158	334
2011	S	480	NA	479
2011	W	958	NA	949
2014	N	443	191	443
2014	S	355	191	355
2014	W	684	51	684

Females

1997	N	143	93	143
1997	S	268	NA	268
1997	W	502	NA	502
1999	N	463	339	463
1999	S	602	325	602
1999	W	1553	699	1550
2002	N	1004	757	1004
2002	S	1378	175	1378
2002	W	1492	146	1492
2005	N	712	362	712
2005	S	830	88	830
2005	W	1533	183	1533
2008	N	633	604	633
2008	S	741	648	741
2008	W	1720	1455	1494
2011	N	376	243	376
2011	S	451	207	451
2011	W	866	382	825
2014	N	238	208	238
2014	S	545	301	545
2014	W	805	71	621

Major issues:

- No age data for all fish sampled
- Most years in strata W/S only females with age
- How to extrapolate to population?

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Proportion of mature fish at age

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Last Benchmark assessment (WKPELA 2012):

Revision of Acoustic and DEPM maturity ogives

"WG considered that the DEPM maturity ogives should be used in the assessment. For years with no DEPM survey, 80% fish mature at age 1, corresponding approximately to the historical mean of DEPM ogives, is assumed. For simplicity, the ogive assumes 100% of fish are mature at age 2."

"Finally, the choice of the ogive has become less critical in the present assessment than in earlier assessments since the WG agreed to use B1+ (Biomass of age 1 and older) as the index of stock size and for the identification of reference points."

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Issues for proportion of mature at age...

... Which population abundance indices use to raise proportion of mature fish at length?

- **Numbers estimated from spring acoustic surveys the same year? But DEPM and Acoustic surveys often separated by 1-2 months lag in strata W and S (variations of body condition at end winter-beginning spring)**
- **Egg production estimates for each stratum? But Ptot good proxy of population abundance?**
- **The SSB estimates per stratum from the DEPM survey?**

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... Age data?

- Use only fish with otoliths information? But likely not representative
- Which ALKs use to complete age data?
  - From DEPM survey? Applied to all fish? Applied only to fish without age information
  - From spring acoustic survey of the same year? But often 1-2 months lag between surveys
- For strata W and S, most years, only age data for females. Assume similar growth pattern for both sexes?

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Mean weight at age

Instituto Português do Mar e da Atmosfera (IPMA)

Instituto Español de Oceanografía (IEO)

Workshop on Atlantic Sardine (WKSAR),
Lisboa, 26-30 September 2016

Last revision: Silva et al. 2006 (WGMHSA):

Weight-at-age calculated from biological samples from Portuguese and Spanish acoustic surveys and compared to estimates obtained from catch samples. Since then, input for assessment of weight-at-age from Spring Acoustic surveys.

Methodology:

- **Power models fitted to weight-at-length biological data**
- **Predicted values raised to population numbers with length frequency distributions (from the acoustic estimation) and ALKs, for each year and stratum (N; W, S)**

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But if, since 2012, maturity ogives provided by DEPM surveys, ...

... Maybe mean weights at age should also be obtained from the same surveys.

... But DEPM surveys only every three years

- **Which data to use between years? Cf. Inter-annual variation of weight-at-age**

... Similar issues as for maturity ogives :

And which population abundance indices use to raise weight at length values?

- **Numbers estimated from spring acoustic surveys the same year? But DEPM and Acoustic surveys often separated by 1-2 months lag in strata W and S (variations of body condition at end winter-beginning spring)**

- **Egg production estimates for each stratum? But Ptot good proxy of population abundance?**

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Workshop on Atlantic Sardine (WKSAR), Lisboa, 26-30 September 2016

- The SSB estimates per stratum from the DEPM survey?

... Age data?

- Use only fish with otoliths information? But likely not representative
- Which ALKs use to complete age data?
  - From DEPM survey? Applied to all fish? Applied only to fish without age information
  - From spring acoustic survey of the same year? But often 1-2 months lag between surveys
- For strata W and S, most years, only age data for females. Assume similar growth pattern for both sexes?

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Oceanographic conditions: connectivity through eggs, larvae, adults

Northern limit (Temperature-dependent)

Shelf distribution; separation in the NW corner of Iberia, separating Canary current upwelling ecosystem and Biscay/North Atlantic current

Important features for small-scale mixing: Upwelling (advective loss), Eddies (retention & advection), frontal boundaries, river plumes, local topography

Southern limit (Abrupt, related to sub-tropical front and dependent of upwelling lowering temp. to suitable conditions)

"Semi-permeable" boundary: Off Galicia (Galician front, extension of IPC and advection of upwelling filament)

"Semi-permeable" boundary: Combination of coastal deflection of the Azores current, flow isolation in the Bay of Cadiz and interruption of latitudinal flow due to Mediterranean inflow. Mesoscale activity promoting exchange with Africa (Oliveira & Stratoudakis).

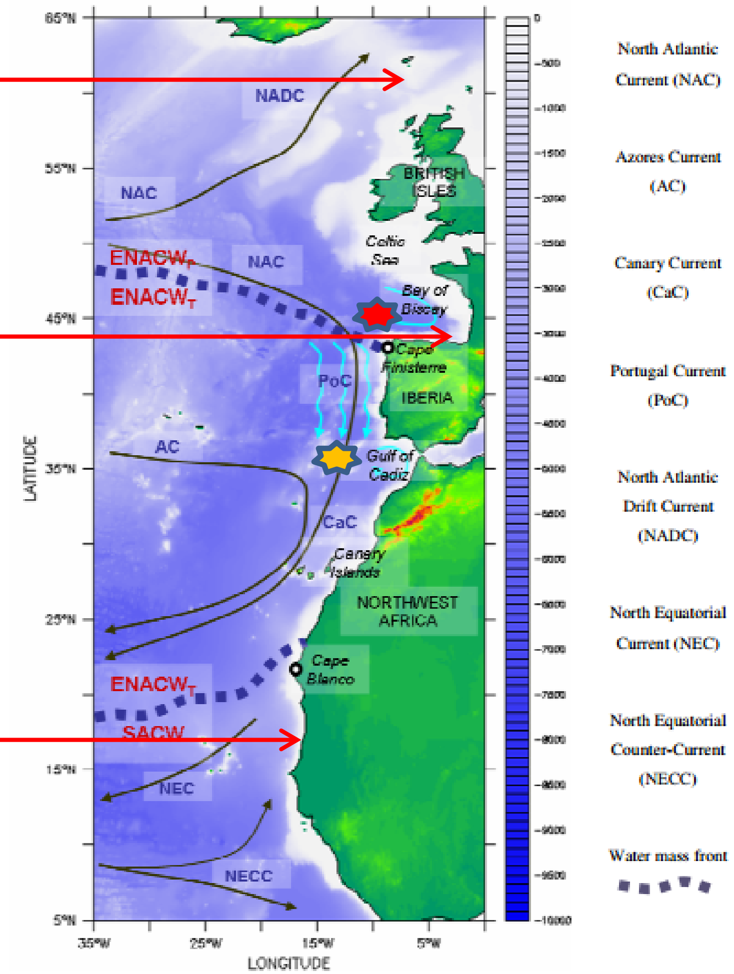


Figure 1. The eastern North Atlantic region. The principal water masses are eastern North Atlantic Central Water of sub-polar ($ENACW_P$) and sub-tropical ($ENACW_T$) origins, and South Atlantic Central Water (SACW). The main large-scale surface currents are the North Atlantic Current (NAC), the Azores Current (AC), the Canary Current (CaC) and the Portugal Current (PoC). Also shown are the North Atlantic Drift Current (NADC), the North Equatorial Current (NEC) and the North Equatorial Counter-Current (NECC). The general circulation of the Bay of Biscay and the Gulf of Cadiz are indicated.

There are seasonal or weaker boundaries related to river plumes (English Channel and SE Biscay, Canyons, Capes, Upwelling.

Evan et al. 2006
SARDYN

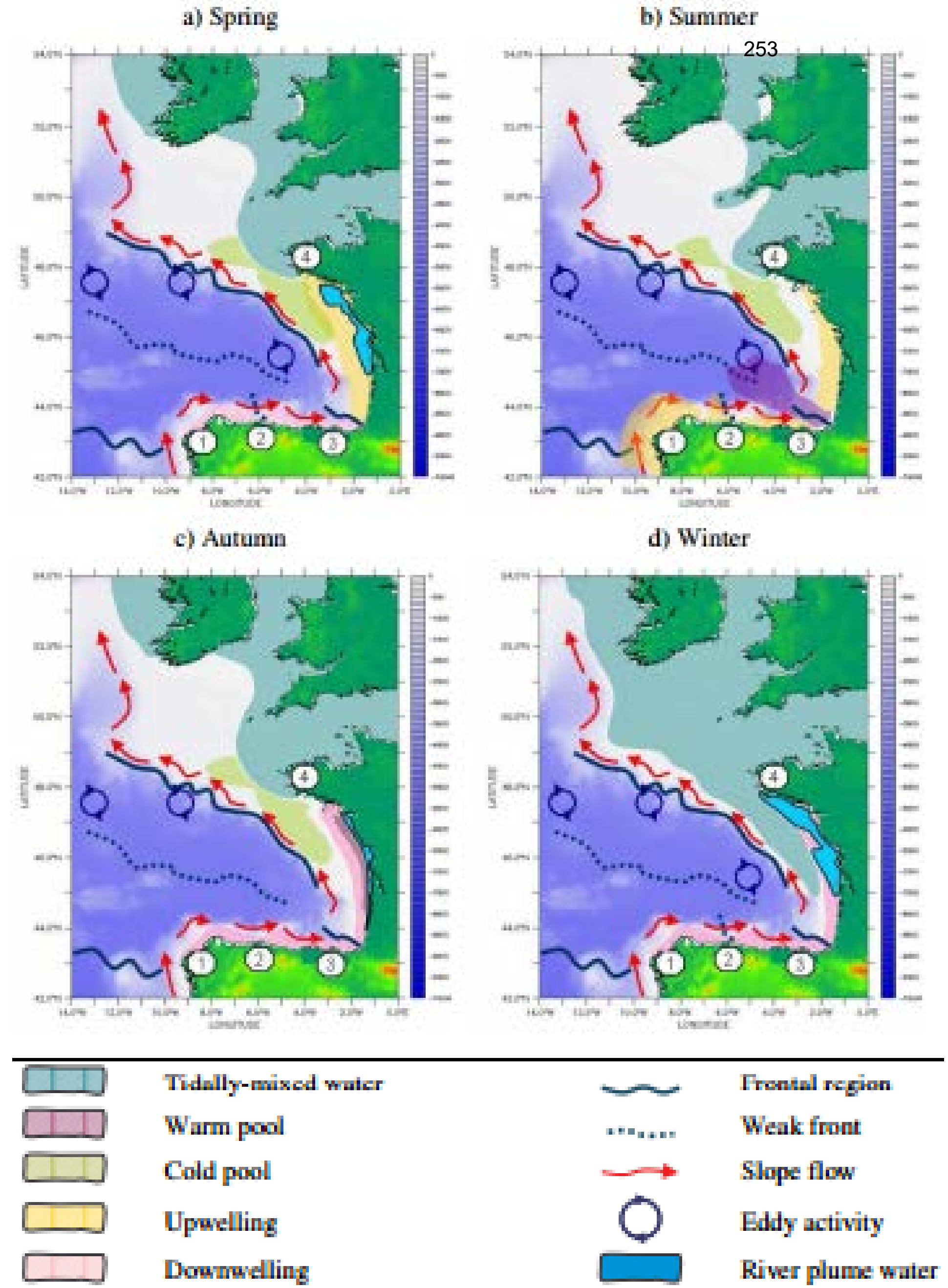
CELTIC SEA AND BAY OF BISCAY

Celtic Sea

Strong seasonality of temperature.
Strong persistent southwesterly winds.
Low river inflow.
Persistent poleward flowing current.
Porcupine bank is responsible for an anticyclonic circulation that promotes retention and productivity.

Bay of Biscay

Complex topography influences circulation.
Water masses in the upper layers (100-600 m): Eastern North Atlantic Central Water (ENACWP) of subpolar origin.
Permanent front at Cap Breton Canyon,
Permanent but weak thermal front between 44- 47°N and Galician Front.
At Cape Finisterre (NW tip of Iberia) there is a sharp, deep (~200 m) water mass front (<u>Galician Front</u>) separating the ENACWP from warmer, saltier ENACWT (sub-tropical origin) to the south.
Central water with weak anticyclonic eddies.
Weak geostrophic currents in the surface (1-2cm s-1).
Poleward currents in the slope.
Poleward winter flow of Gironde and Loire plumes.
Spring = downwelling
Presence of buoyant plumes.



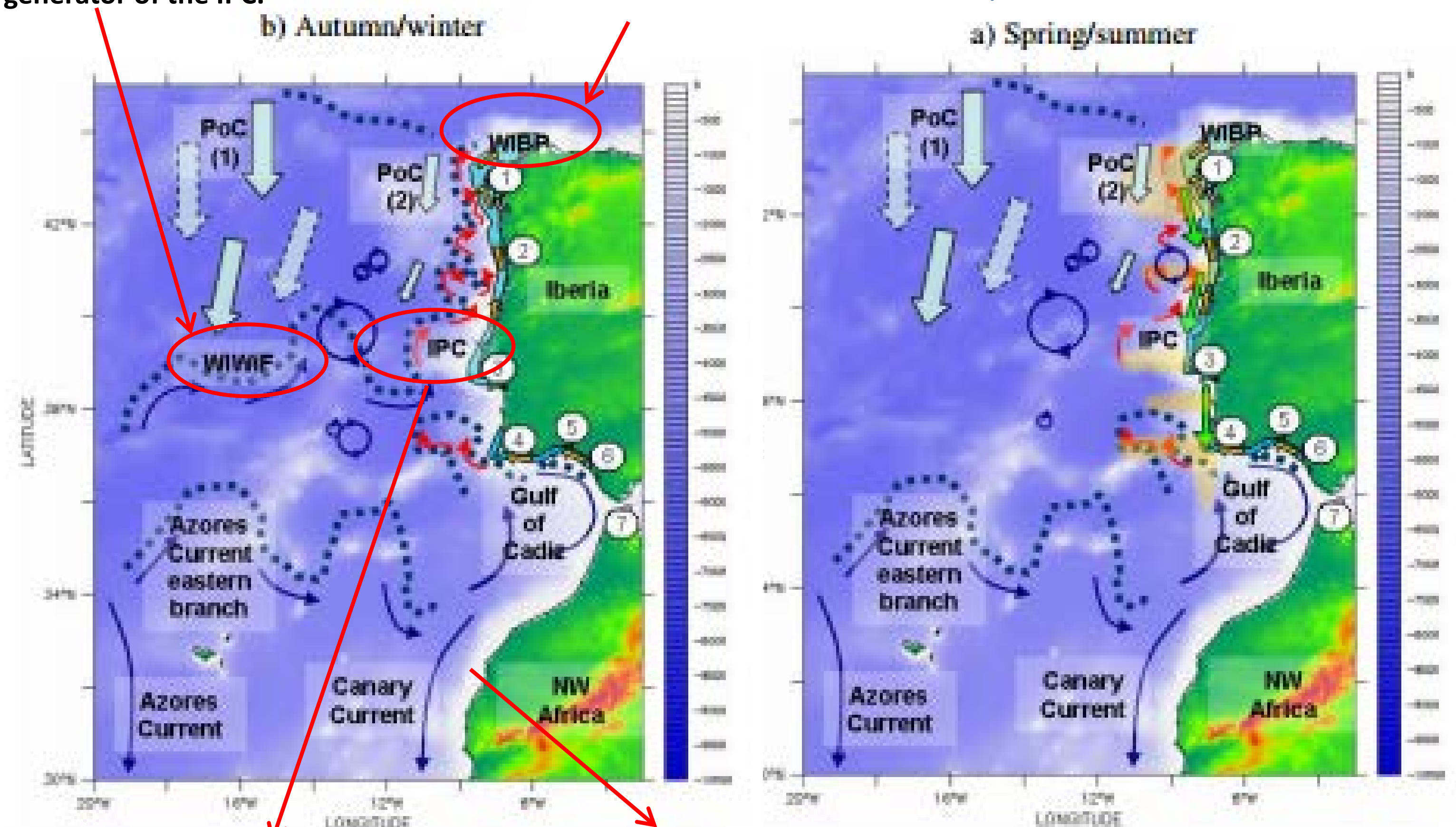
1) Cape Finisterre; 2) Cape Peñas; 3) Cape Matxitxako; 4) Ushant

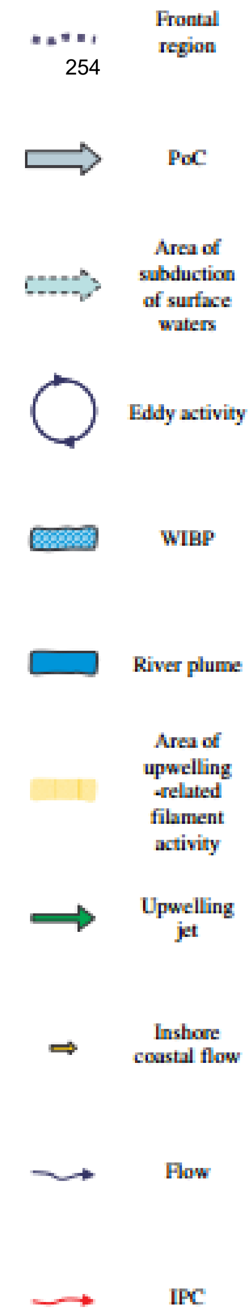
Evan et al. 2006

WESTERN AND SOUTHERN IBERIA

Western Iberia Winter Front (warm and salty water): flowing eastward is the main generator of the IPC.

Western Iberia Buoyant Plume: year-round, from NW Portugal to Rias Baixas: low salinity, nutrient rich (rivers).





Iberian Poleward Current: enhancement of productivity and retention: Garcia-Garcia (2016) relates its intensity to faster larvae growth.

Africa has permanent equatorward winds that favour upwelling while at W Iberia winds reverse seasonally (poleward during autumn/winter)

Evan et al. 2006

1) Cape Finisterre; 2) Douro River; 3) Cabo da Roca; Cape S. Vicente; 5) Guadalquivir River; 6) Gibraltar Strait

Western Iberia Buoyant Plume: year-round, from NW Portugal to Rias Baixas: low salinity, nutrient rich (rivers) increases upw stratification and creates inshore front and northward transport: vertical retention area for larvae (Santos et al. 2004)

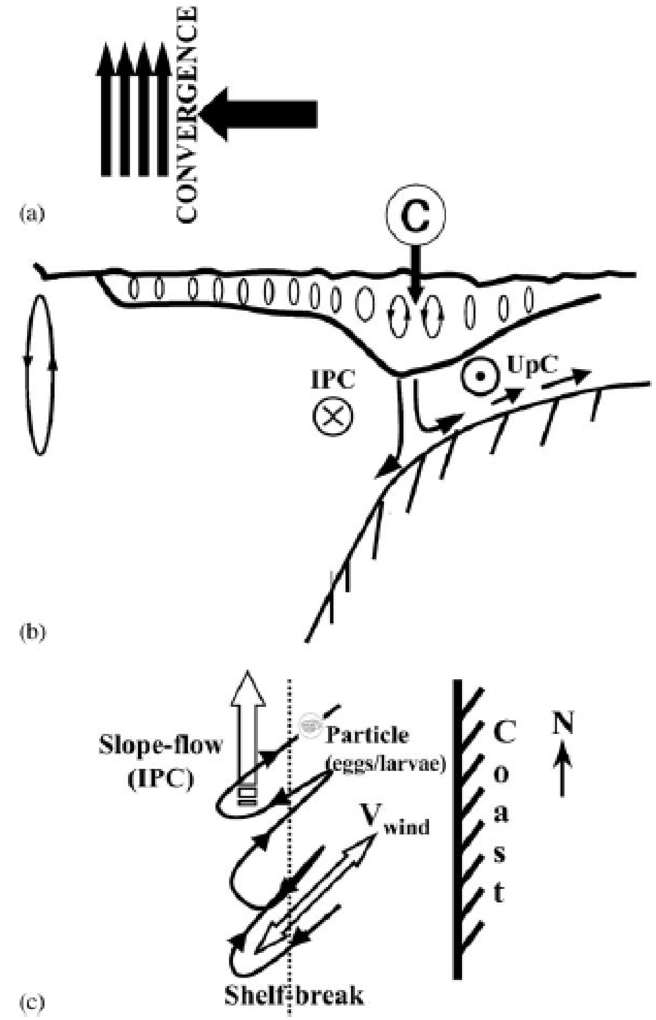


Fig. 13. Schematic representation of a retention mechanism and poleward egg and larval drift: (a) the convergence zone mechanism; (b) the vertical retention inside the buoyant plume (IPC—Iberian Poleward Current; UpC—Upwelling current; C—Convergence zone); and (c) the hroizontal retention and modulated poleward transport due to the joint effect of the poleward slope flow (IPC) and the cross shelf Ekman transport (V_{wind}).

Gulf of Cadiz

Strong seasonality
Cape Santa Maria divides Southern Iberia in two sides with different oceanographic features.
Eastern wider shelf is more productive. It has a cyclonic circulation cell that enhances productivity during summer (anchovy takes advantage).
At Cape St Vicent there is an almost permanent upwelling spot.
Both shelves can be linked under eastelies in east-to-west direction. Plankton is dispersed in these conditions.
Westerlies induce upwelling in all S Iberia and decrease biological transport between the shelves. Production in the eastern shef increases.

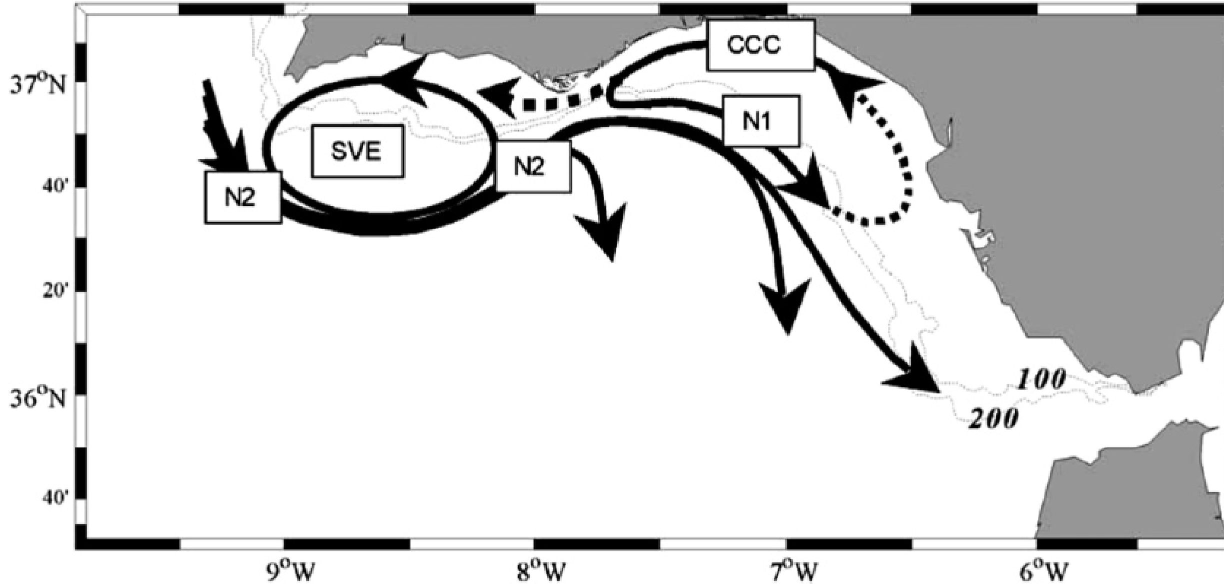
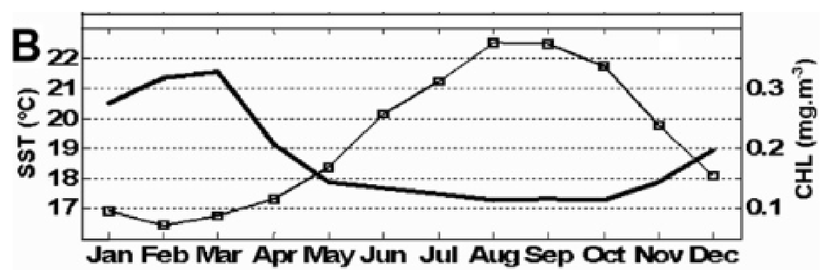


Fig. 17. Sketch of the surface circulation in the Gulf of Cádiz proposed by García Lafuente et al. (2006). Core N2 is a branch of the longer-scale Portuguese-Canary eastern boundary current that veers eastward into the Gulf of Cádiz. It moves around a cyclonic eddy off cape San Vicente (SVE), which is a quasi-permanent feature of the circulation in the Gulf associated probably with the quasi-permanent positive wind stress curl there. Part of core N2 moves further east toward the Strait of Gibraltar to feed the Atlantic inflow of nearly 1 Sv into the Mediterranean Sea and the remaining veers southwards to re-join the Canary current or detach from shore as a filament off Cape Santa Maria. The eastern shelf is dominated by a cyclonic circulation bounded by core N1 (identified with the Huelva front) at the south and a – warmer – coastal counter current (CCC). The presence of Cape Santa Maria seems necessary to close the cyclonic cell by the west. Under easterlies, the coastal counter current bifurcates off Cape Santa María and a branch invades the western shelf (dashed arrow) making the SVE drift to the south. The spatial extension of SVE is exaggerated in the sketch (figure adapted from García Lafuente et al., 2006).



Lafuente et al. 2006 in Lafuente & Ruiz 2007

WESTERN IBERIA

Anomalies during the last decade:

2007 and 2008: Strong and persistent upwelling from summer until end of December

2013: Almost no upwelling

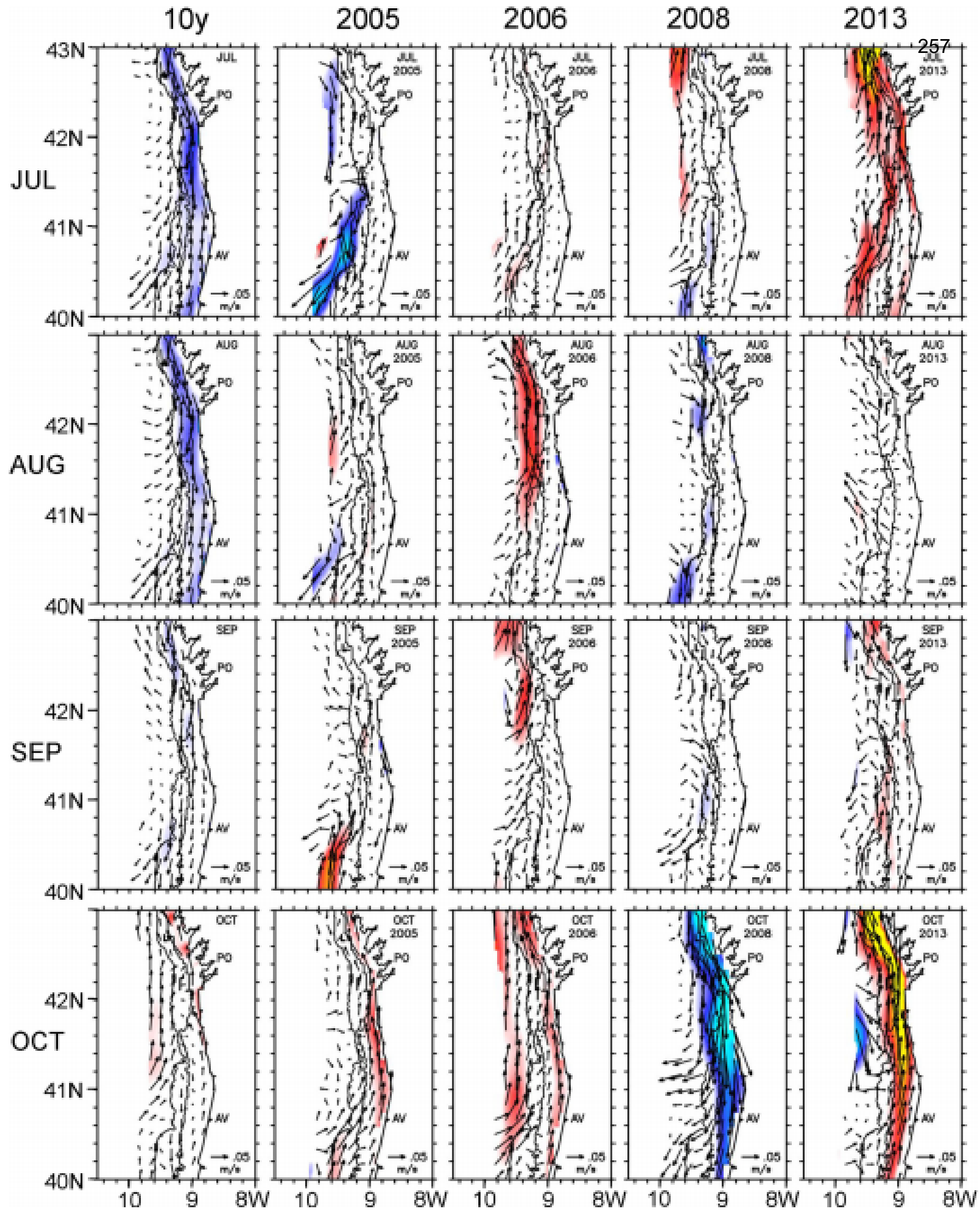
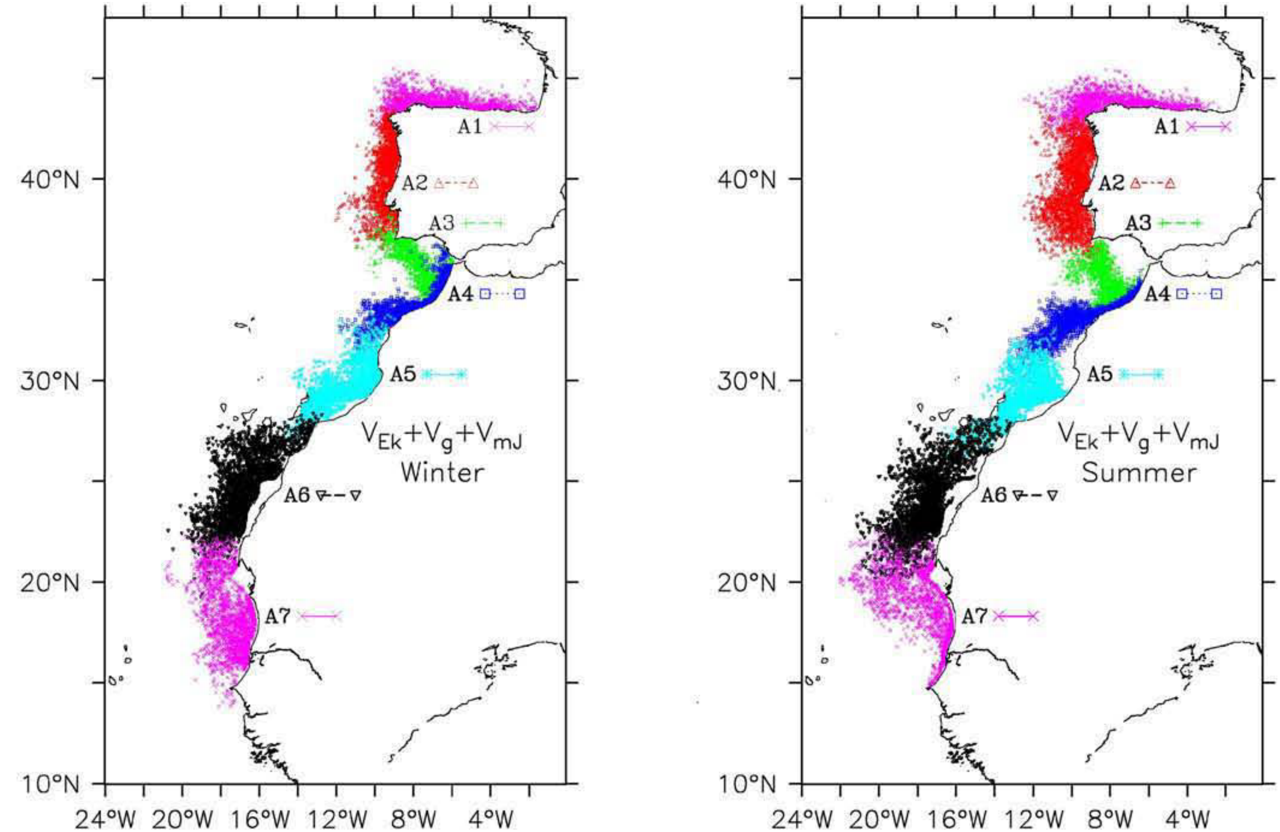


Fig. 8. Ten-year monthly mean surface currents (0–30 m) off NW Iberia (left column, July-top to October-bottom) and monthly surface current anomalies for selected years relative to the 10-year mean. Shaded areas correspond to absolute NS currents/anomalies higher than 0.05 m s^{-1}. Poleward and equatorward NS currents/anomalies are indicated by vector directions.

Moita et al. 2016

Simulation model of particle dispersion



"...the exchange between adjacent shelf areas was generally small (less than 5%) within the study period (~1 month), with the exception of the Gulf of Cadiz. In the latter area, up to 50% of particles released in the southern Iberian shelf reached the Moroccan shelf in several events. (Oliveira and Stratoudakis. 2008)

Lagrangian particle release, inhert particles no vertical information of currents, no data of the inner shelf).

Biophysical model

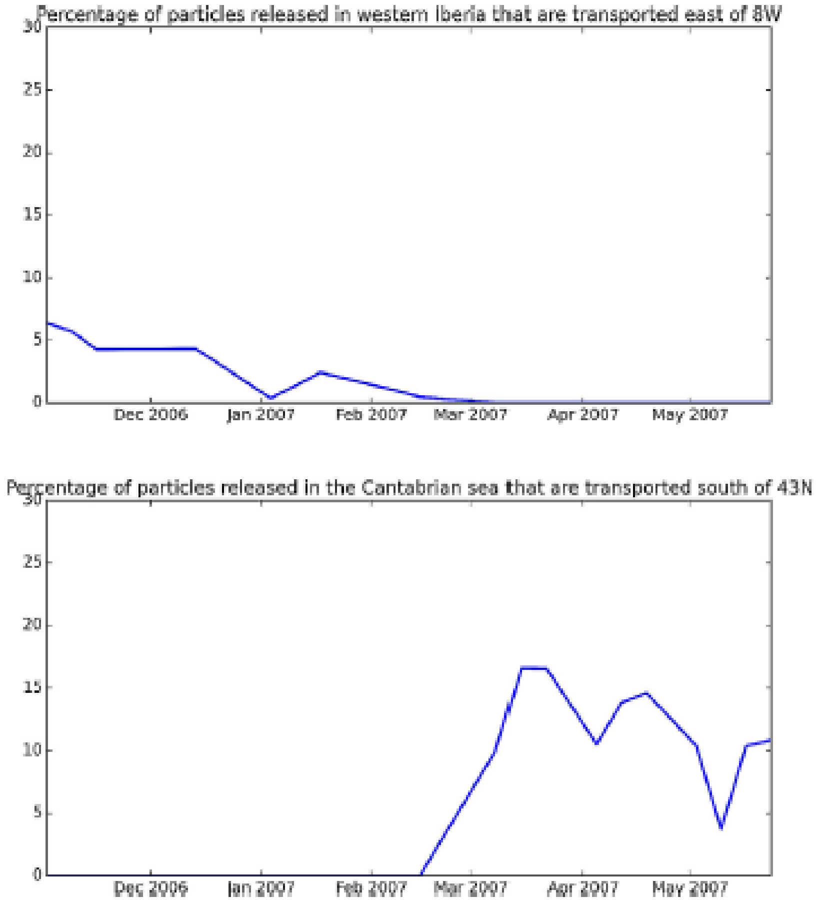


Fig. 23. Top row: Percentage of particles that, being released in western Iberia, end up in the Cantabrian sea. Bottom row: Percentage of particles that, being released in the Cantabrian sea, end up in western Iberia.

Garcia-Garcia et al. (2016) show that there can be larval transport from the Cantabrian Sea to Northwestern Portugal and vice-versa. Conectivity increases with population density.
Refers to a eastward current off the Cantabrian that can favour such transport.
Larvae transported to the Cantabrian Sea end up in a cold area with limited food;
Larvae transported to northern Portugal end up in a more favourable environment.

Over the Atlantic distribution of sardines, three areas are identified in terms of prevailing **winds**; **1)** wind stress is predominantly equatorward and upwelling-favorable over the sub-tropical African coasts, **2)** off the Iberian Peninsula this equatorward wind forcing reverses seasonally to become poleward in autumn and winter and **3)** further to the north the wind stress is stronger, prevails for most of the year and has a more westerly y component.

Main **large-scale currents** are North Atlantic Current (NAC, north of the Iberia), the Azores Current (AC, south of the Iberia) and the Canary Current (CaC). Two major oceanic **water masses** are found in this area: North Atlantic Central Water (NACW, salty) and South Central Atlantic Water (SACW, nutrient-rich, African upwelling).
Local Currents such as the poleward flows (e.g. IPC) are below the depths (<50 m) at which the early life stages of pelagic fish generally occur and will, therefore, have little direct effect on structuring the population.

There is a **coastal boundary layer** near-shore with slow flows and a tendency for near-shore **retention** of larvae as a consequence of these weak currents and associated weak dispersion.
Buoyancy-driven coastal currents are generated by less saline waters from rivers, and when combined to relatively large costal currents, remain trapped to the coast and flow poleward due to geostrophic forces. It can be a mechanism for egg and larval **dispersal** to other areas.
Santos et al. (2004) demonstrated a retention mechanism for sardine larvae produced by the interaction of a strong winter upwelling event, the IPC and the buoyant (WIBP) river plume off western Iberia in February 2000. The WIBP is a particularly important feature owing to the maximum regional rainfalls that characterize the winter months. In some cases, the WIBP may be associated with strong poleward transport over the shelf.
On the other hand, the interaction between buoyancy-driven coastal currents and oceanic waters further offshore, sometimes result in eddies (Rossby-radius scale eddies) that are responsible for significant shelf-ocean exchange of water, probably causing dispersal of nutrients, plankton (and potentially larvae).
Eddies, that are formed in curved coastlines are known to occur in the Bay of Biscay and Western Iberia and can promote either retention of larvae as well as dispersal (high instability).

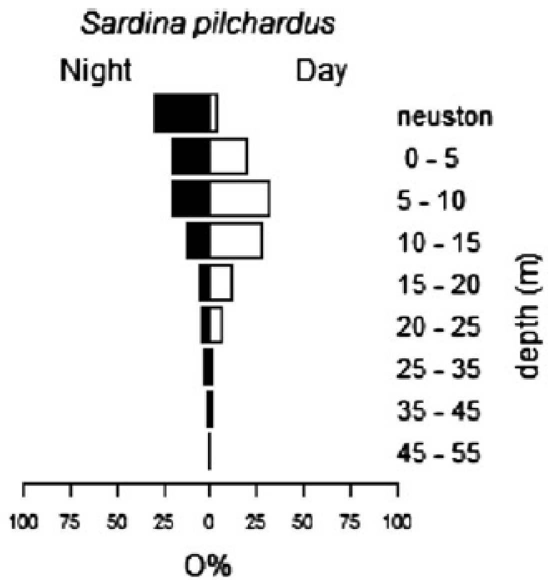
Fronts separate water masses and are considered boundaries. These are narrow zones of enhanced gradients of water properties (horizontal or vertical). Can be observed from different scales of space and time (100 m to 10000 km along-front, from hours to many years). Generally are more productive and may benefit larvae to adult stages. Are considered **barriers** for larval dispersal and adult migration.

The relationship between Oceanography and Dispersal/Conectivity must be studied in relation to the **ontogeny** of the fish.

Four stages can be considered during the life of sardines with respect to the influence of oceanographic features on dispersal and conectivity, related to the ontonegy of the fish:

1) **Eggs and early-larvae** have no migration abilities and therefore the main factor determining their retention or dispersal are the oceanographic features at the location at which the eggs are spawned. This, coupled with intrinsic (e.g. egg quality) and extrinsic factors (e.g. predation) will determine the potential survival at this stage.
In all the distributional range of sardines, production is discontinuous (to a lesser extent off Africa at the permanent upwelling system). Given that eggs and larvae are carried passively, the sucess of reproduction is, to a great extent, dependent of how stable and productive is the nursery ground chosen by adult sardines, The spawning sites of sardine populations will depend, upon other factors, of the population size. High density populations will occupy a broader area that will promote conectivity (e.g. Carrera and Porteiro 2003) namely through higher dispersal of the early life stages. Sardines seem to spawn eggs where they are located, therefore the highest the population density and habitat occupation, the higher the probability that some eggs will find optimal feeding grounds. However, spawning stock biomass is just weakly related to recruitment strenght...

2) **Larvae after the flexion of the notochord** (ca. 20 dph) start to have limited locomtory abilities (Silva et al. 2014). They perform vertical migrations (Santos et al. 2004, 2007) and can resist moderate currents for limited periods of time (Silva et al. 2014, Garrido et al., in press). It is likely that they remain, however, in retention nutrient-rich areas, as growth at this stage implies high energy demands and consequently the need for high food availability. Vertical migrations, described for larvae and adults of this species can modify the horizontal distribution of fish by exposing populations to depth-specific variation in current strength (Neilson and Perry 2001).



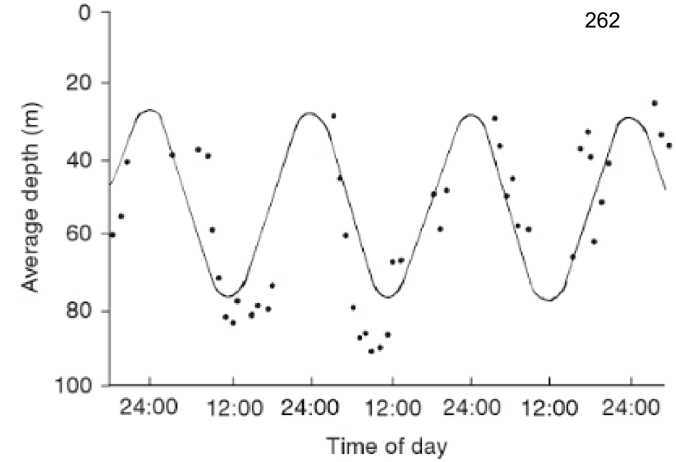


Figure 1 Vertical distribution of the sardine (*Sardina pilchardus*) in the Thracian Sea. The dots show the observed average depths, and the solid line shows the predicted average depth of the distribution according to a cosine function model based on the time of day. (Modified from Giannoulaki M, Machias A and Tsimenides N (1999) Ambient luminance and vertical migration of the sardine *Sardina pilchardus*. *Marine Ecology Progress Series* 178: 29–38.)

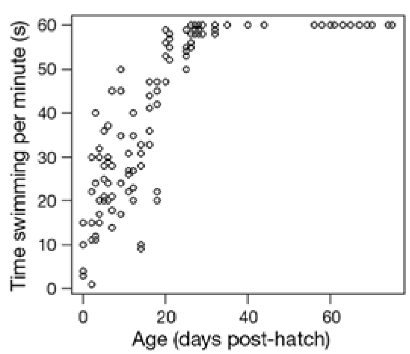


Fig. 2. Time spent swimming by sardine *Sardina pilchardus* larvae during a 60 s period of observation throughout larval ontogeny for larvae reared with high prey concentrations (Diet C)

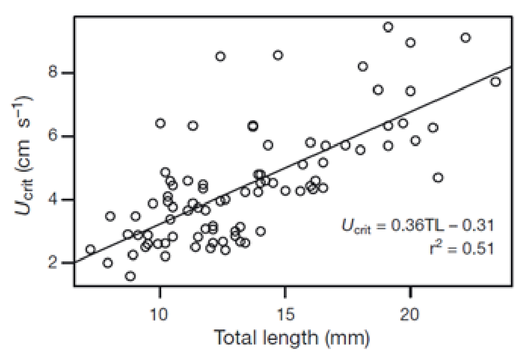
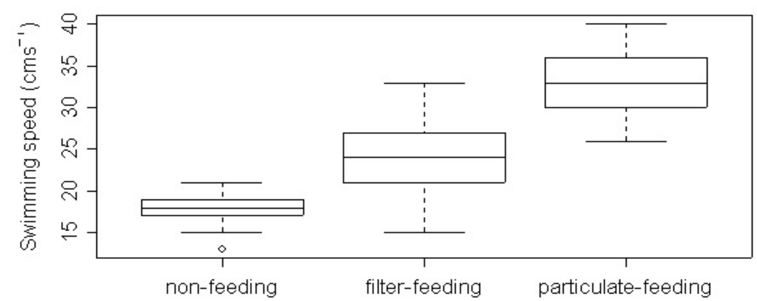


Fig. 4. Critical swimming speed (U_{crit}) of sardine *Sardina pilchardus* larvae throughout ontogeny for larvae from all feeding treatments. Each symbol represents the U_{crit} for an individual larva



3) **Juveniles** have migration abilities but are still very vulnerable to predators when compared to adults and depend upon high concentrations of food to grow. Preferred recruitment areas are known for the species.
Optimal temperature generally changes with ontogeny. Tolerance for higher temperatures increases with ontogeny since eggs and early larvae will perish in temperatures that are suitable for juvenile and adult fish (Garrido et al. in press). Migration to areas with higher temperatures would be benificial for juveniles that would grow faster but their needs for food availability would also increase.

4) **Adults** have migration abilities but their movements are most likely influenced by prevailing currents and fronts.

Why would currents and fronts be considered **barriers** for adult fish that have migration abilities?
Water is a fluid environment that is much more resistant to movement than the air, and has much less oxygen (Arnold 2001). This justifies why fish generally swim slow at cruising speeds (less than 1 body length per second) and only speed up for feeding or avoiding predators. This is also the reason why currents are so important for fish dispersal, even at the adult stage. Currents can help dispersal by sparing energy but can also provide direction.

After recruiting to the adult stock, fish generally home to the same spawning ground (Arnold 2001).

Generally, fish **horizontal migration**, when occuring, is annual and separates the spawning and feeding seasons (Arnold et al. 2001).
In the Adriatic, sardines are described to migrate at the end of the spawning season from the spawning grounds to shallower, high productive regions (Škrivanić & Zavodnik 1973).
There is no evidence that such migration of adult sardines during the resting season (May to October) occurs for Atlantic populations. (correct?) However, food concentrations at the main recruitment areas off the Iberia are generally higher than off the Mediterranean Sea, so the need to migrate to find suitable food concentrations is potentially lower.

The most important prey for sardine larvae are very **similar** to those of the adults, which means that preferred feeding grounds can match those of the spawning grounds. Actually, contrary to most other pelagic species that increase their trophic level during ontogenetic development, sardines decrease their trophic position by being able to retain smaller prey as their feeding apparatus develops. Therefore, areas of high primary production are beneficial for the species, where competition with other fish is lower.

Conclusion:

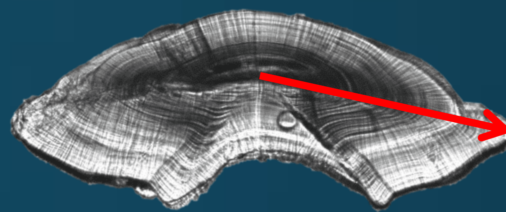
- Several studies describe large and small scale oceanographic features of the region (both spatial and temporal variability) and the knowledge of the oceanographic processes ocurring at Iberian waters are now properly described in 3D hydrodinamic models (e.g. ROMS).

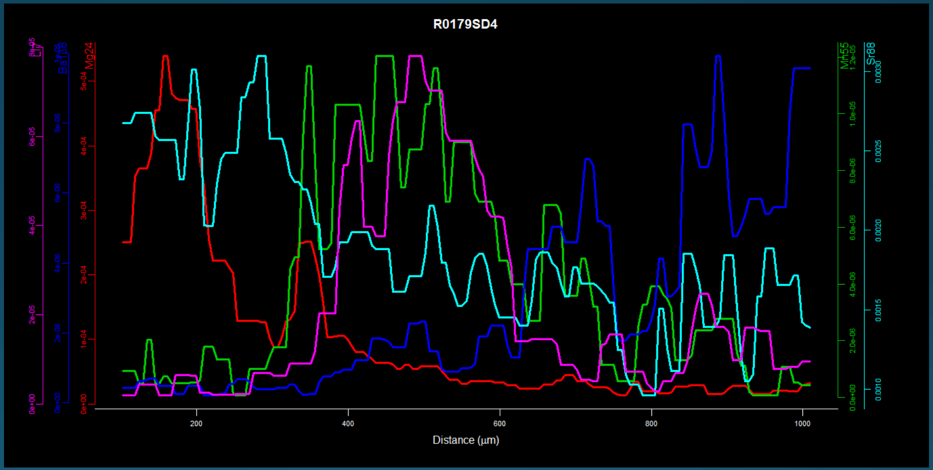
- Recent studies have provided a large number of vital rates of sardine eggs and larvae in relation to prevailing water temperature and food availability conditions. These can be used as species-specific parameters of individual based models

- However, studies addressing the influence of the major oceanographic features on sardine ELS dispersal and connectivity are missing. The study by Garcia-Garcia et al. 2016 mainly focuses on the temporal variability of sardine recruitment but shows some results on larval connectivity; models of the type used in this study would be very useful to fill this knowledge gap.

- In order to know the potential dispersal and migration of juveniles and adults, other methodologies should be adopted, such as following strong cohorts and using stable isotopic compositon analysis.

Microchemistry of sardine and anchovy otoliths from the bay of Biscay





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UMR CNRS/UBO/IRD/Ifremer

Pamal
Femtosecond laser ablation

Ifremer

SEAMAN

Introduction

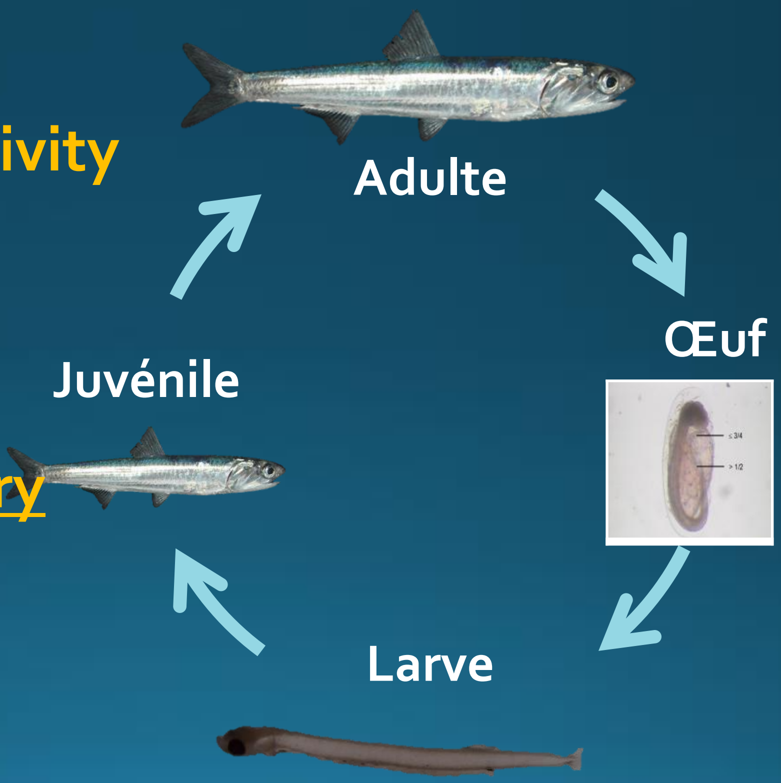
PHD project

Connectivity of marine populations during different states of their life. Comparative approach of sardine and anchovy of thye bay of Biscay.?

- Identify
  - **Essential habitats**
  - **Migrations diagrams / connectivity**

- Compare **strategies of life history**

→ Models & **otoliths microchemistry**

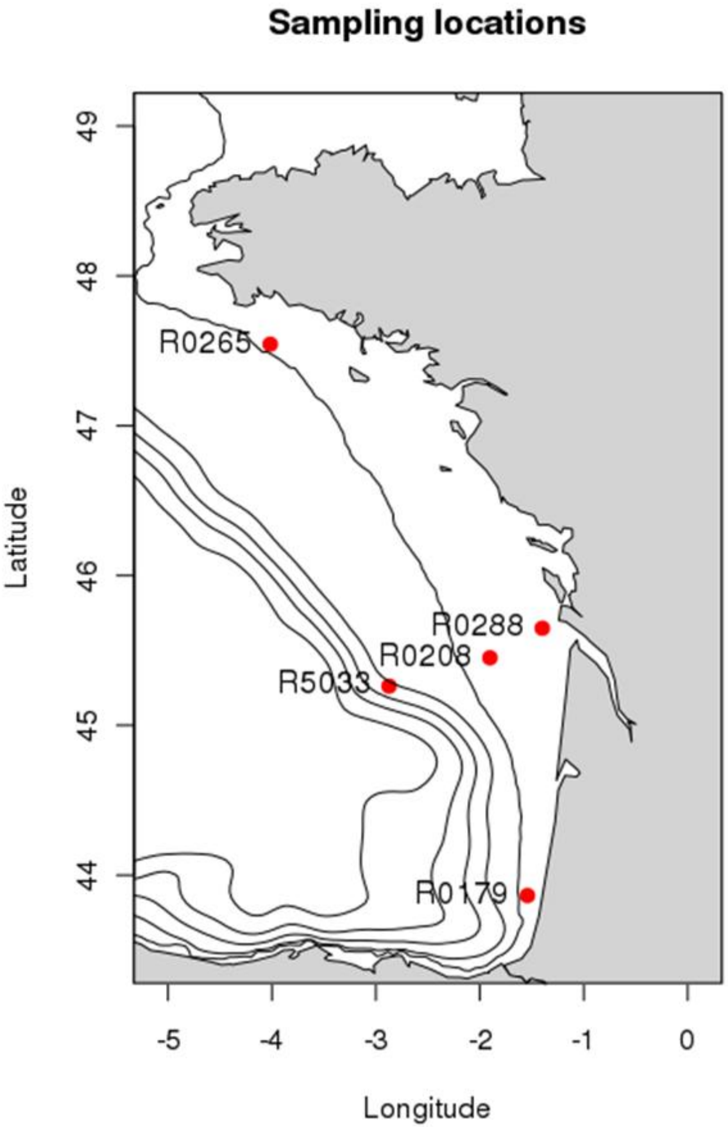


Introduction

Informations of all the history of life of the fish ? Elementary signatures with large diversity of process.

Hypothesis : have individuals with comparable elementary signatures similar stories ?

samples



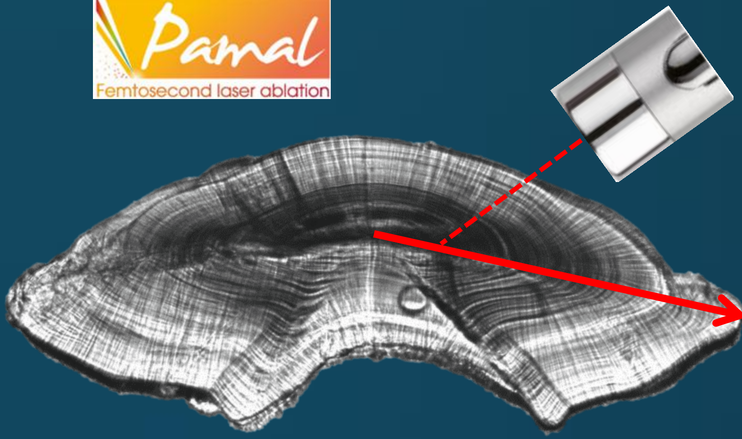
Samples collected during PELGAS13

5 stations to « maximise » North/South and coastal/offshore gradient

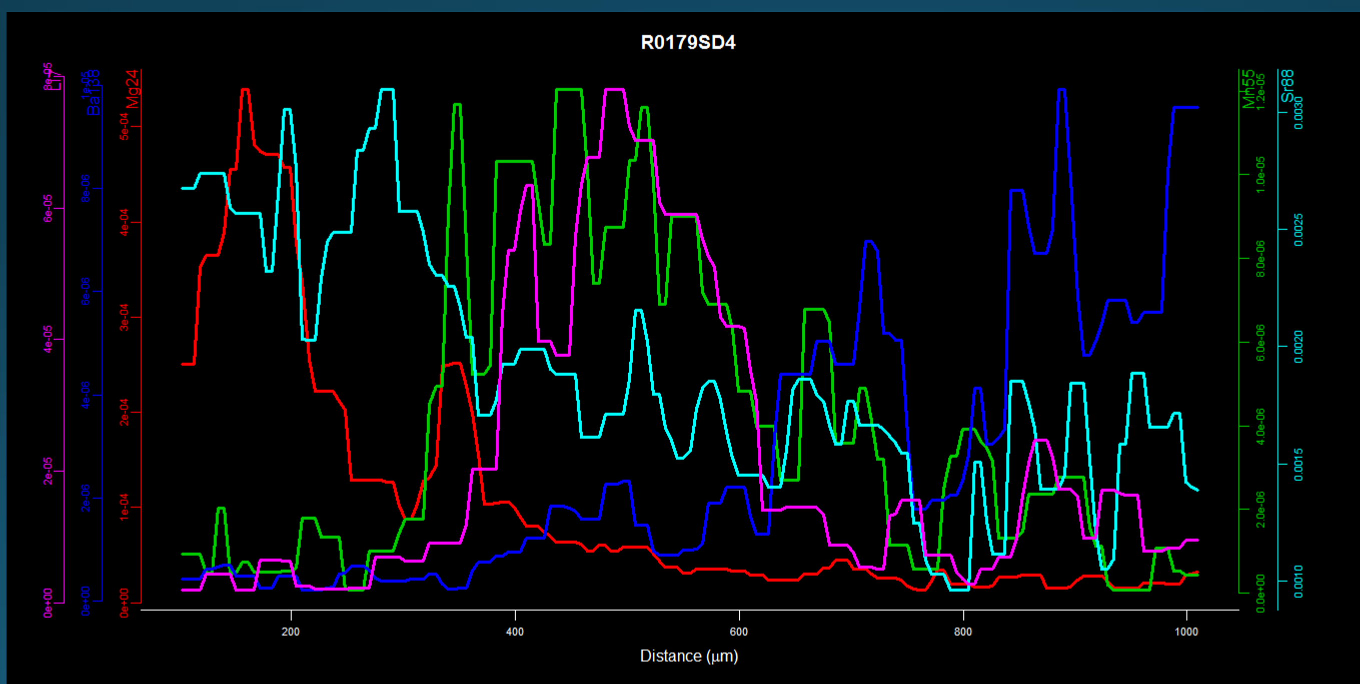
Selection of « old fish » (3y.o.) for more « life history »

	R0179	R0208	R0265	R0288	R5033	R5034	Total
Anchovy	7	2	1	4	0	5	19
Sardine	9	6	0	3	6	0	24

Microchemistry

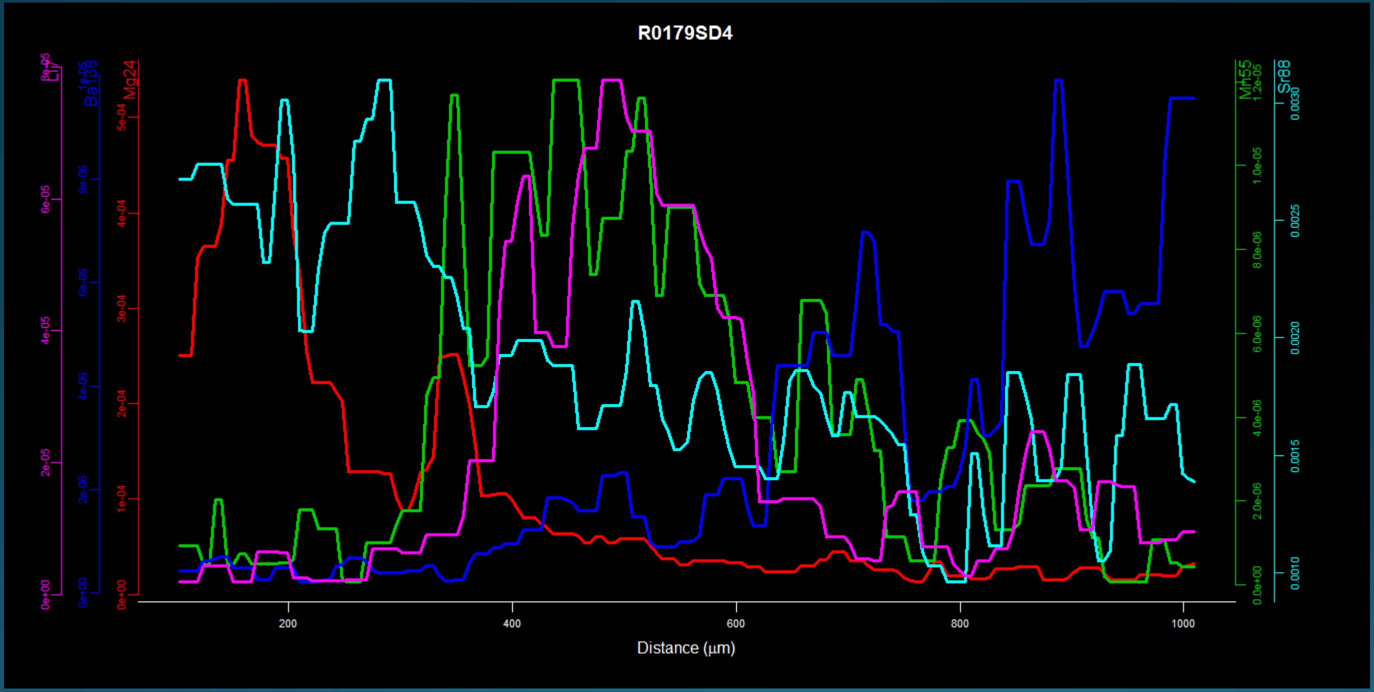


- **LA-ICPMS**
- **Transect laser continuous**
  Nucleus → edge
  birth → death
- **Elements : Sr, Ba, Mn, Mg & Li**

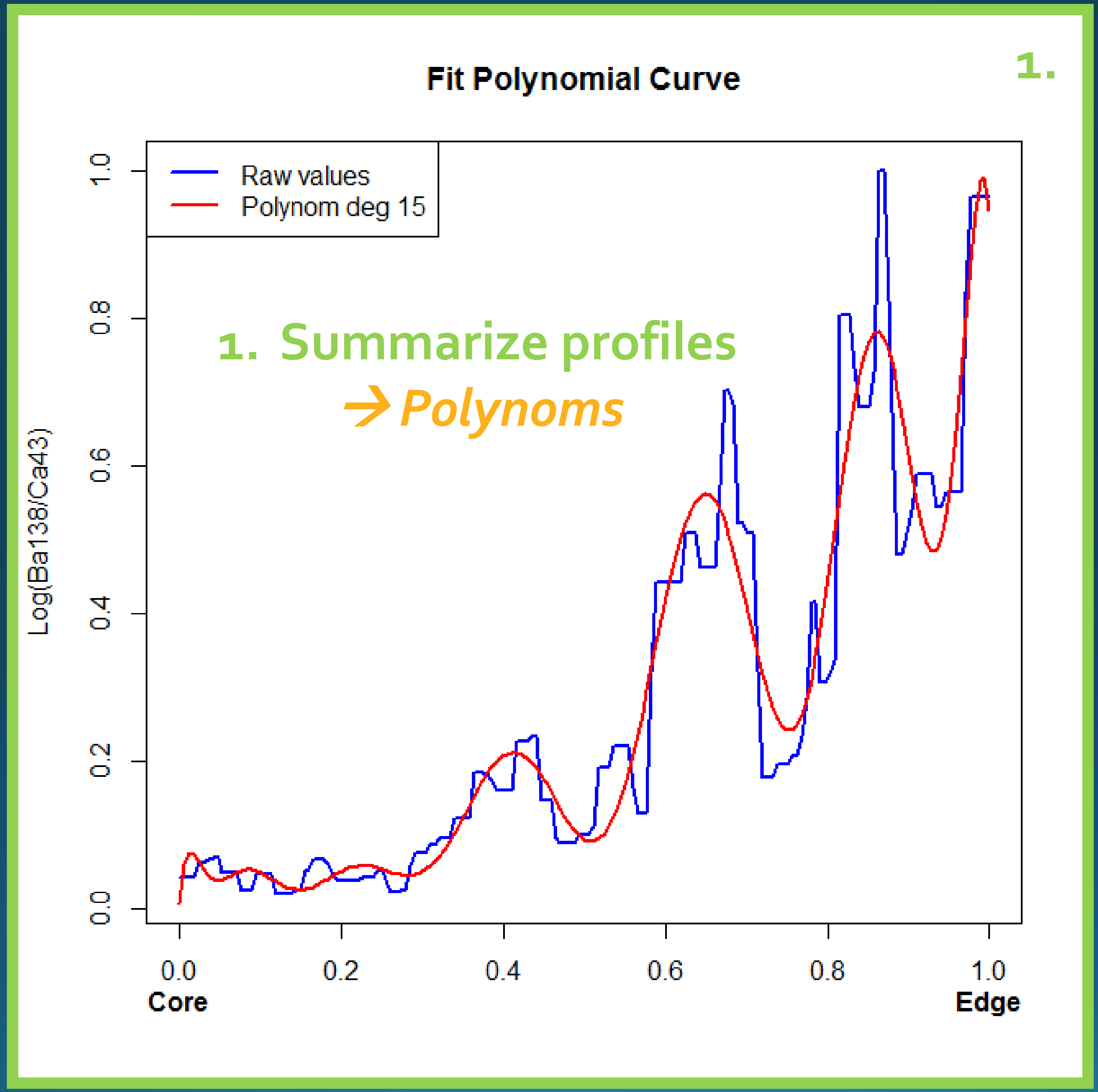


Classification

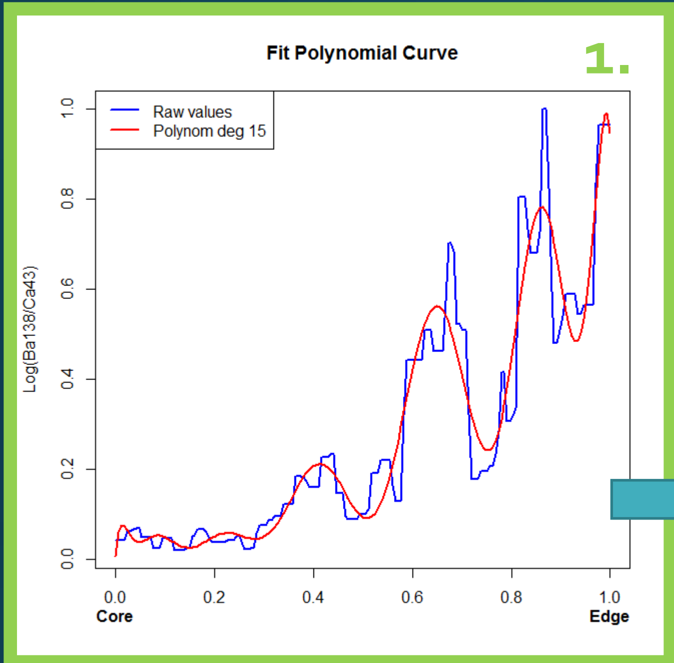
How could it be possible to identify/group individuals with similar trajectories ?

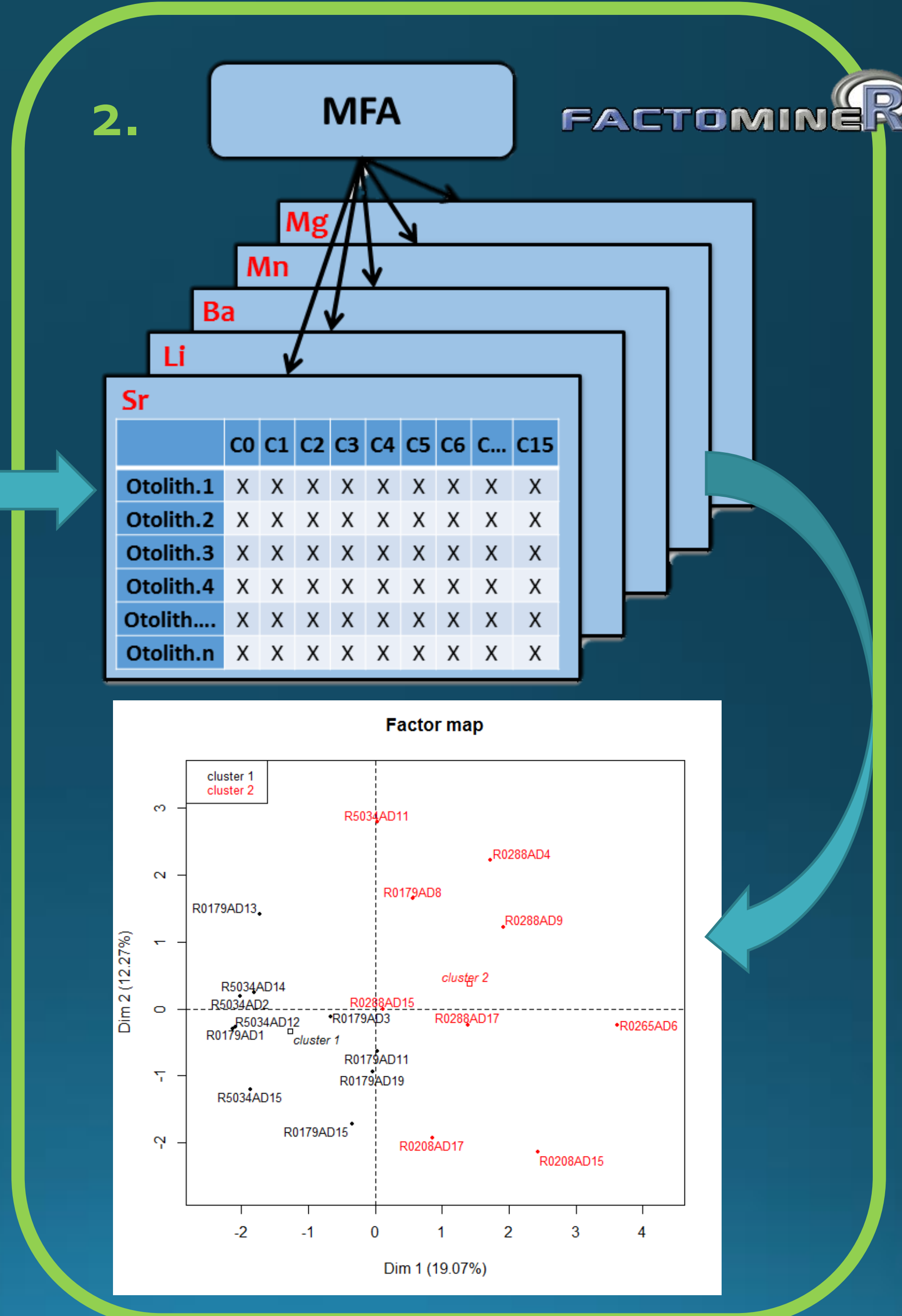


Classification



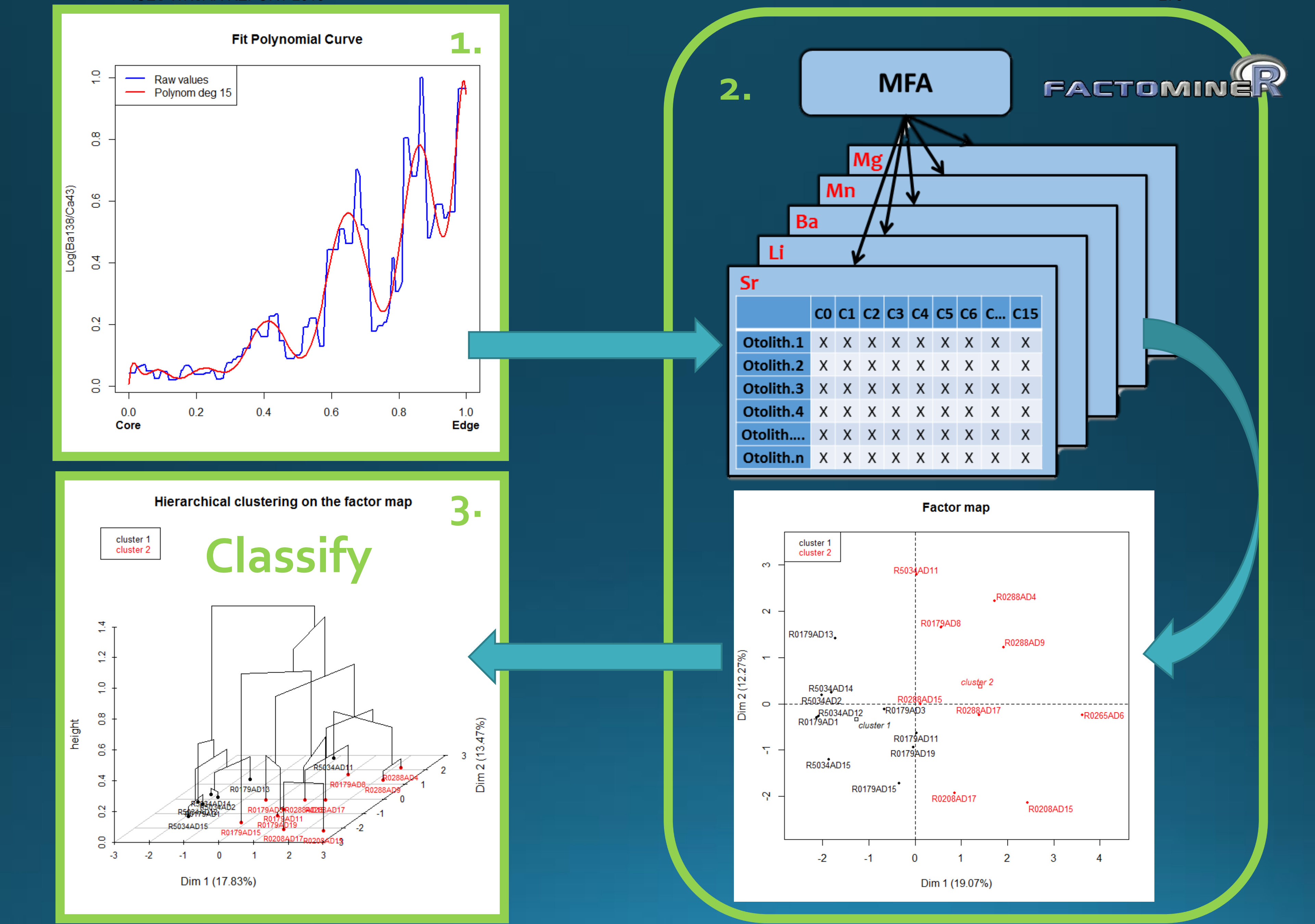
Classification



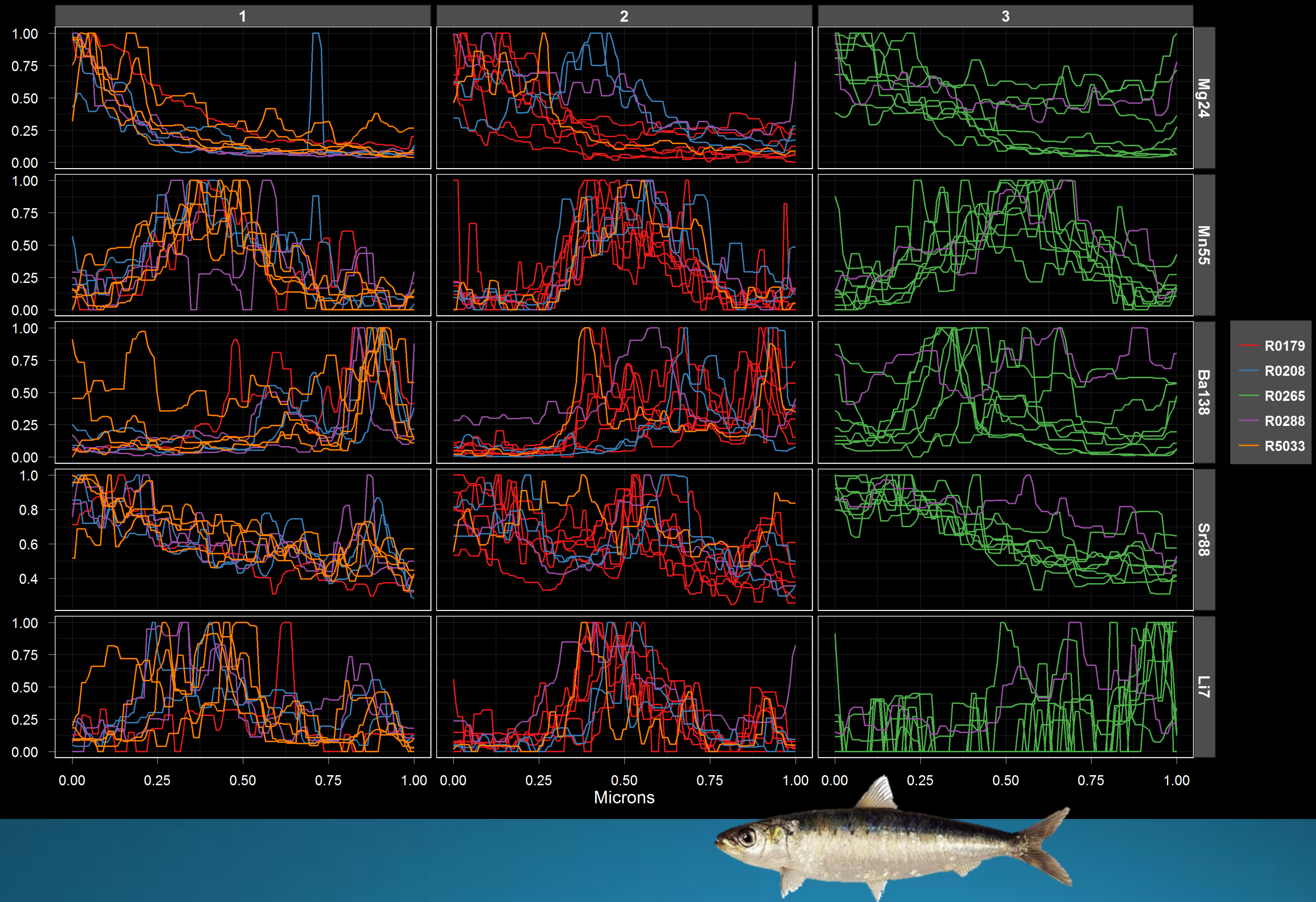


2. Extract variability

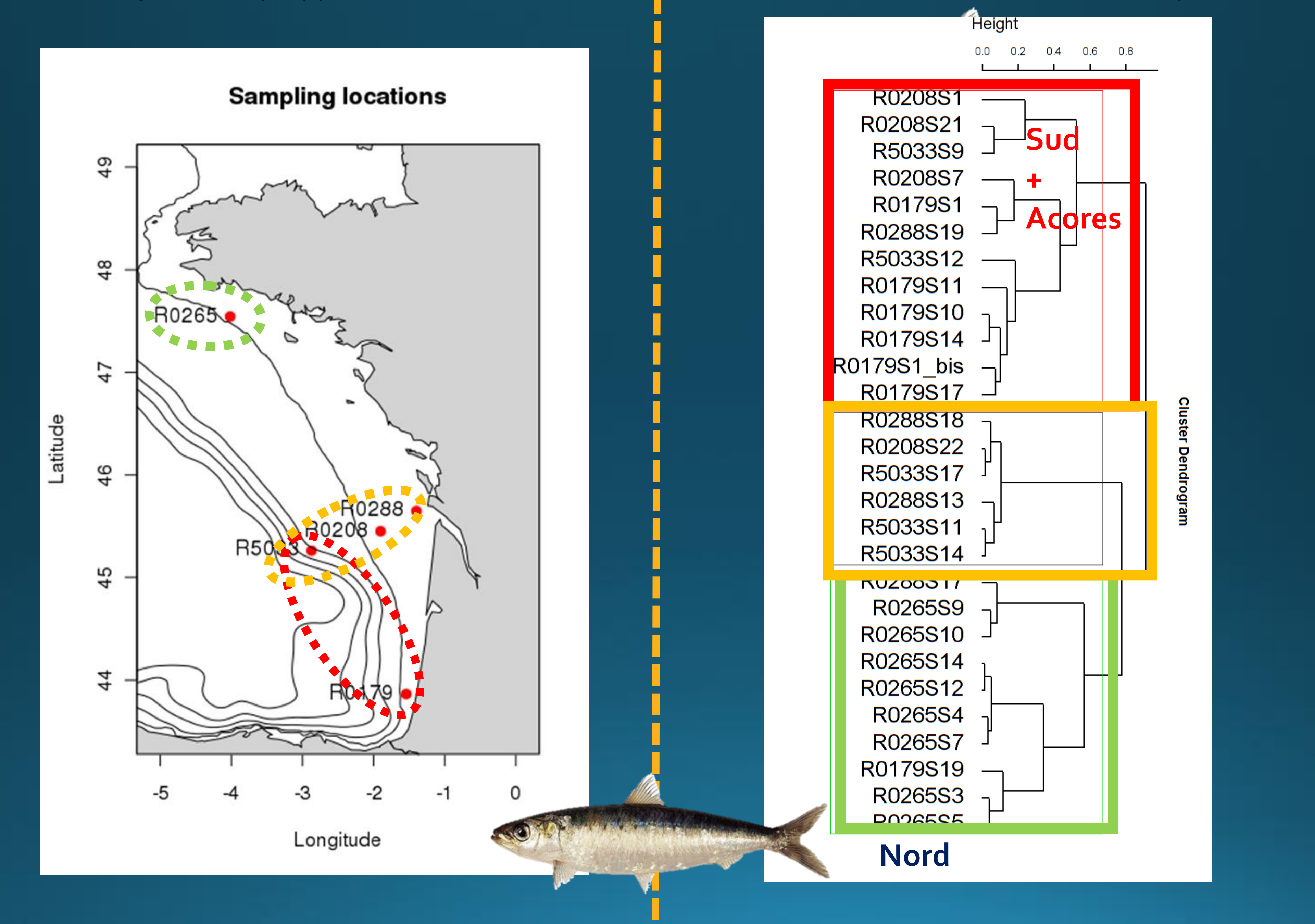
Classification



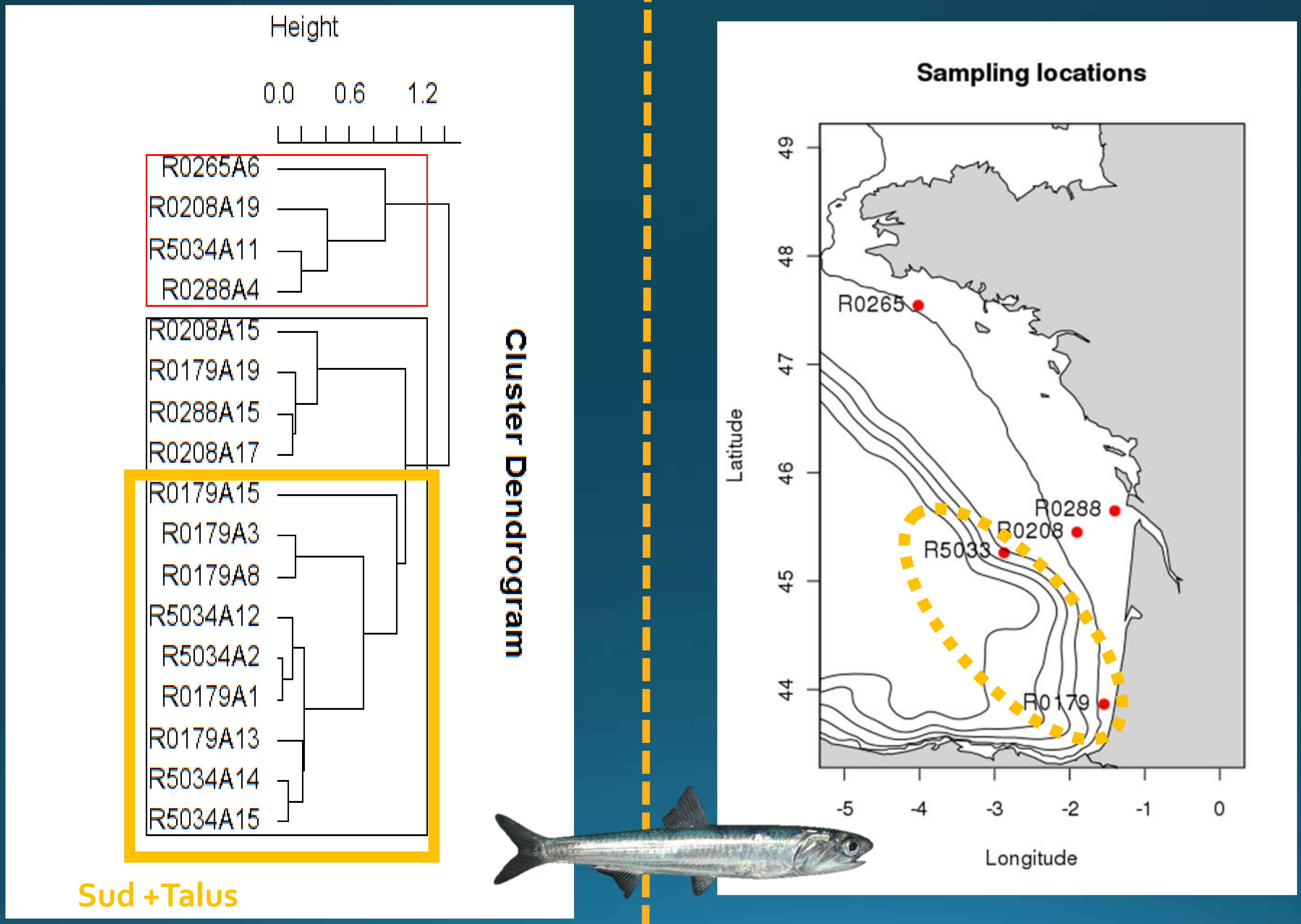
Results


1
2
3
Mg24
Mn55
Ba138
Sr88
Li7
R0179
R0208
R0265
R0288
R5033
Microns
0.00
0.25
0.50
0.75
1.00
0.4
0.6
0.8
1.0

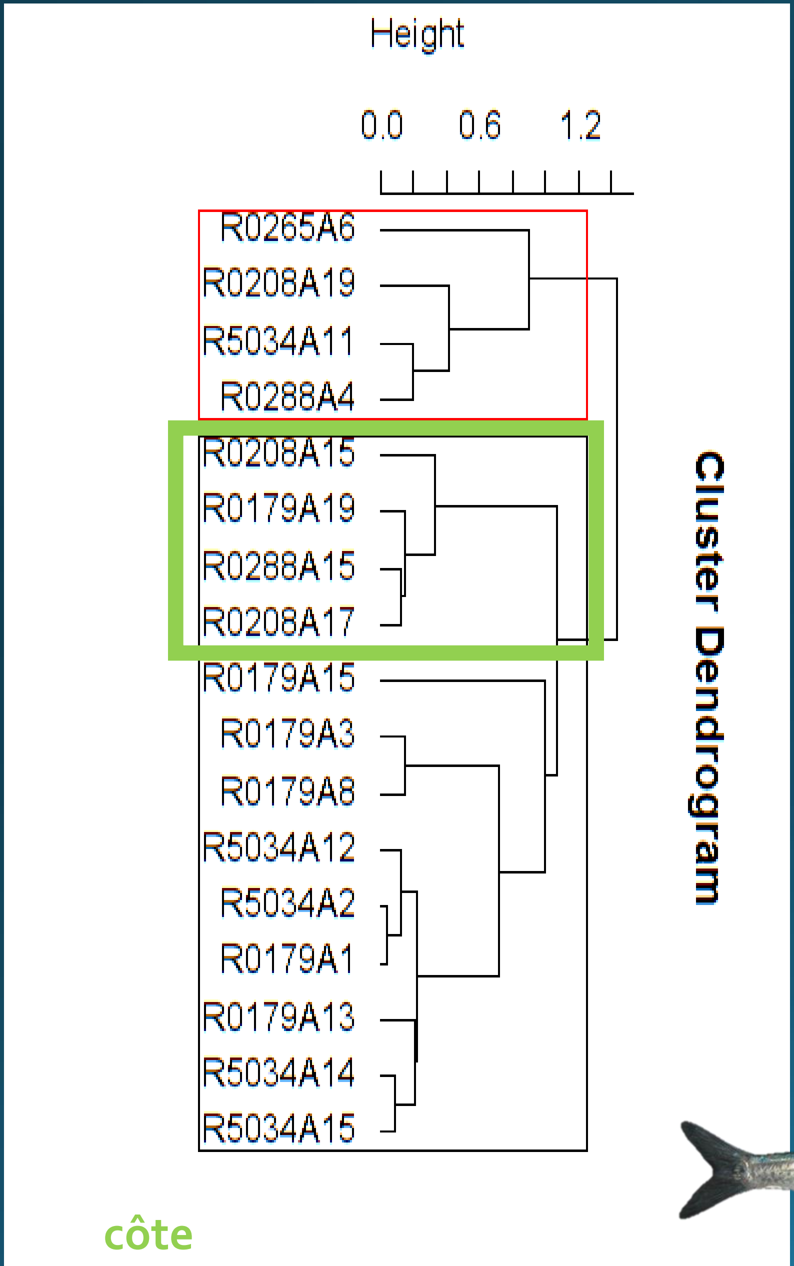
Results


Sampling locations
Latitude
Longitude
49
48
47
46
45
44
-5
-4
-3
-2
-1
0
R0265
R0288
R0208
Height
0.0
0.2
0.4
0.6
0.8
R0208S1
R0208S21
R5033S9
R0208S7
R0179S1
R0288S19
R5033S12
R0179S11
R0179S10
R0179S14
R0179S1_bis
R0179S17
R0288S18
R0208S22
R5033S17
R0288S13
R5033S11
R5033S14
R0265S9
R0265S10
R0265S14
R0265S12
R0265S4
R0265S7
R0179S19
R0265S3
Sud
+
Acores
Nord
Cluster Dendrogram

Results


Height
0.0 0.6 1.2
R0265A6
R0208A19
R5034A11
R0288A4
R0208A15
R0179A19
R0288A15
R0208A17
R0179A15
R0179A3
R0179A8
R5034A12
R5034A2
R0179A1
R0179A13
R5034A14
R5034A15
Cluster Dendrogram
Sud +Talus
Sampling locations
Latitude
49
48
47
46
45
44
R0265
R0288
R0208
R5033
R0179
-5 -4 -3 -2 -1 0
Longitude

Results



Height
0.0
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R0265A6
R0208A19
R5034A11
R0288A4
R0208A15
R0179A19
R0288A15
R0208A17
R0179A15
R0179A3
R0179A8
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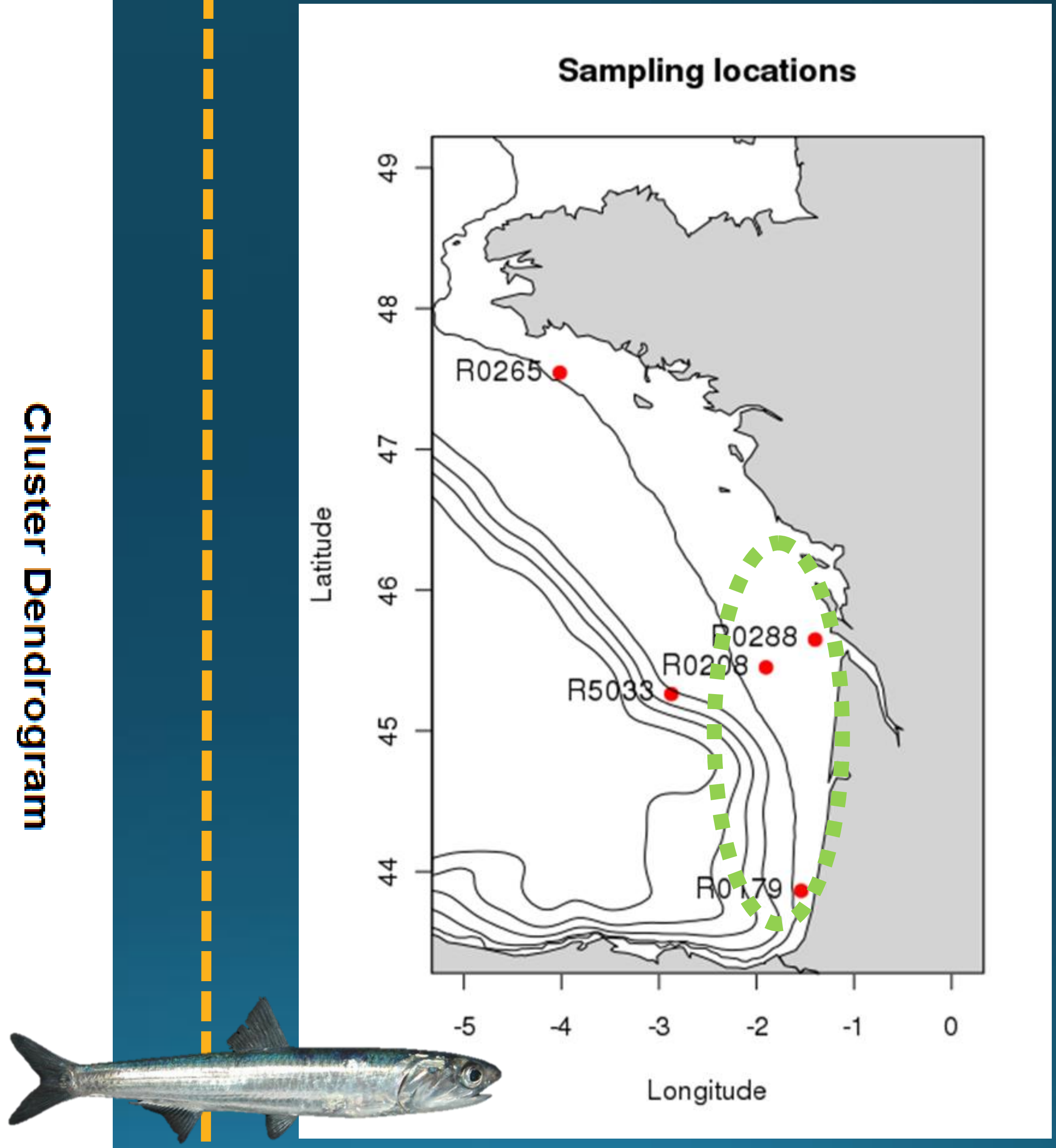
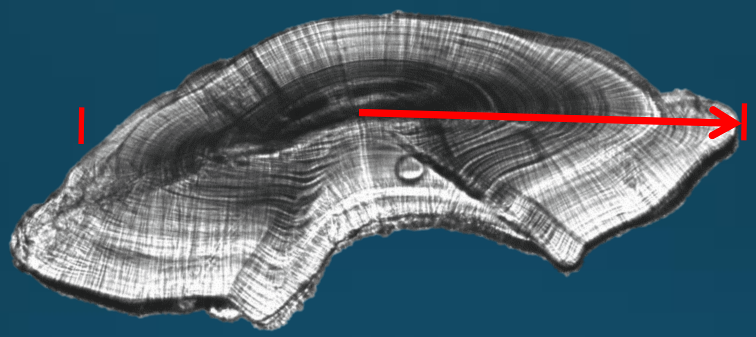
R5034A2
R0179A1
R0179A13
R5034A14
R5034A15
Cluster Dendrogram
côte



Sampling locations
R0265
R0288
R0208
R5033
R0179
Latitude
Longitude
49
48
47
46
45
44
-5
-4
-3
-2
-1
0

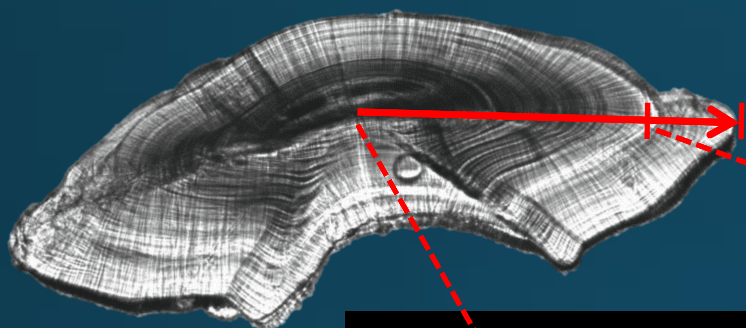
Further...

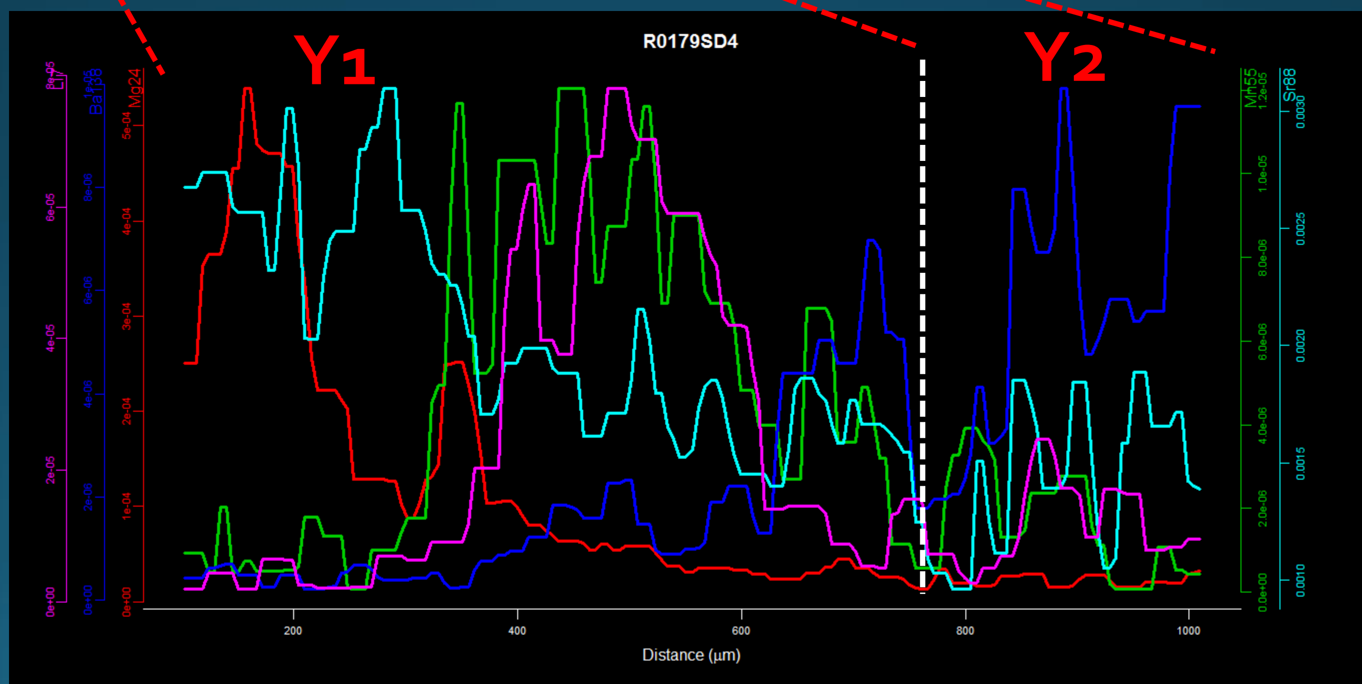


« cut » transects in many years of life

Further…

With annual rings measurement





Further…

	R0179	R0208	R0265	R0288	R5033 – R5034	Total
Anchovy	7-**8**	2-**4**	1	4	5-**7**	19-**24**
Sardine	9-**11**	6-**9**	0-**8**	3-**9**	6-**11**	24-**48**

Explore all samples (and not just age 3)

1 transect = 1 individual

Further…

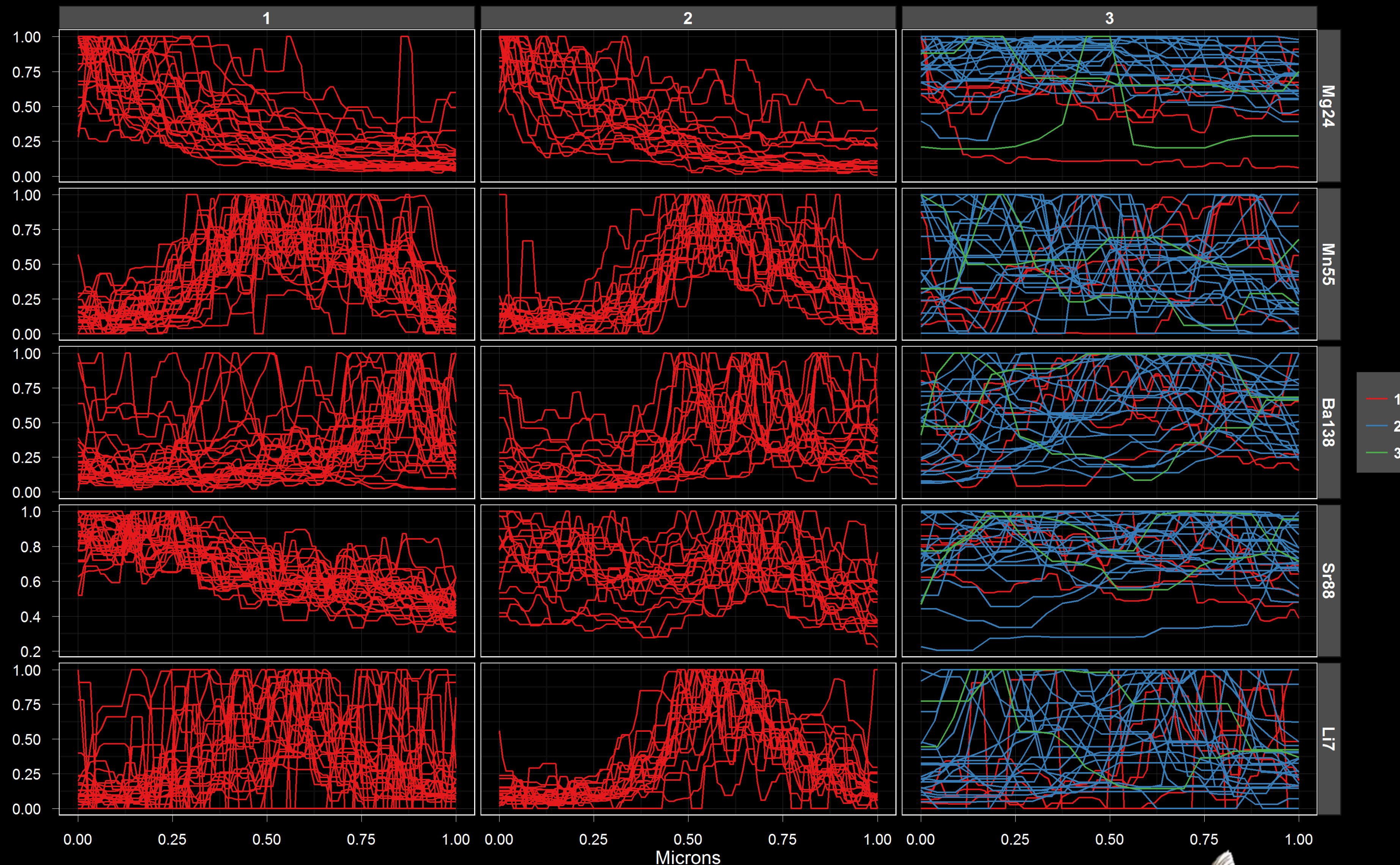
Classify portions of transects / life period :

-> same traject for each year ?

-> for each cohort ?

-> indices of aggregation/ division of schools ?

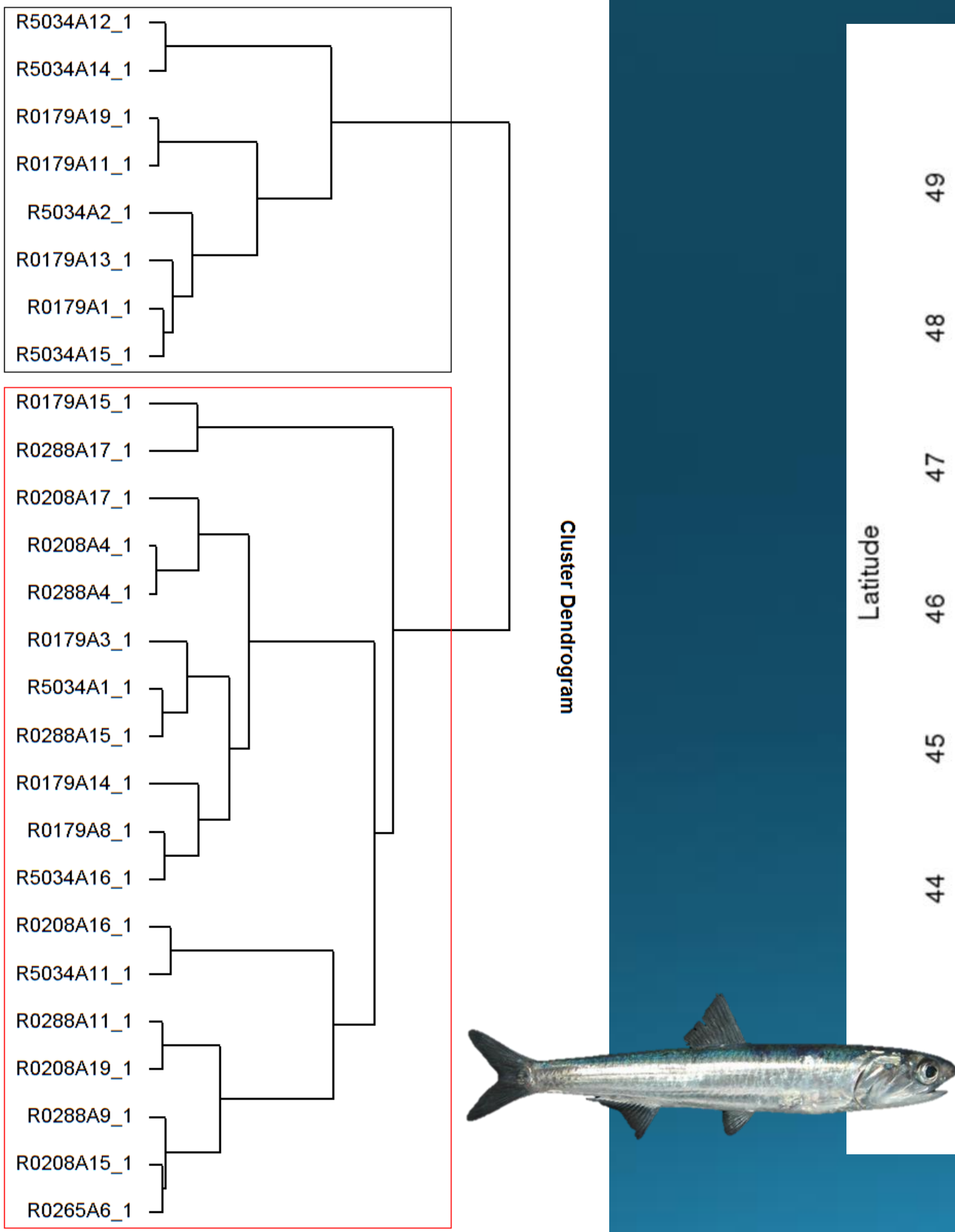
Results : interannual redondance ?

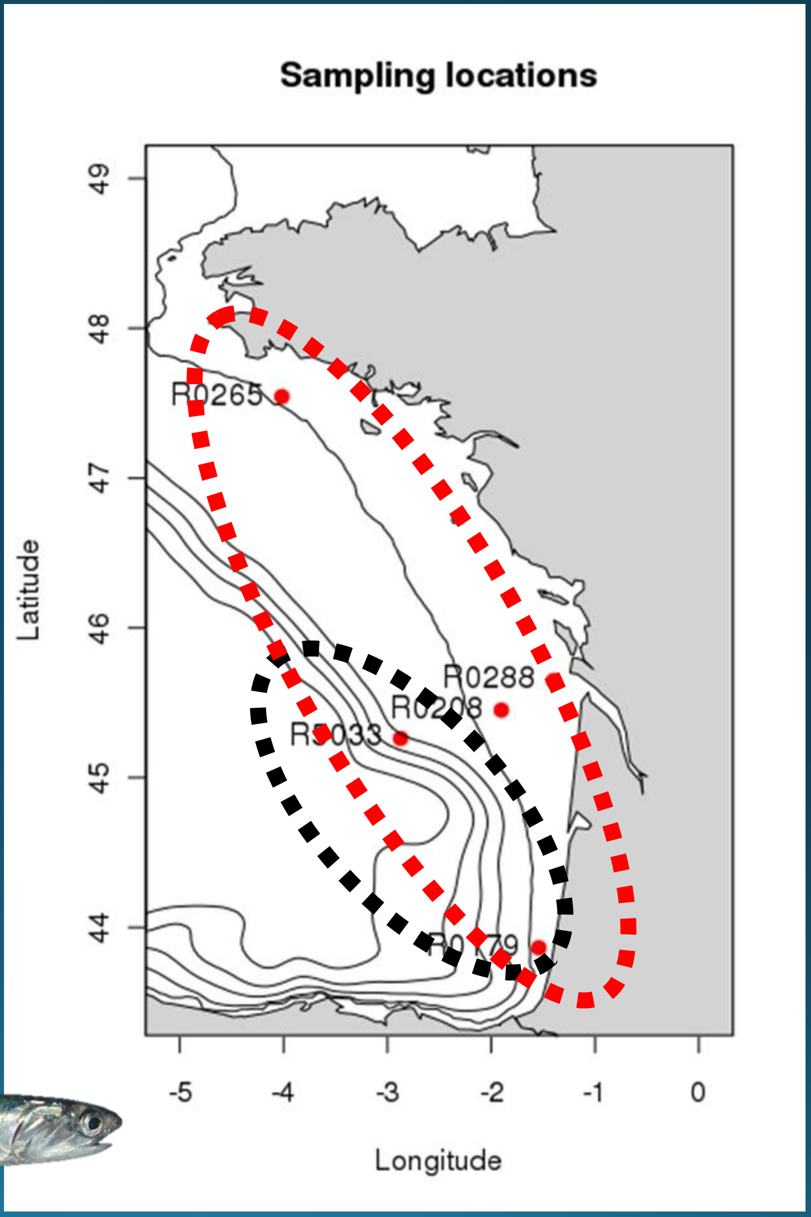


2nd and 3rd years reclassify together → not really discriminant ?

→ Signal compression ← lower growth of otoliths

Results : Classification of the firsts years of life





Conclusion

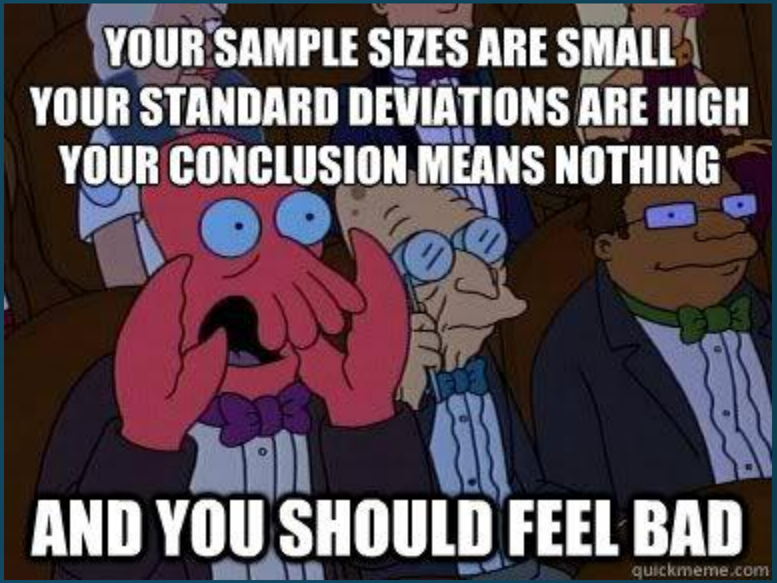
- A method of classification which allows to group individuals with similar patterns

- Geographical effect :
    - -North/South
    - -Coast/platform/shelfbreak

- The whole signal not easy to use -> preference for the first year

Conclusion

Limits



Few samples (spatial, years/cohorts)

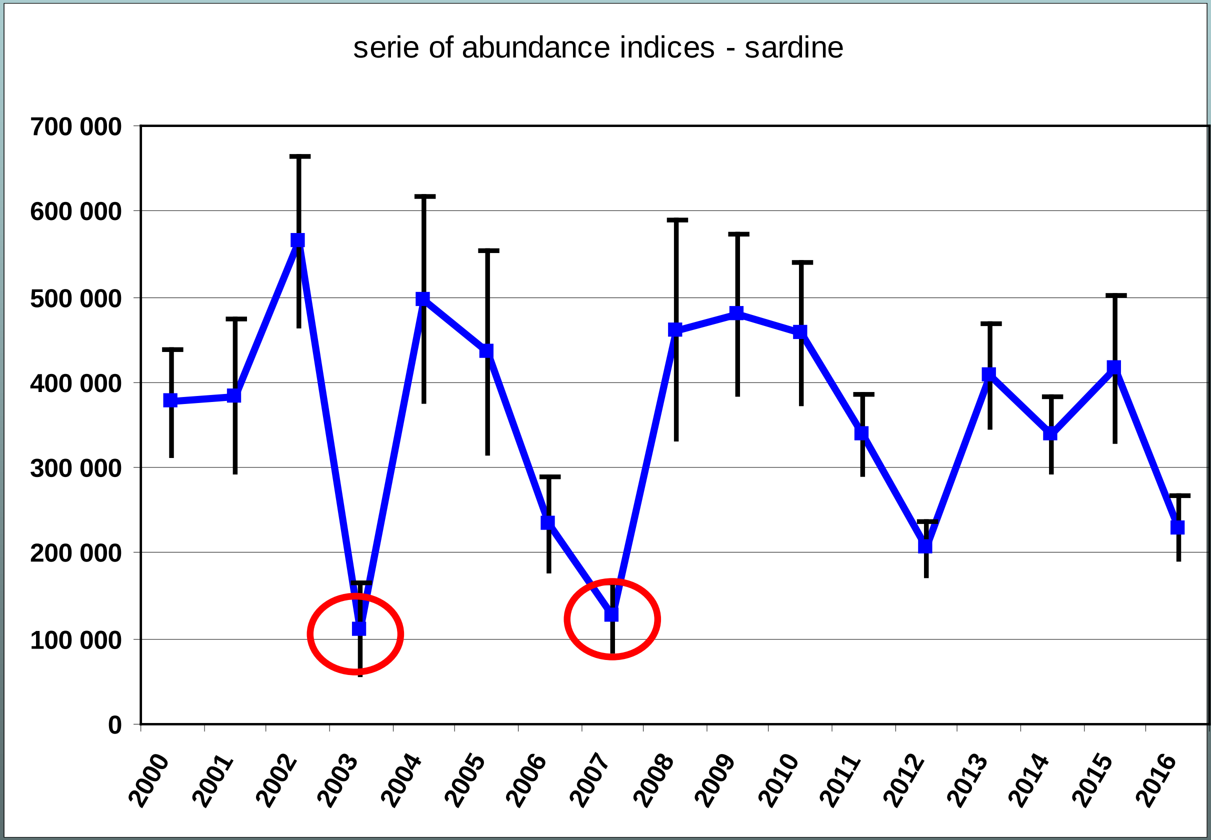
Elements not really discriminant and heavy metals (Cd, Cu, Pb) tested but nothing conclusive

Thanks !!

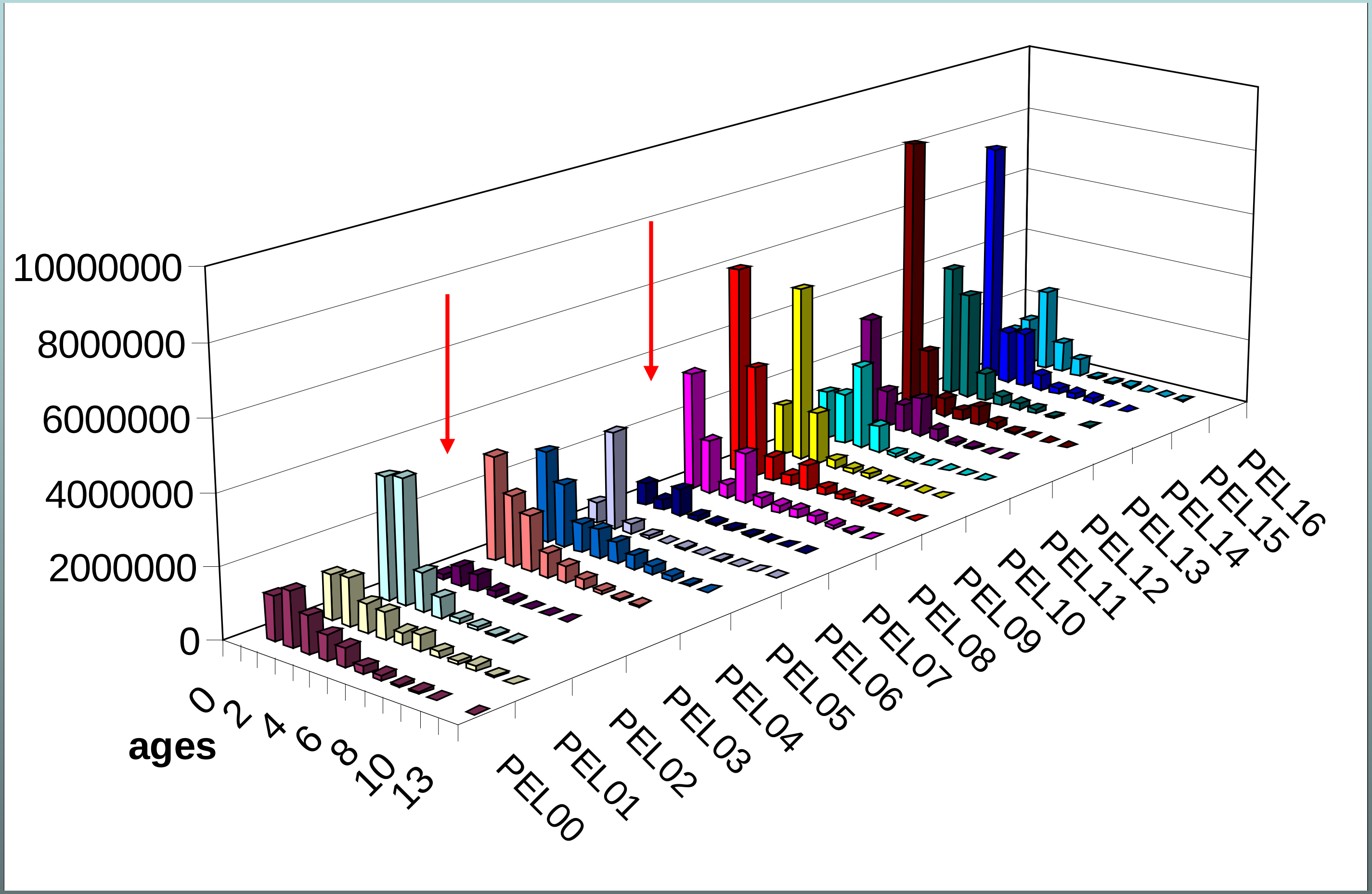
Almost sure : the end of the signal…

Quick elements to scrutinize sardine results from pelgas surveys in 2003 and 2007

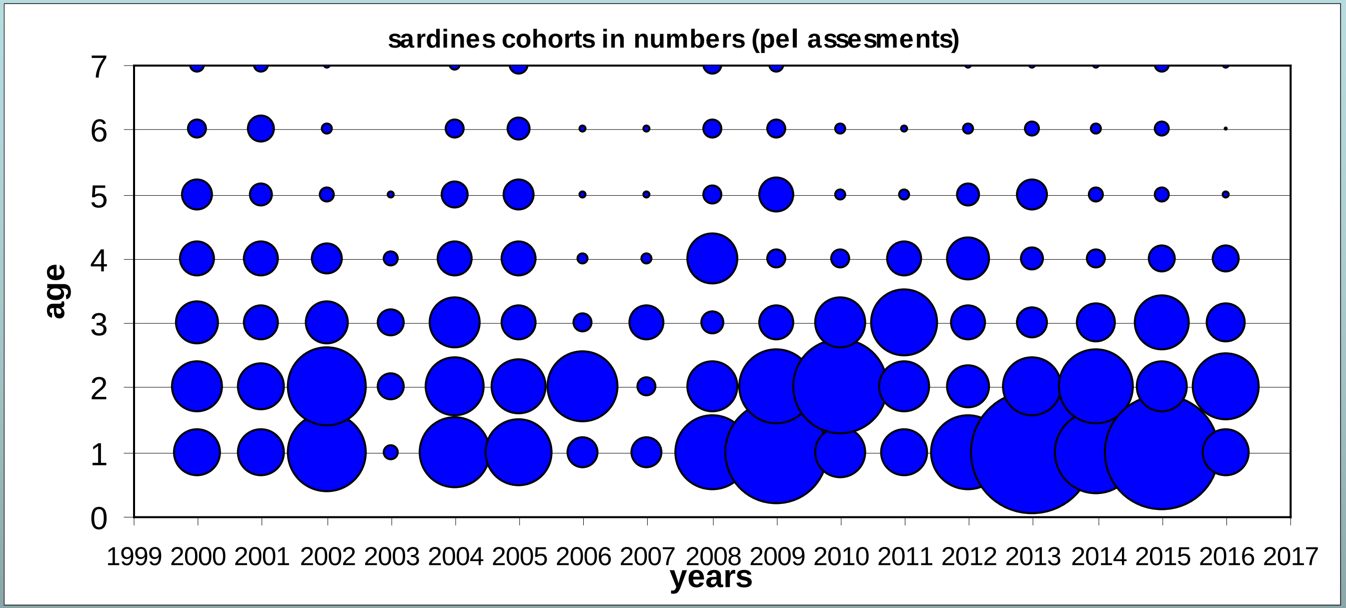
E. Duhamel, M.Doray, M. Huret…

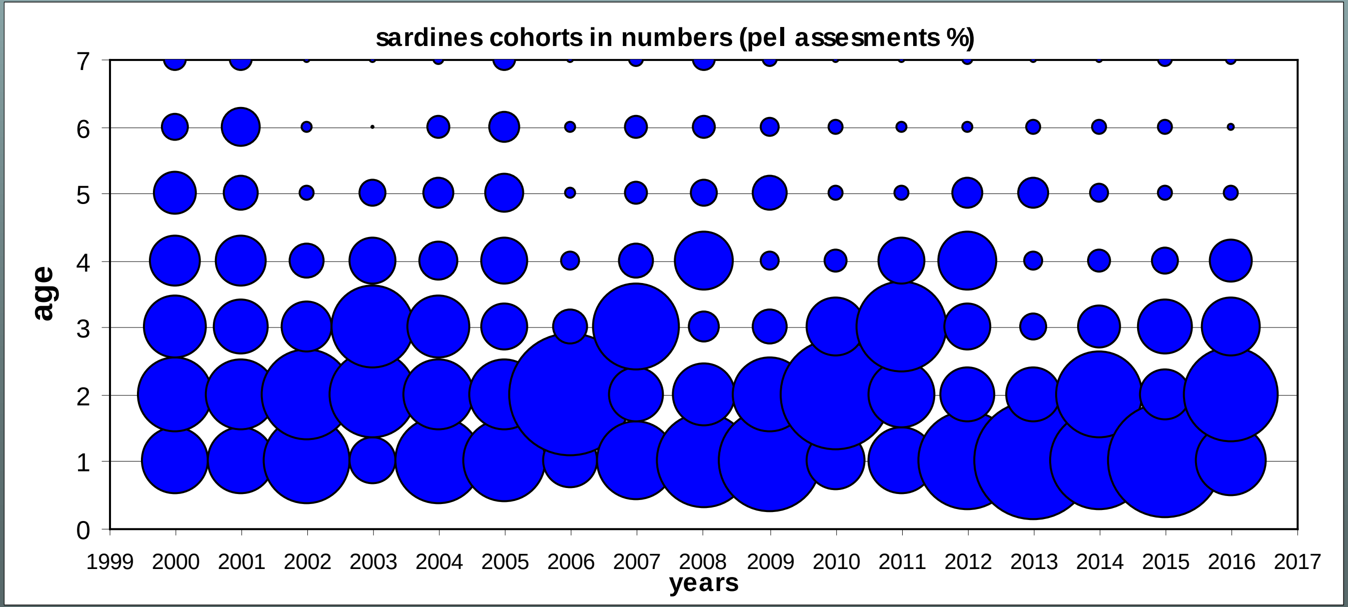


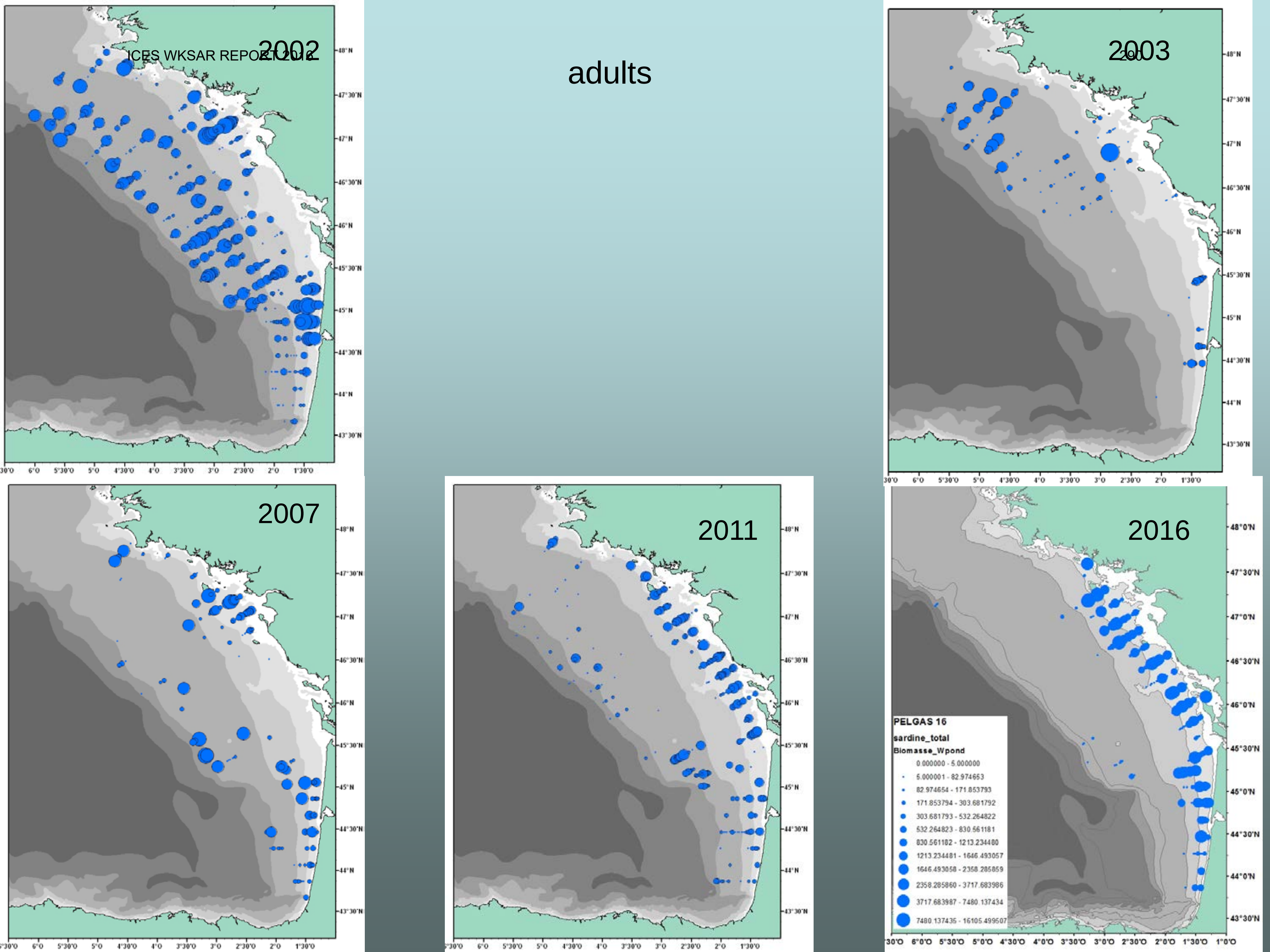
Tracking cohorts ?



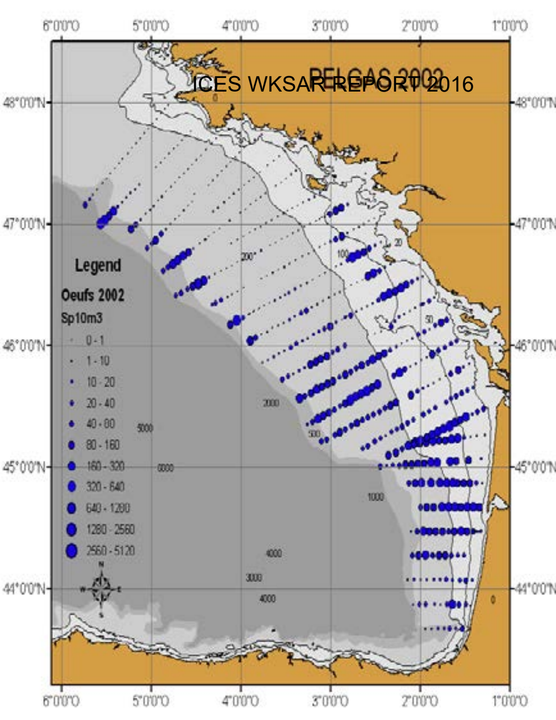
Tracking cohorts ? (again)

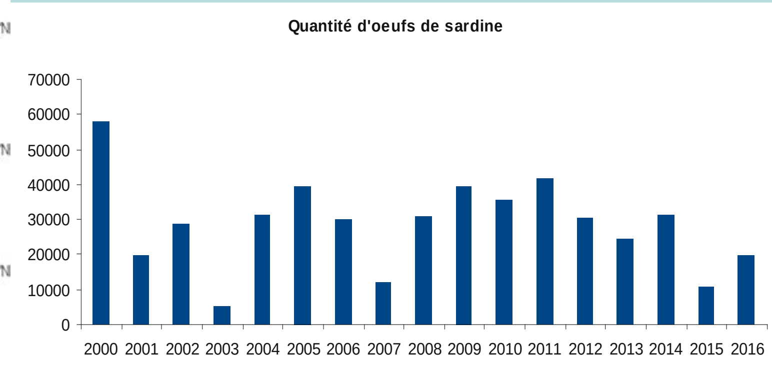


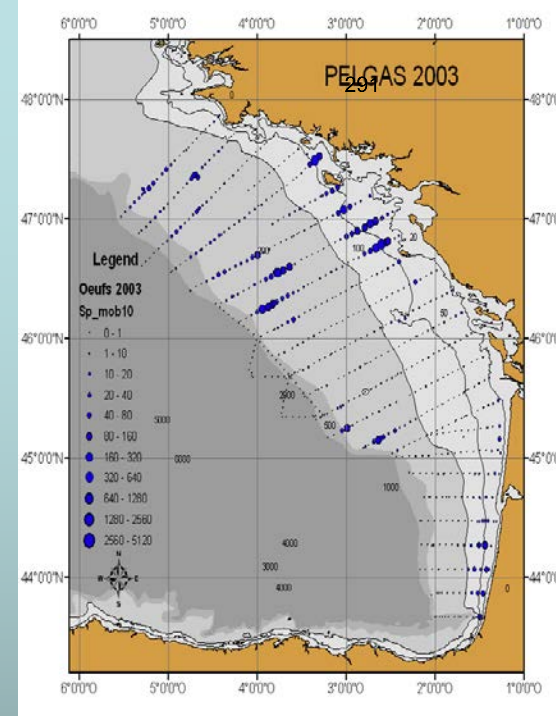


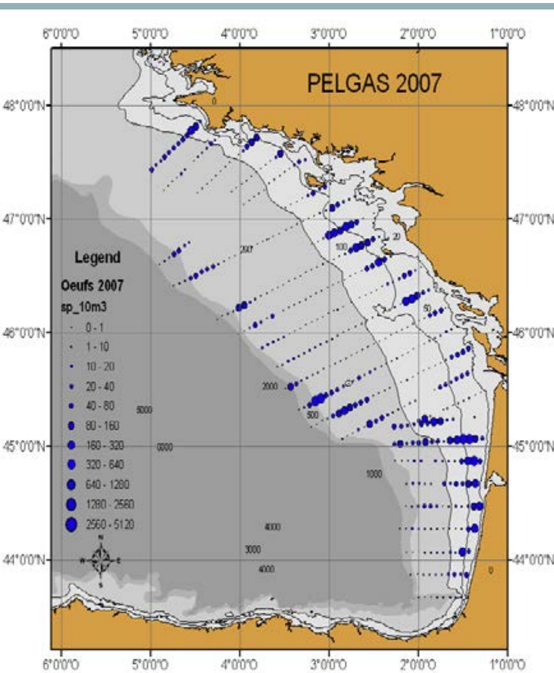

adults
2002
2003
2007
2011
2016
PELGAS 16
sardine_total
Biomasse_Wpond
0.000000 - 5.000000
5.000001 - 82.974653
82.974654 - 171.853793
171.853794 - 303.681792
303.681793 - 532.264822
532.264823 - 830.561181
830.561182 - 1213.234480
1213.234481 - 1646.493057
1646.493058 - 2358.285859
2358.285860 - 3717.683986
3717.683987 - 7480.137434
7480.137435 - 16105.499507

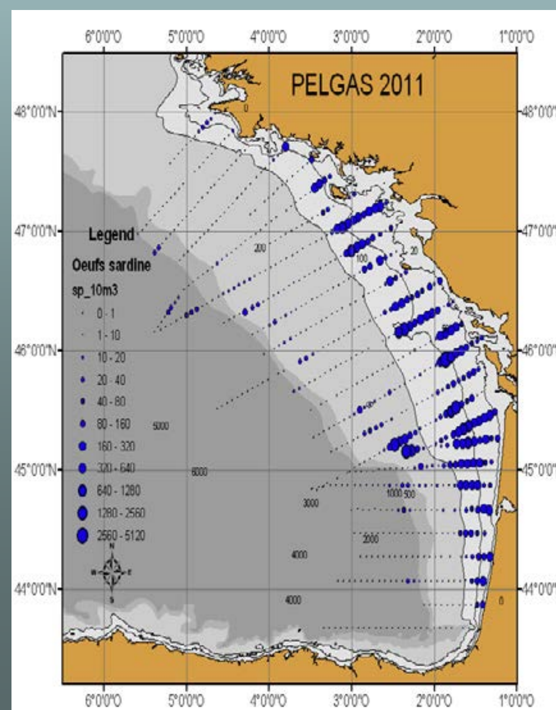
eggs

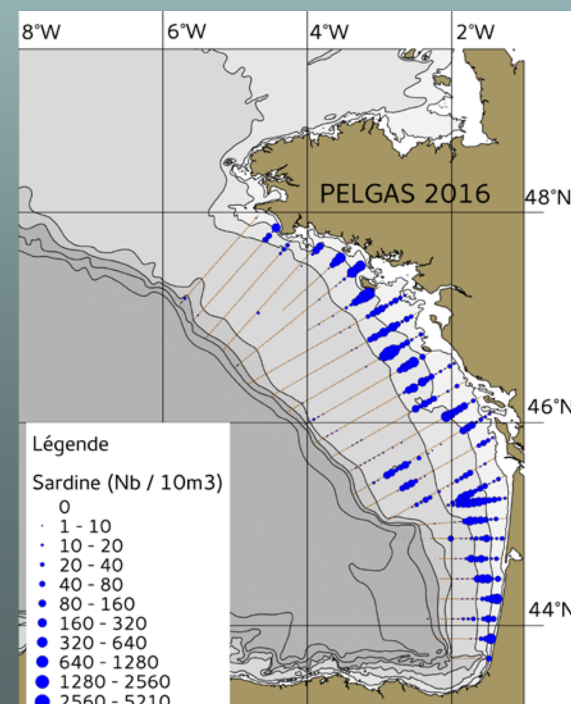

PELGAS 2002
Legend
Oeufs 2002
Sp10m3
0 - 1
1 - 10
10 - 20
20 - 40
40 - 80
80 - 160
160 - 320
320 - 640
640 - 1280
1280 - 2560
2560 - 5120


Quantité d'oeufs de sardine
70000
60000
50000
40000
30000
20000
10000
0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

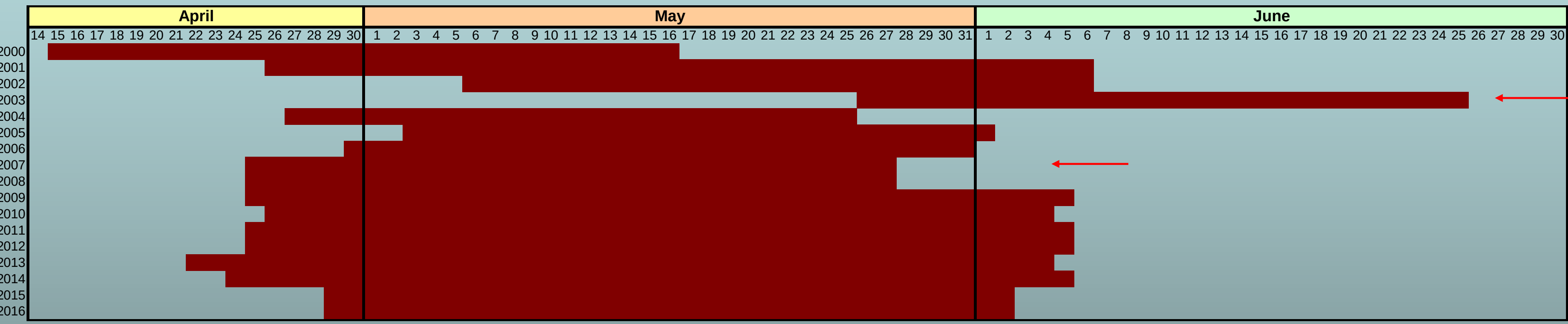

PELGAS 2003
Legend
Oeufs 2003
Sp_mob10
0 - 1
1 - 10
10 - 20
20 - 40
40 - 80
80 - 160
160 - 320
320 - 640
640 - 1280
1280 - 2560
2560 - 5120


PELGAS 2007
Legend
Oeufs 2007
sp_10m3
0 - 1
1 - 10
10 - 20
20 - 40
40 - 80
80 - 160
160 - 320
320 - 640
640 - 1280
1280 - 2560
2560 - 5120


PELGAS 2011
Legend
Oeufs sardine
sp_10m3
0 - 1
1 - 10
10 - 20
20 - 40
40 - 80
80 - 160
160 - 320
320 - 640
640 - 1280
1280 - 2560
2560 - 5120


8°W
6°W
4°W
2°W
48°N
46°N
44°N
PELGAS 2016
Légende
Sardine (Nb / 10m3)
0
1 - 10
10 - 20
20 - 40
40 - 80
80 - 160
160 - 320
320 - 640
640 - 1280
1280 - 2560
2560 - 5210

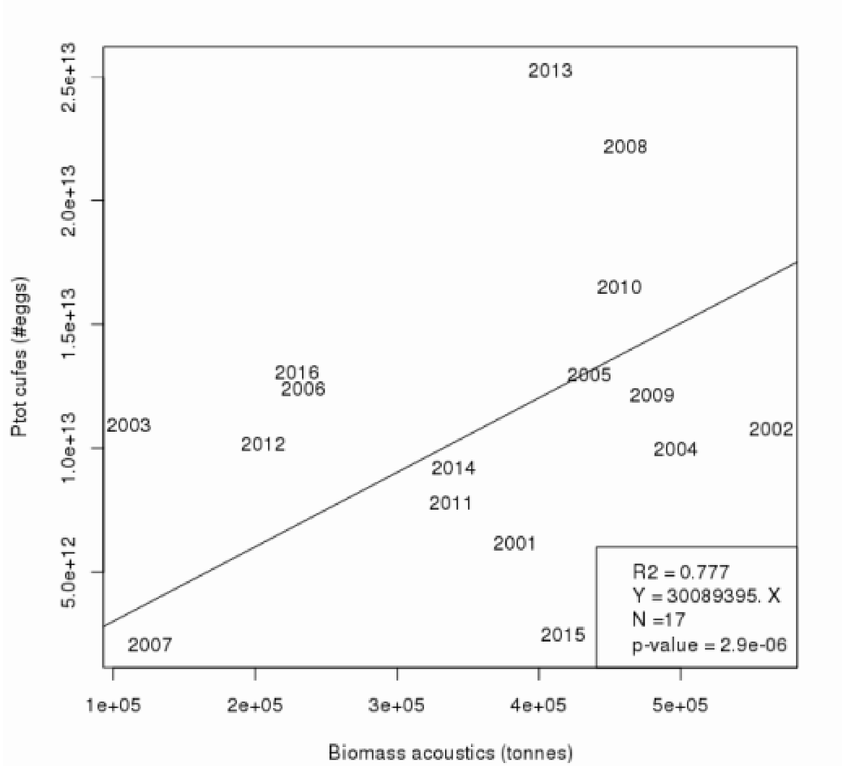
Period of the surveys

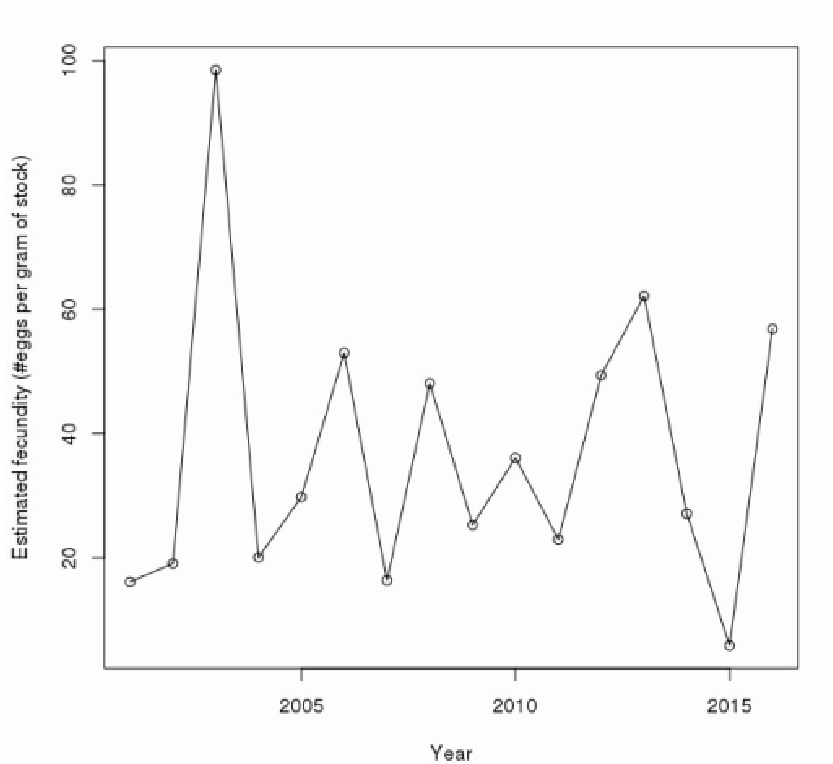


Ptot, acoustics and estimated fecundity

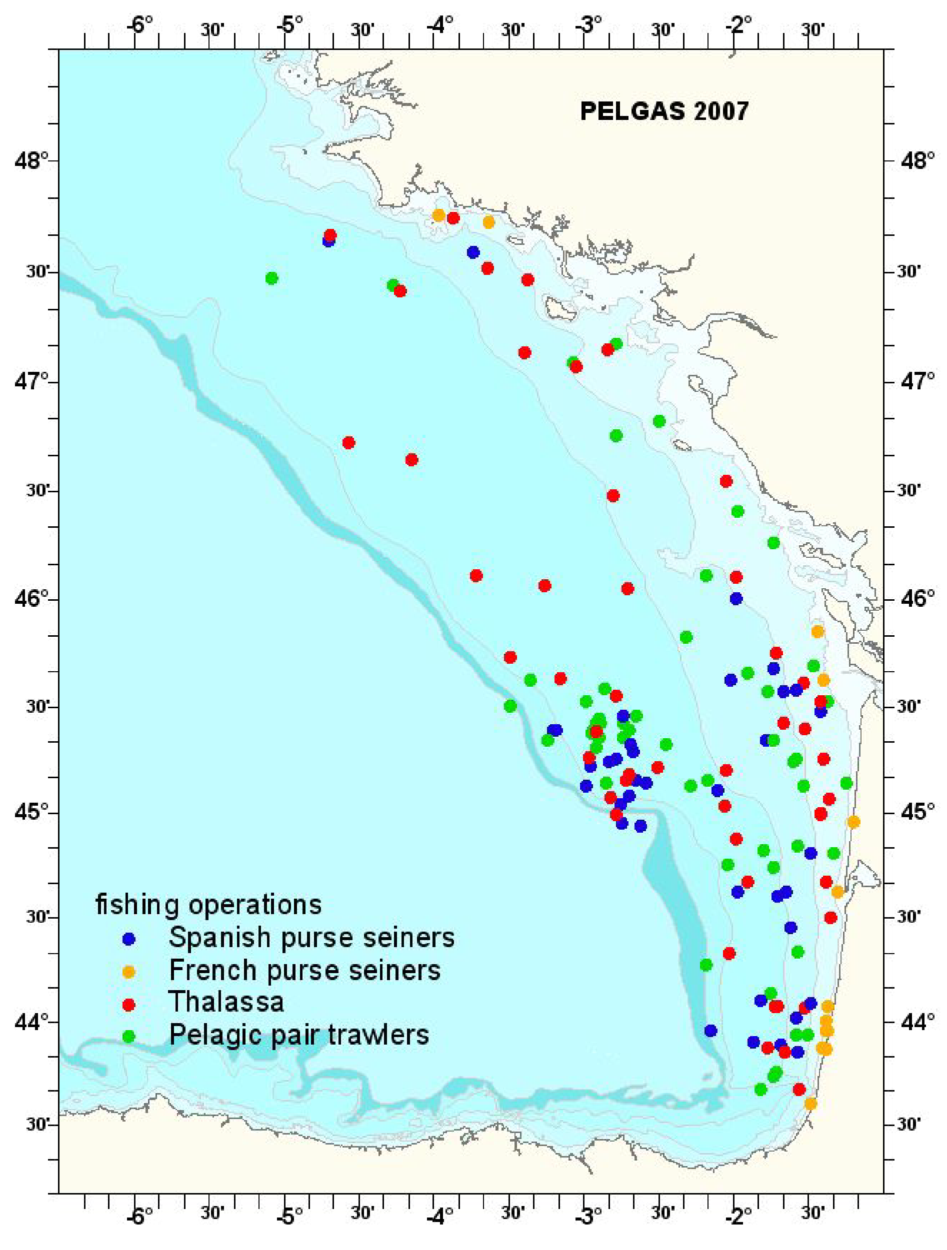
- Slope : average daily fecundity (DF)

  DF = 30 eggs g^{-1} d^{-1}



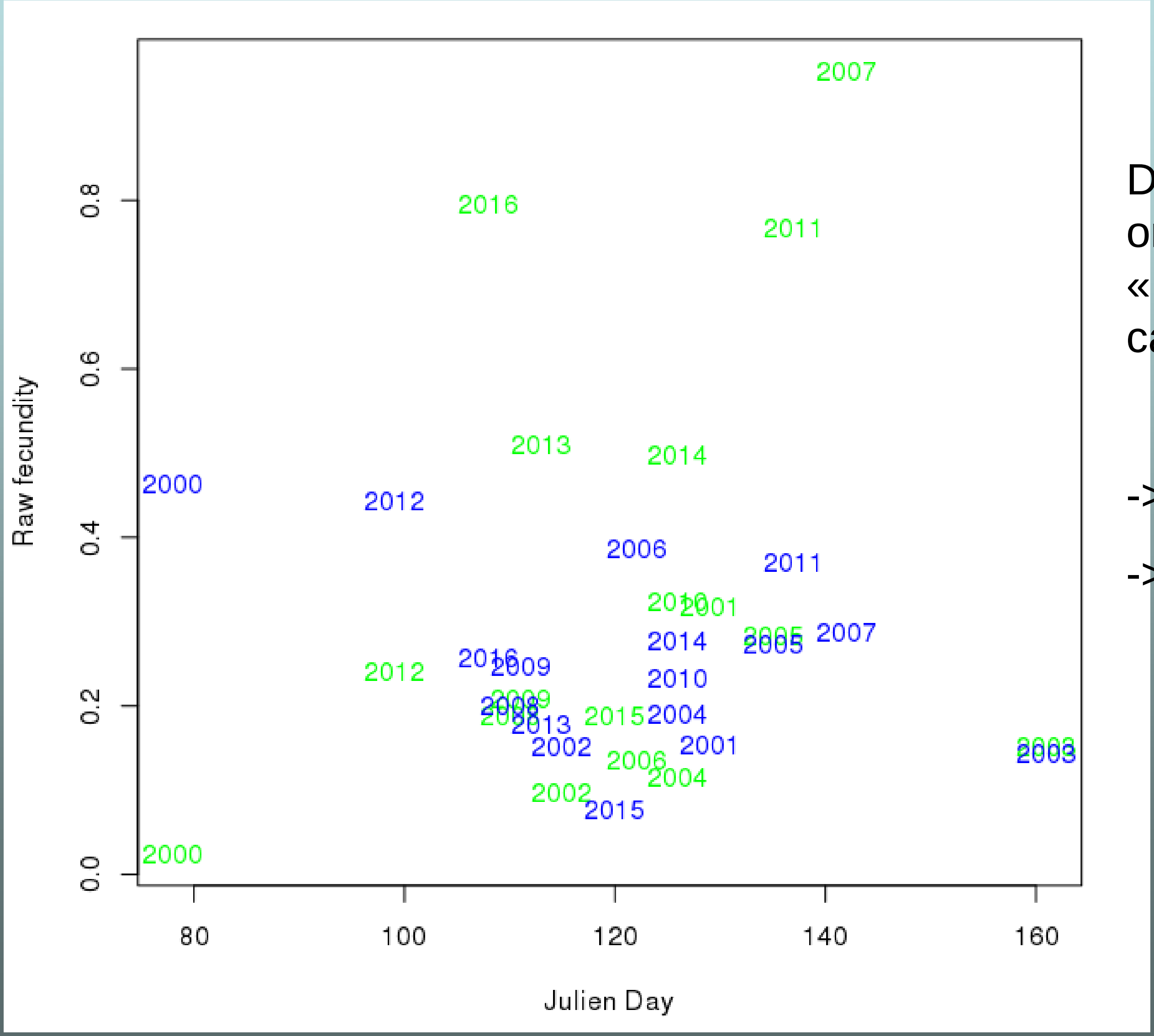


2003 : low row numbers of eggs but high in Ptot -> high uncertainty this year in the vertical model -> it'll be checked for Acegg



2007 = not a problem of number of fishing hauls, 1st year of consort survey

Hydro : 2003 and 2007 are the warmest years of the whole serie.



Dates recalculated based on the temperature :
« natural » dates instead of calendar dates.

-> green = anchovy

-> blue = sardine

Hypothesis : when temperature increase (« summer » condition), sardine move…

to North ? Offshore ? Coast ? …

An overview of the abundance and distribution of sardine (*Sardine pilchardus*) in the eastern Celtic Sea and western Channel

Jeroen van der Kooij, Serena Wright, Joana Silva

Introduction

The waters to the southwest of the British Isles are home to a diverse community of small pelagic fish. In VIIe and f they include a mixture of warm- and cold water species: sardine, anchovy, sprat and herring. Particularly sprat, sardine and horse mackerel are targeted by locally important fisheries which are thought to operate sustainably. However, most of these stocks are data limited (ICES, 2013). Recently these fisheries have started to catch anchovy opportunistically which have appeared in relatively large numbers in some years. Evidence has emerged that this northern anchovy is likely to be a separate population from those in the Bay of Biscay (Petitgas et al., 2012; Zarraonaindia et al., 2009, 2012). This area is also an important nursery for mackerel and, in consequence, it has been closed to mackerel directed trawling activities since the 1990s to avoid bycatch of juvenile mackerel. Large-scale changes in mackerel behaviour and distribution elsewhere have emphasized the lack of knowledge and it is not known what current role the area plays in the mackerel life cycle.

The western Channel and eastern Celtic Sea make up the northern-most limit of sardine spawning (Wallace & Pleasants, 1972). There appear to have been changes in the area however as in recent years, small numbers of eggs and larvae have also been observed in the southern North Sea, particularly along the Dutch and German coast (Kanstinger & Peck, 2009; Voss et al., 2009). In addition, spawning activity in the western Channel appears to have shifted from summer to autumn in recent years (Coombs et al., 2010).

Methods

All data were collected during the PELTIC survey series, as part of the UK Government funded project Poseidon. While the survey is currently not funded through the European DCF initiative, the survey is coordinated through two ICES working groups: Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VII, VIII and IX (WGACEGG) and International Pelagic Surveys (WGIPS). Details of the survey are provided elsewhere (ICES, 2015) but a short summary is provided here.

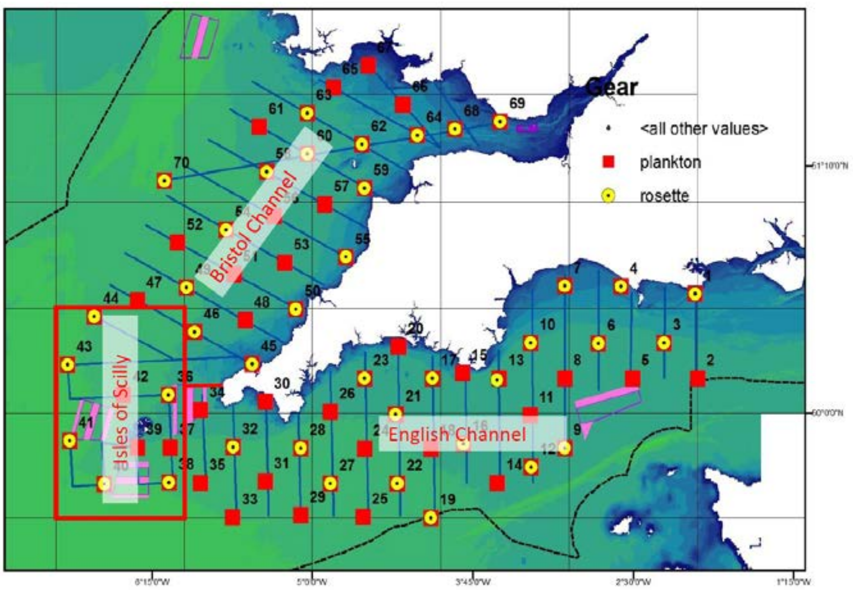


Figure 1. Overview of the survey area, with the acoustic transect (blue lines), plankton stations (red squares) and hydrographic stations (Yellow circles). Emboldened red lines delineate the three "ecoregions"

The PELTIC survey is carried out annually over ~18 days in October on board the RV 'Cefas Endeavour' (Table 1). The first of these surveys was conducted in 2012 and the last survey available for this report was 2015. In this report the 2012 survey was not included because it was conducted several weeks later, effectively sampling winter conditions and was therefore not comparable to the other surveys.

The survey follows a systematic parallel transect design with 10 nmi spaced transects running perpendicular to the coastline or bathymetry (Figure 1). Three main areas are identified in the survey, the western English Channel, The Isles of Scilly and the Bristol Channel.

Ichtyoplankton are sampled using a 270µm mesh ringnet of 1 m diameter at regular stations (indicated in red in Fig 1). The eggs and larvae of sardine are counted, staged into 5 categories (eggs) and measured (larvae). Volumes filtered are measured by flowmeters and used to calculated numbers per m^2.

Acoustic data were collected using a Simrad EK60 scientific echosounder, at a ping rate of 0.6 s-1 and pulse duration of 0.512 µs. Split-beam transducers are mounted on the vessel's drop keel and lowered to the working depth of 3.2 m below the vessel's hull or 8.2 m sub surface. Three operating frequencies are used during the survey (38, 120 and 200 kHz) for trace recognition purposes, with 38 kHz data used to generate the abundance estimate for clupeids (and other fish with swimbladder) and 200kHz for mackerel. All frequencies are calibrated at the start of the survey. Regular trawls are conducted to collect biological data and ground-truth acoustic marks for species and size information.

Table 1. Timing of the three Peltic Surveys

Survey	**Dates**
Peltic13	11-31 October 2013
Peltic14	30 Sept – 19 Oct 2014
Peltic15	3-21 October 2015

Acoustic data are processed in Myriax Echoview. An Echoview processing template is used with an algorithm developed to utilize the typical multifrequency response properties to separate four different echo-types: fish with a swimbladder, jellyfish and juvenile fish, fish without swimbladder and fluid-like zooplankton (*sensu* Ballon et al., 2011). For each Echoview processing file a duplicate processing file is created which contains a different algorithm specifically designed to extract mackerel. Details on the detection algorithm are described elsewhere (van der Kooij et al., 2016). The swimbladder-fish component is then further scrutinized and partitioned into species using expert knowledge and trawl information. The trawl catch composition is converted to acoustic equivalent values by species and size using published b20 values (Table 2), which are in turn used to raise the acoustic data attributed to fish with swimbladders for each 1 nmi interval.

To estimate the abundance, the allocated NASC values are averaged by stratum within the survey area. For each stratum, the unit area density of fish (SA) in number per square nautical mile (N*nmi-2) is calculated using standard equations (Foote et al., 1987, Toresen et al., 1998). Pending further analysis to identify ecologically relevant strata, survey stratification is based on ICES statistical rectangles with a range of 0.5 degrees in latitude and 1 degree in longitude, large squares 2° lat by 1° long or other geographical bounds.

Table 2: b_{20} values for each of the key species used to convert acoustic densities to abundance

Species	**b 20**
Sardina pilchardus (PIL)	-71.2
Sprattus sprattus (SPR)	-71.2
Engraulis encrasicolus (ANE)	-71.2
Trachurus trachurus (HOM)	-68.9

The biomass estimates of the four main species are further broken down by length group in the individual species section of the results. It is pointed out however that the length-based abundance and biomass estimates should be used with caution. In contrast to the partitioning of acoustic data into species, which combined trawl information, a multi-frequency algorithm as well as expert knowledge, partitioning into length categories is solely based on nearby trawl catches. In some instances, no trawl could be conducted due to for example the presence of static gear or bad weather, in which case trawl catches from further away were used. This may not have been representative for the size distribution. In addition, partitioning based on trawl catches assumes equal catchability of the different species and lengths. During the scrutiny process, supplementary information from the trawl headline sonar and GoPro footage was incorporated to establish catchability of the different species; however no equivalent level of detail could be obtained for the different lengths. For the same reason no attempts were made to further partition the biomass estimates by age groups although the age length relationships are provided.

Results and Summary

General

A rich species diversity of small pelagic fish is found in the waters to the SW of the UK. Dominant species are sardine and sprat, although anchovy and horse mackerel are also found in good numbers (Table 3). Small numbers of herring are found mixed in with other pelagic fish, mainly in the inshore coastal waters. Boarfish (*Capros aper*) is also found on occasion, but only in the deeper waters of the Isles of Scilly and north-western sections Bristol Channel transects. The latter included juvenile specimens. Most of the species observed were increasing overall, although the patterns varied between species and sub-region.

Table 3. Abundance estimates (tonnes) for the dominant pelagic species in each region per year. Three letter codes: SPR=sprat, ANE=anchovy, HER=herring, PIL=sardine, HOM= horse mackerel, BOF=Boarfish.

English Channel			
	2013	**2014**	**2015**
ANE	1,595	7,459	18,846
BOF	0	0	0
HER	4.9	45.27	56.11
HOM	9,378	53,491	37,882
PIL	56,995	122,277	99,395
SPR	77,039	79,578	56,781

Isles of Scilly			
	2013	**2014**	**2015**
ANE	0	0	0
BOF	0	15,777	0.19
HER	0	0	0
HOM	773	201	13,995
PIL	227	553	1,068
SPR	NA	7,646	1,200

Bristol Channel			
	2013	**2014**	**2015**
ANE	0	2.91	186
BOF	0	0.69	3.89
HER	969	257	3,931
HOM	2,030	591	14,346
PIL	3,592	5,944	55,754
SPR	24,555	57,232	147,553

Sardine, *Sardina pilchardus*

Sardine (pilchard) is widespread in the study area during the autumn, particularly in the western part of the English Channel (Fig 2). Sardine abundance in the Bristol Channel area increased from low numbers in 2013 to occupy most of the area in 2015, avoiding only the deeper offshore parts of the transects (Fig. 2, Tables 4, 5). This may suggest a density dependent northwards expansion of the population, possibly driven by juvenile fish settling after hatching in the area. The presence of large numbers of juvenile fish in all subareas, suggests that the area is an important nursery area for this species. In 2015 there was a noticeable absence of the largest sardine length classes (>20 cm) in the English Channel; although catchability issues were considered as a possible cause, the local ringnet fishery on sardines found a similar lack of these large fish in their landings, suggesting these large fish were not in the area.

The area constitutes the northern-most consistent spawning area for this species (Wallace and Pleasants, 1974). Good numbers of eggs were found in the western parts of the English Channel (Fig 3), corresponding to areas known to be have been key spawning sites also in late spring (Wallace and Pleasants, 1974).

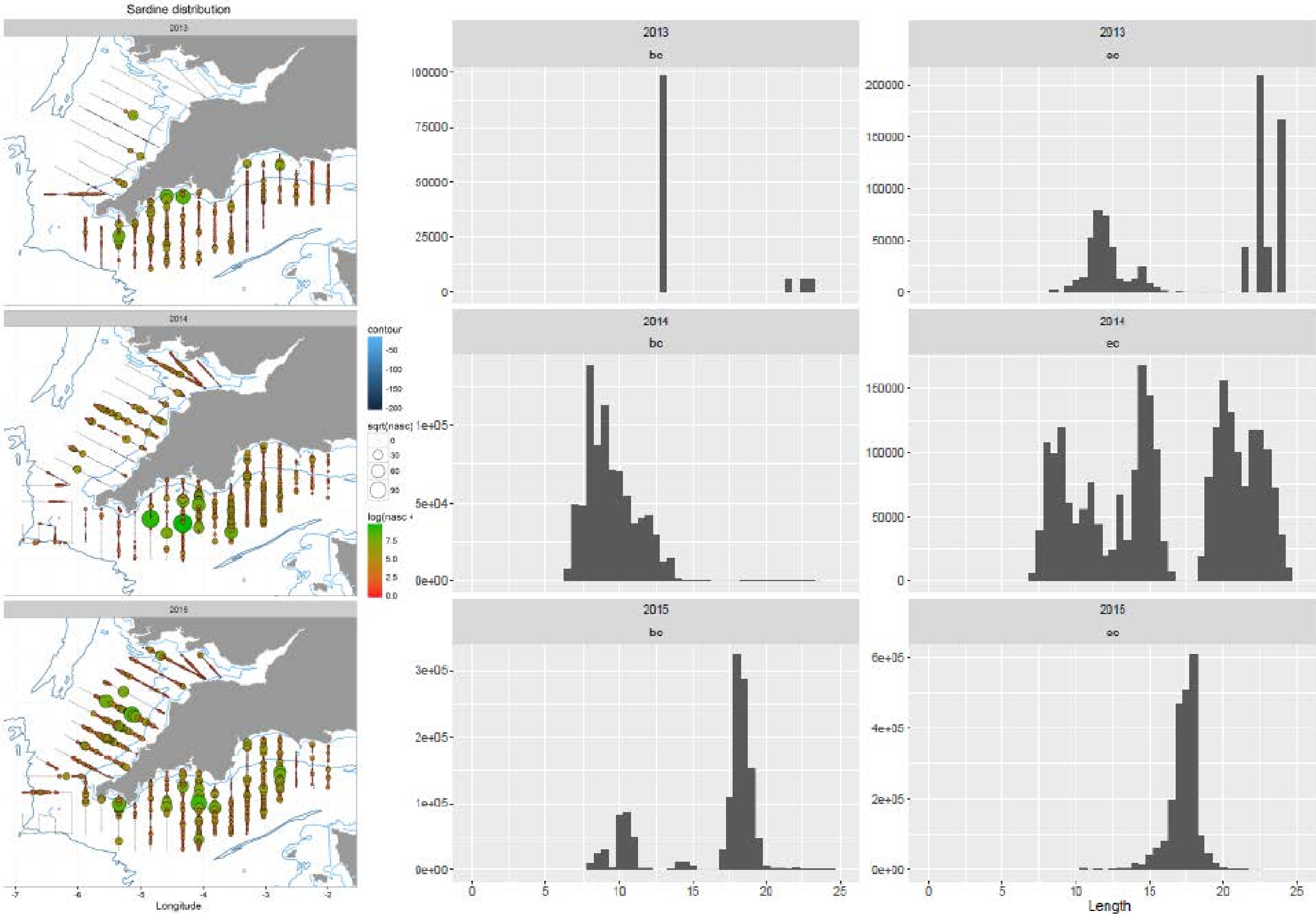


Figure 2. Acoustically derived sardine density distribution per 1 nmi sampling interval (left) and numbers of sardines (in 1000s) per length category for the Bristol Channel (BC, centre) and English Channel (EC, right) regions for the years 2013 (top) to 2015 (bottom). Please note the different scales on the y axis.

	2013			2014			2015		
Length	**English Channel**	**Bristol Channel**	**Isle of Scilly**	**English Channel**	**Bristol Channel**	**Isle of Scilly**	**English Channel**	**Bristol Channel**	**Isle of Scilly**
4	0	0	0	0	0	0	0	0	0
4.5	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
5.5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
6.5	0	0	0	0	7349021	0	0	0	0
7	0	0	0	5830301	49363214	0	0	0	0
7.5	0	0	0	39145237	47913770	0	0	0	0
8	0	0	0	108435700	138613600	0	0	9974040	0
8.5	2113593	0	0	98916170	87080040	0	0	22826810	0
9	0	0	0	119339600	112454600	529614	0	30894130	0
9.5	6400882	0	0	60138518	70707416	1935150	0	4614589	0
10	10633812	0	0	45067106	70638891	23039925	0	81525889	0
10.5	13561567	0	0	55548177	54246267	5207642	3471761	85492116	0
11	52529088	0	0	76218676	37079356	4119928	0	49439141	0
11.5	79704366	0	0	44081394	40340169	20902063	975972	2846585	0
12	73547070	0	0	19044070	42138560	355300	0	2842399	0
12.5	42759290	0	0	24282283	29463336	62422	312112	0	0
13	12454566	98258809	0	67012177	11793261	0	3637174	0	0
13.5	9091138	0	0	32405507	14125477	0	3274765	244385	195508
14	11711280	0	0	85766621	1393163	0	16674424	10666407	9099098
14.5	23905644	0	0	168196064	77869	0	15768381	12147493	10317583
15	8562406	0	0	144232853	69897	0	40400576	6570336	5591775
15.5	4879466	0	0	102185466	62961	0	61701637	0	0
16	995722	0	0	30042361	28449	0	79970718	0	0
16.5	0	0	0	6137751	0	0	197749061	0	0
17	23445	0	0	0	0	0	468687383	30079832	0
17.5	0	0	0	0	0	0	507010928	108549024	1645654
18	0	0	0	0	0	0	607996089	324653934	2695520
18.5	0	0	0	18020435	17895	0	96544433	286966920	2272686
19	0	0	0	80996774	32865	0	43152268	152068198	1446078
19.5	0	0	0	120165582	60491	0	17905367	46472292	0
20	0	0	0	156183602	83677	0	8019071	5480860	0
20.5	0	0	0	131726983	64433	0	760310	2731962	0
21	0	0	0	100008790	47720	0	1049836	2827399	0
21.5	42076927	5886123	741297	73189290	11064	0	685977	44257	0
22	0	0	0	118020632	10279	0	0	3021953	0
22.5	208588100	5891888	736486	117569900	9565	0	0	373025	0
23	42084380	5892348	739886	101667500	8914	0	0	240686	0
23.5	0	0	0	72530039	0	0	0	232975	0
24	166507933	0	0	36149697	0	0	0	85552	0
24.5	0	0	0	10126319	0	0	0	131038	0
25	0	0	0	1446507	0	0	0	47762	0
Total Numbers	**812130674**	**115929167**	**2217670**	**2469828082**	**815286220**	**56152045**	**2175748242**	**1284091990**	**33263902**
Numbers (M)	**812**	**116**	**2**	**2470**	**815**	**56**	**2176**	**1284**	**33**

Table 4. Sardine numbers by 0.5 cm length category for each of the three regions between 2013-2015.

Length	2013 English Channel	2013 Bristol Channel	2013 Isle of Scilly	2014 English Channel	2014 Bristol Channel	2014 Isle of Scilly	2015 English Channel	2015 Bristol Channel	2015 Isle of Scilly
4	0	0	0	0	0	0	0	0	0
4.5	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
5.5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
6.5	0	0	0	0	15	0	0	0	0
7	0	0	0	15	127	0	0	0	0
7.5	0	0	0	125	153	0	0	0	0
8	0	0	0	424	542	0	0	39	0
8.5	10	0	0	468	412	0	0	108	0
9	0	0	0	676	637	3	0	175	0
9.5	43	0	0	404	475	13	0	31	0
10	84	0	0	356	558	182	0	644	0
10.5	125	0	0	512	500	48	32	788	0
11	561	0	0	814	396	44	0	528	0
11.5	980	0	0	542	496	257	12	35	0
12	1035	0	0	268	593	5	0	40	0
12.5	685	0	0	389	472	1	5	0	0
13	226	1783	0	1216	214	0	66	0	0
13.5	186	0	0	663	289	0	67	5	4
14	269	0	0	1970	32	0	383	245	209
14.5	614	0	0	4320	2	0	405	312	265
15	245	0	0	4127	2	0	1156	188	160
15.5	155	0	0	3246	2	0	1960	0	0
16	35	0	0	1056	1	0	2811	0	0
16.5	0	0	0	238	0	0	7668	0	0
17	1	0	0	0	0	0	19991	1283	0
17.5	0	0	0	0	0	0	23723	5079	77
18	0	0	0	0	0	0	31127	16621	138
18.5	0	0	0	1007	1	0	5395	16036	127
19	0	0	0	4929	2	0	2626	9254	88
19.5	0	0	0	7946	4	0	1184	3073	0
20	0	0	0	11199	6	0	575	393	0
20.5	0	0	0	10222	5	0	59	212	0
21	0	0	0	8383	4	0	88	237	0
21.5	3803	532	67	6615	1	0	62	4	0
22	0	0	0	11482	1	0	0	294	0
22.5	21808	616	77	12292	1	0	0	39	0
23	4721	661	83	11405	1	0	0	27	0
23.5	0	0	0	8717	0	0	0	28	0
24	21409	0	0	4648	0	0	0	11	0
24.5	0	0	0	1391	0	0	0	18	0
25	0	0	0	212	0	0	0	7	0
Total Numbers	**56995**	**3592**	**227**	**122277**	**5944**	**553**	**99395**	**55754**	**1068**
Numbers (M)		**3819**			**128774**			**156217**	

Table 5. Sardine biomass per 0.5 cm length category for each of the three regions between 2013-2015

	2013						2014								2015								
Lgroup (cm)/Age	0	1	2	3	4	Total number	0	1	2	3	4	5	6	Total number	0	1	2	3	4	5	6	7	Total number
6.5							3							3									
7							8							8									
7.5							13							13									
8							16							16	2								2
8.5	1					1	20							20	2								2
9							20							20	2								2
9.5	2					2	18							18	2								2
10	5					5	20							20	4								4
10.5	5					5	18							18	3								3
11	9	3				12	14							14	3								3
11.5	5	4				9	16							16	4								4
12	2	8				10	12							12	1								1
12.5	1	11				12	10							10	2								2
13	1	12				13	10							10	3								3
13.5		10				10	11	1						12	6								6
14		20				20	9	3						12	14								14
14.5		21				21	1	4						5	14								14
15		14				14	2	5						7	24	2							26
15.5		13				13	2	4						6	18	2							20
16		11				11	3	2						5	11	15							26
16.5		2				2	1	1						2		27	2						29
17		3				3										24	11						35
17.5		1				1			1					1		27	14						41
18																25	16						41
18.5								1	2					3		12	16	2					30
19			1			1			7					7		9	15	1					25
19.5			1			1		2	3					5		6	8	3					17
20			1			1		2	2	1				5		1	6	2					9
20.5								1	8		1			10			1	2					3
21								1	3	5	1			10			3	3					6
21.5					1	1		1	1	3	3			8			1	2	1	1		1	6
22									2	6	1			9			1	1	3	1			6
22.5				1		1			1	2	2	1	1	7				2	1	4			7
23					1	1				2	3	1	1	7					4		1		5
23.5										1	5			6				1	2	2		1	6
24					1	1					5			5					1	1			2
24.5										1	3	1		5						2	1		3
25													1	1								1	1
25.5																							
26																					1		1

Table 6. Numbers of sardine aged per 0.5 cm length class per year as collected during the October Peltic survey series.

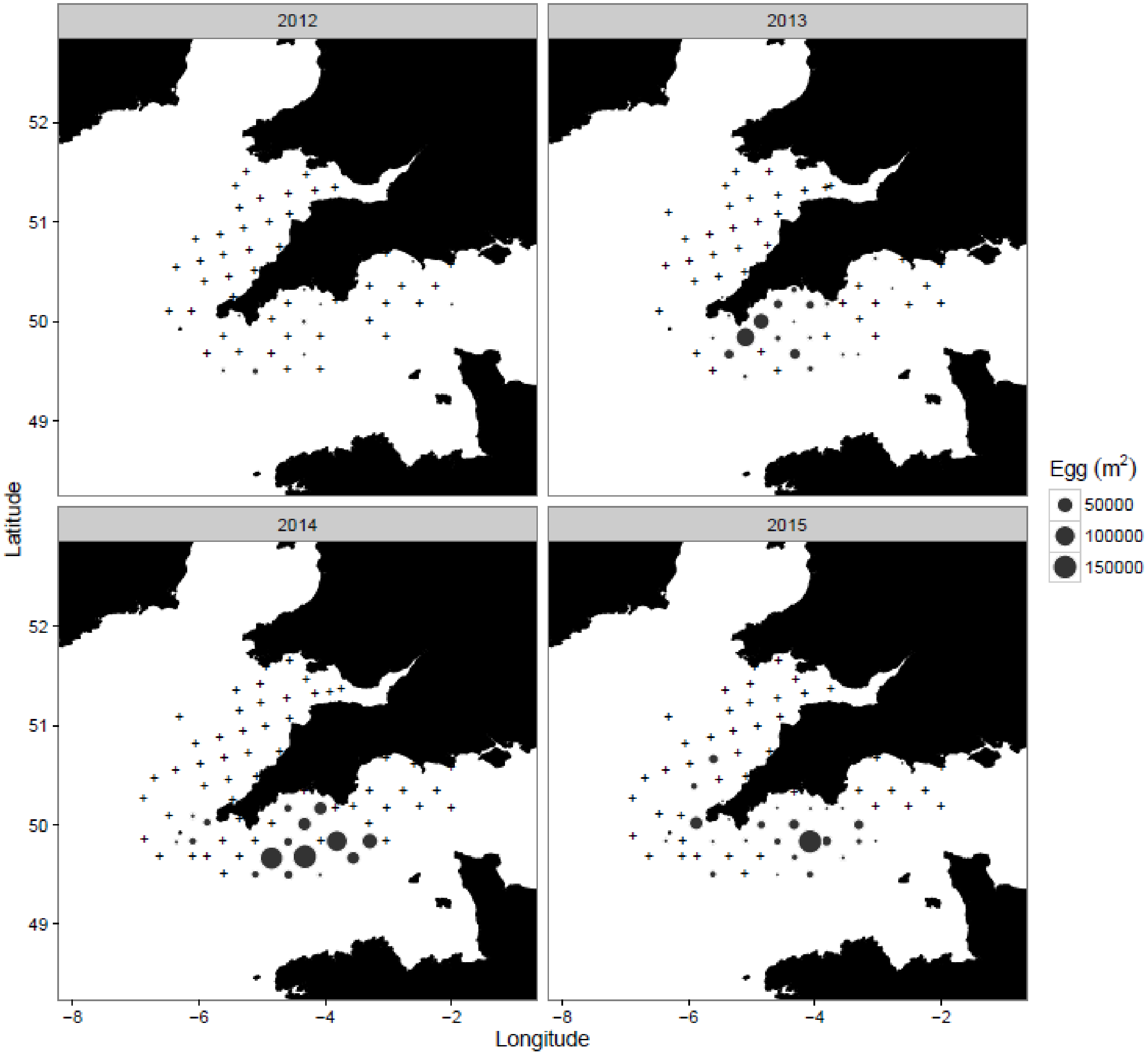


Figure 3. Distribution and abundance of sardine eggs (numbers per m2) as collected between 2012-2015

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Sardine data in the SW

Jeroen van der Kooij

WKSPRAT

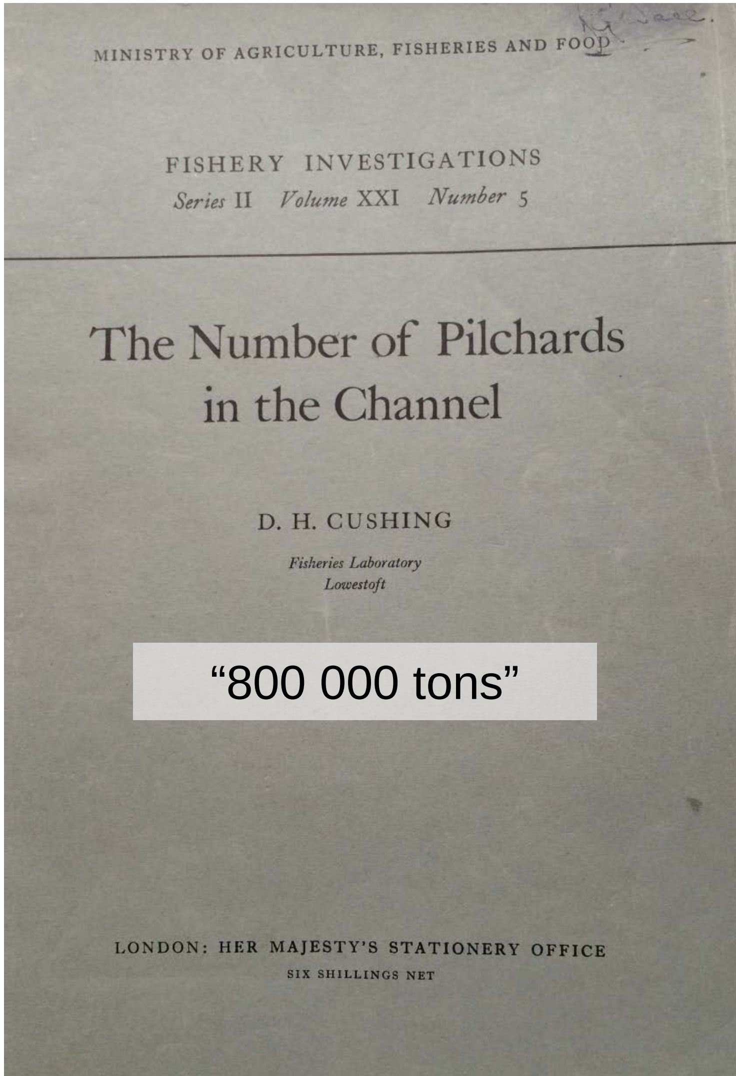
Cefas

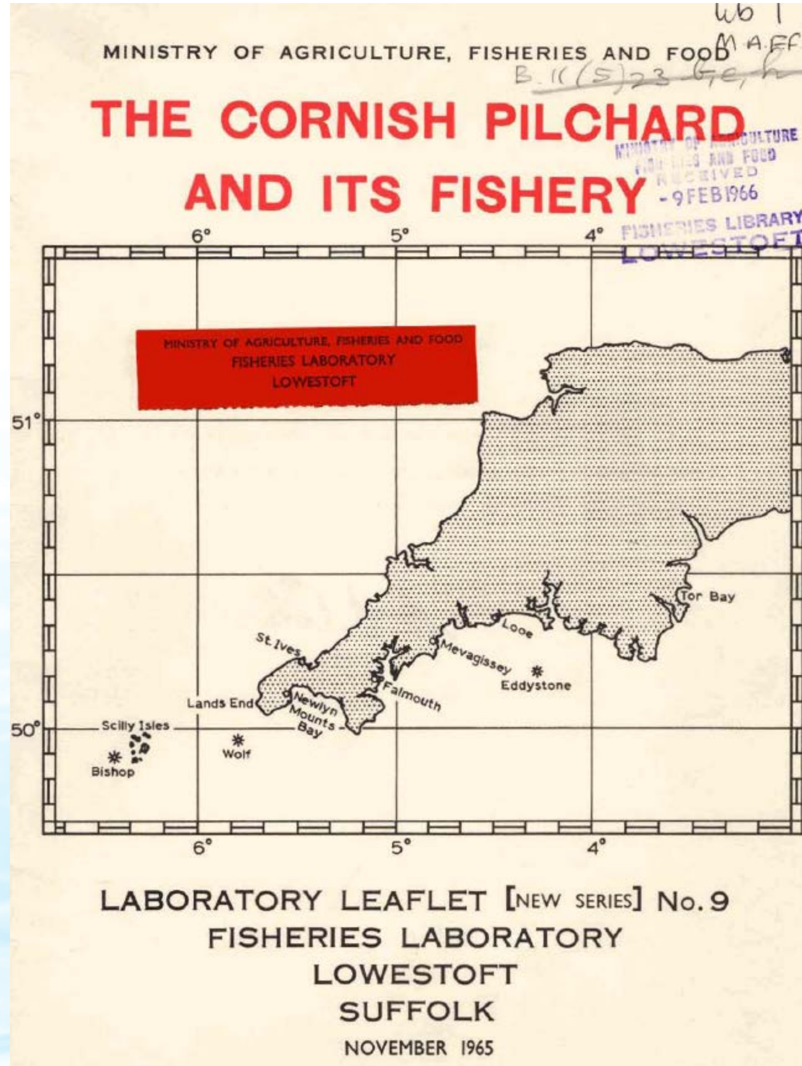
Scientific questions

- Cornish and Biscay sardines: are they part of the same stock?
- Eggs and larvae in the Western Channel and Celtic Sea: where are they transported?
- Where are the juveniles?
- Biomass of Cornish sardine: can we estimate it?

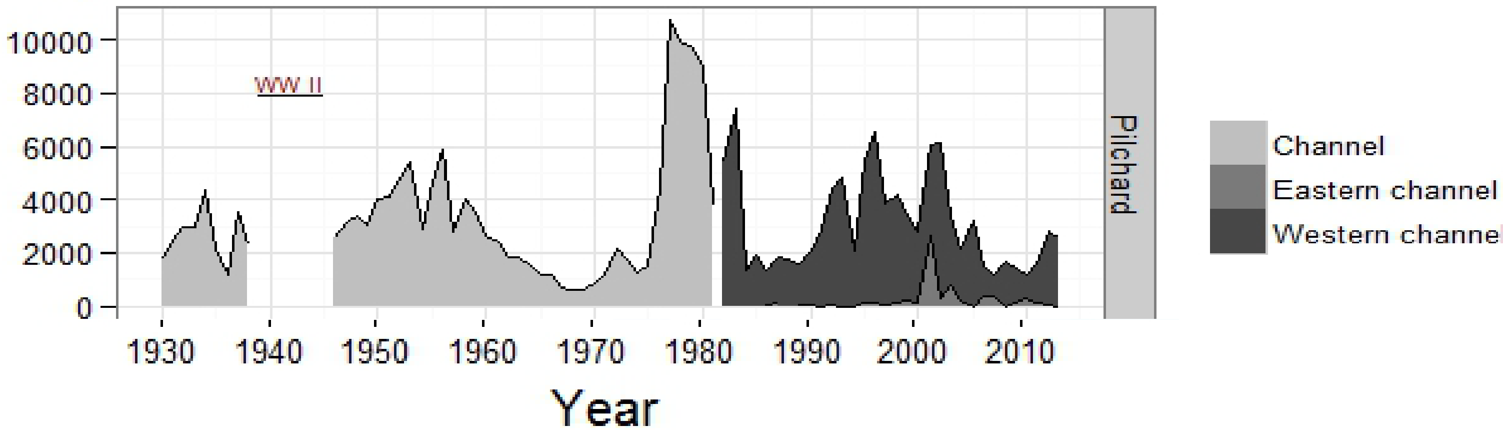
Cefas

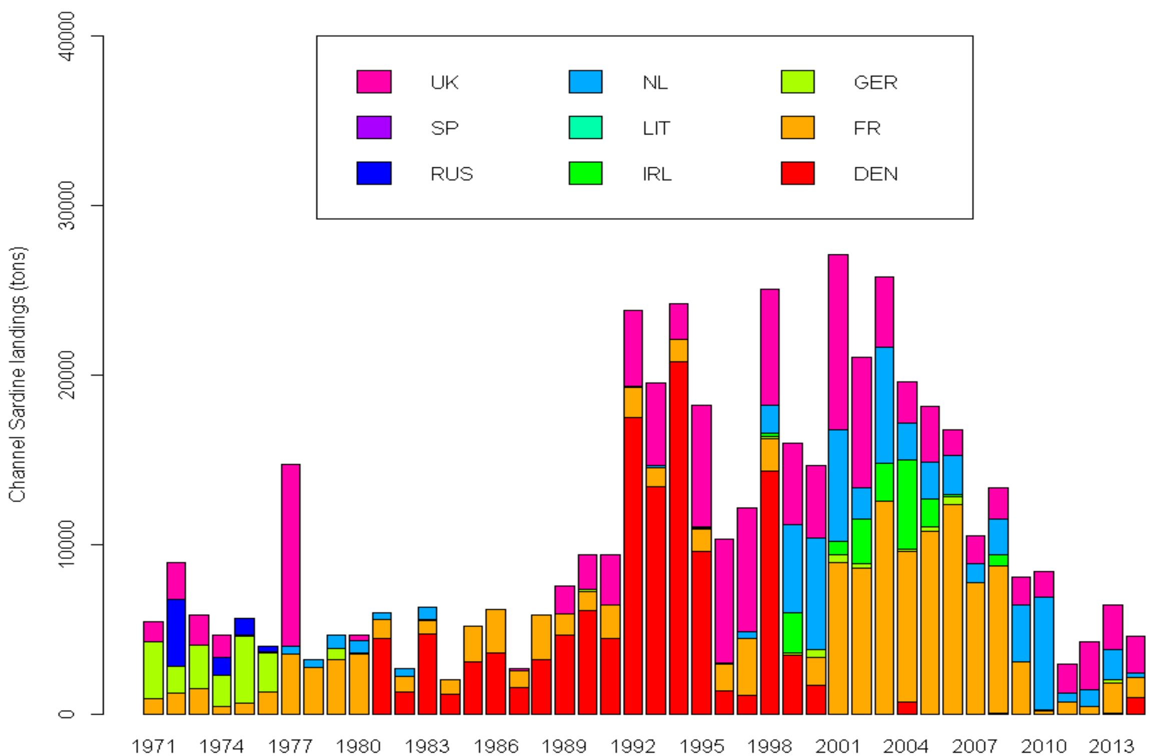
Historic work





Landings

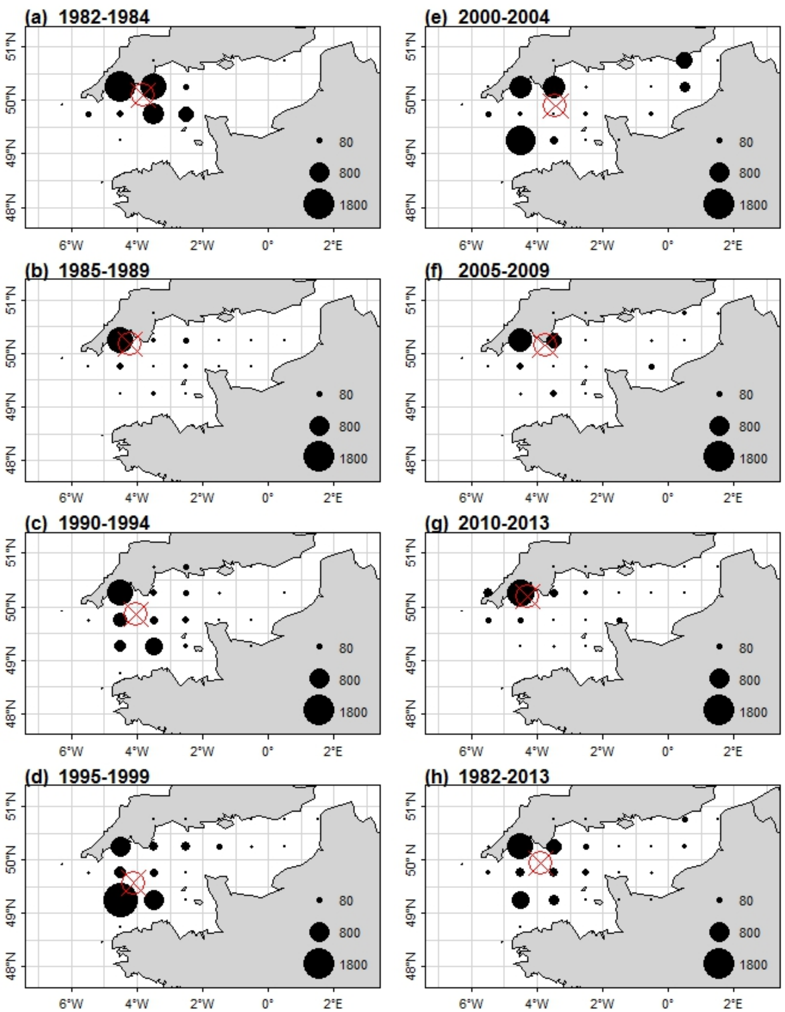




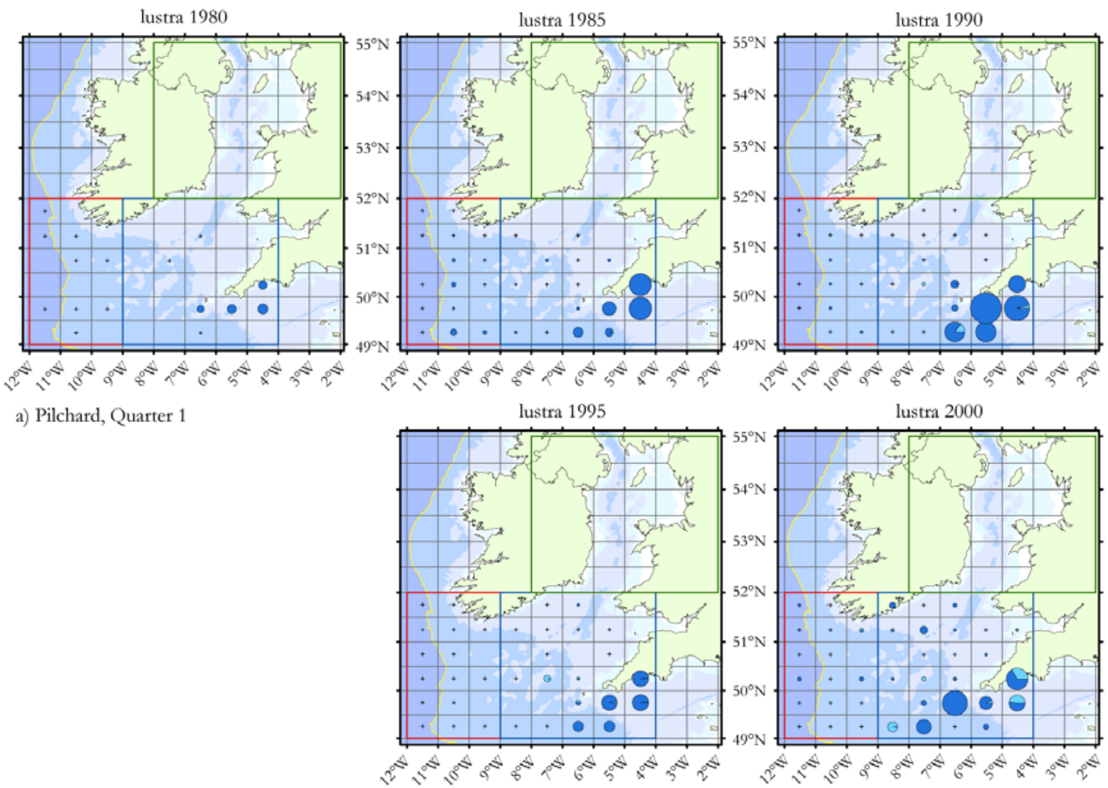
Cefas

Distribution

Landings



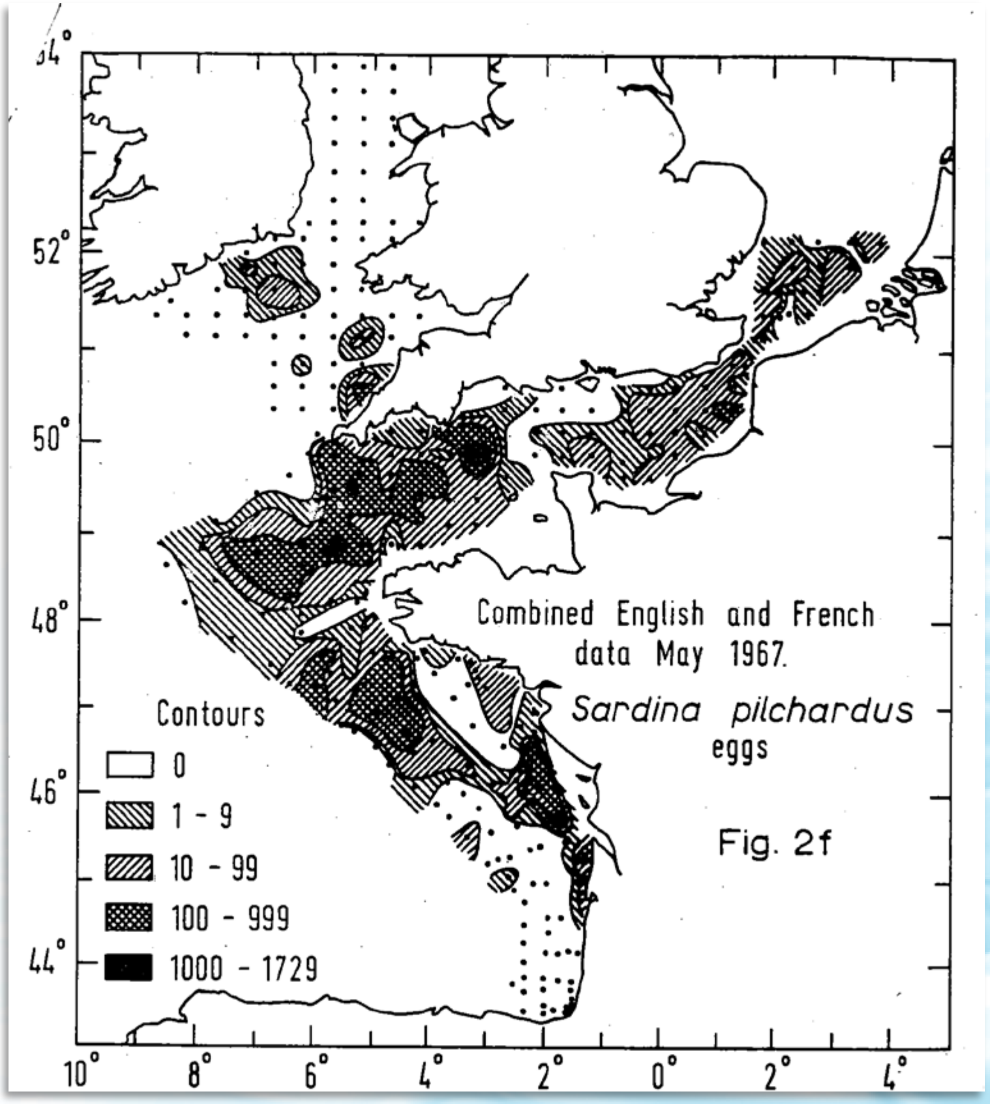
Bottom Trawl Survey



Cefas

Spawning

- **Important spawning area (Wallace & Pleasants 1972)**



Cefas

EFF Peltic Surveys: May-June 2010 & 2011

Assessment of pelagic fish resources in the Celtic Sea and western English Channel

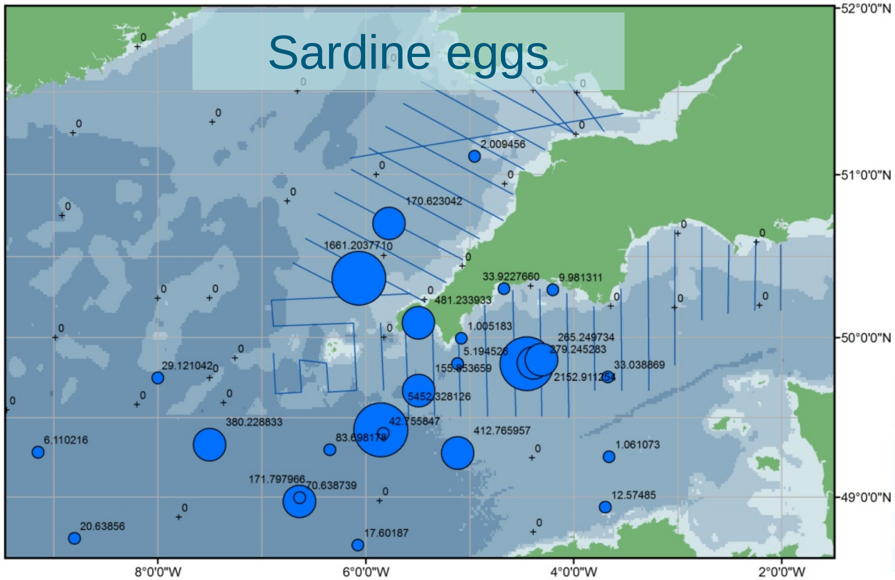
Cefas

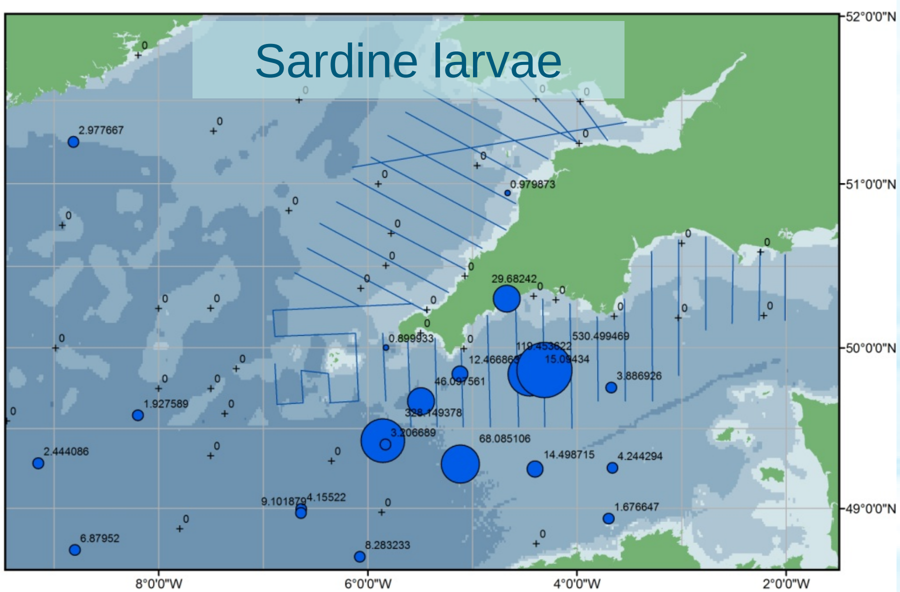
Peltic survey: Genetic study

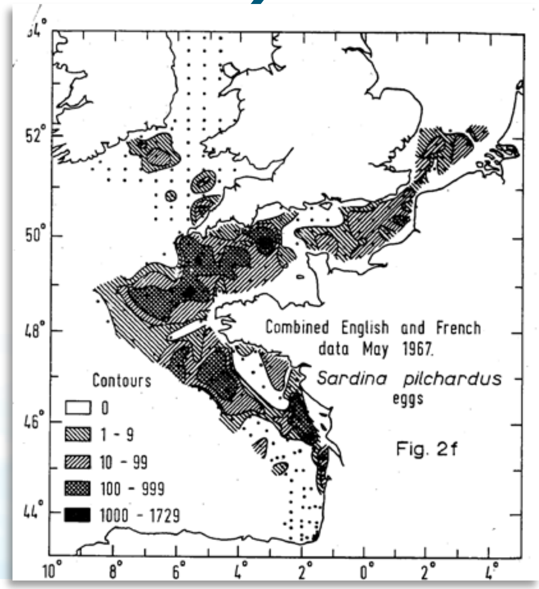
- High resolution nuclear microsatellite DNA markers were employed to investigate genetic population structuring of anchovy and sardine in Eastern Atlantic waters and to subsequently infer patterns of stock connectivity.
- The study revealed no genetic differentiation between sardine samples from Biscay and the English Channel.
- However, It cannot be ruled out that Cornwall and Biscay may harbour demographically independent stock units.

Cefas

Results 2011 (summer)







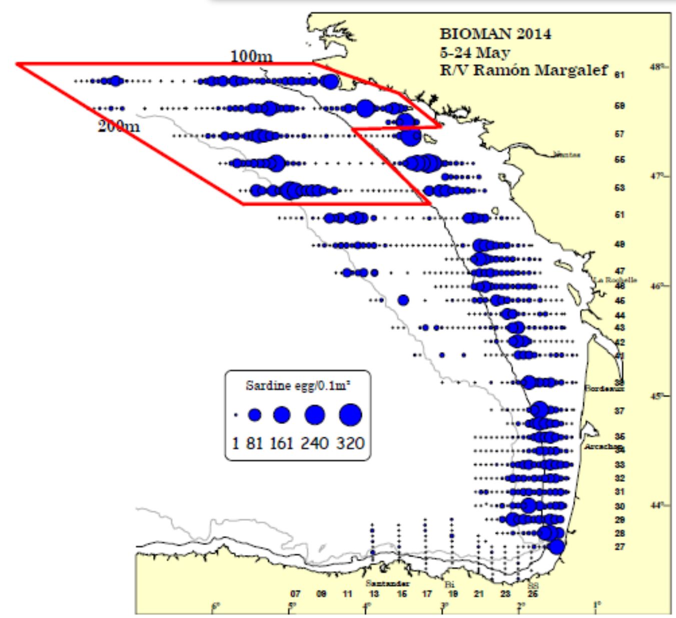


Figure 6.2.2.1.2Distribution of sardine egg abundances (eggs per 0.1m²) from the DEPM survey BIOMAN2014 obtained with PairoVET. The red line represents the stations removed for assessment propose in VIIIa, b, d.

Spawning

- **Changes in spawning? Coombs *et al*., 2010**
  - Autumn more important

Summer

Autumn

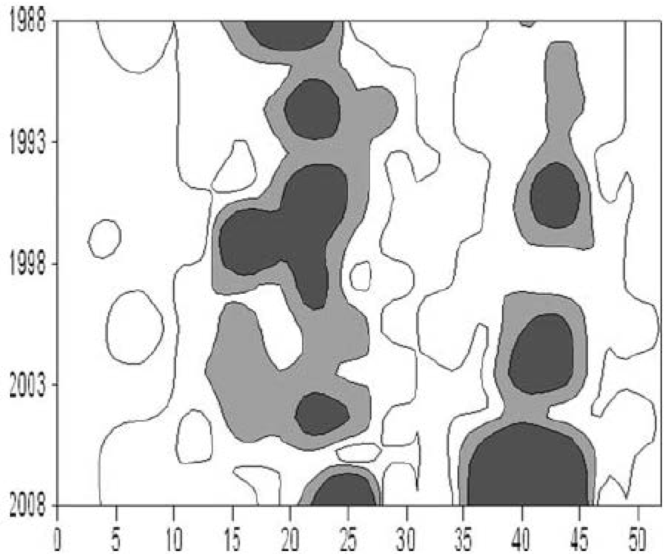


Fig. 1. Contoured abundance of sardine eggs at station L5 by weeks (*x*-axis) over the years 1988–2008; contour levels 1, 50 and 150 eggs m^{-2}.

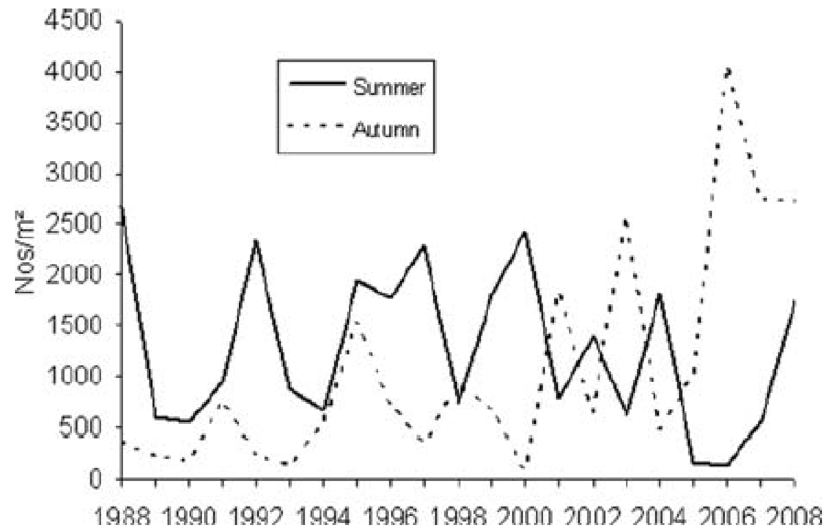
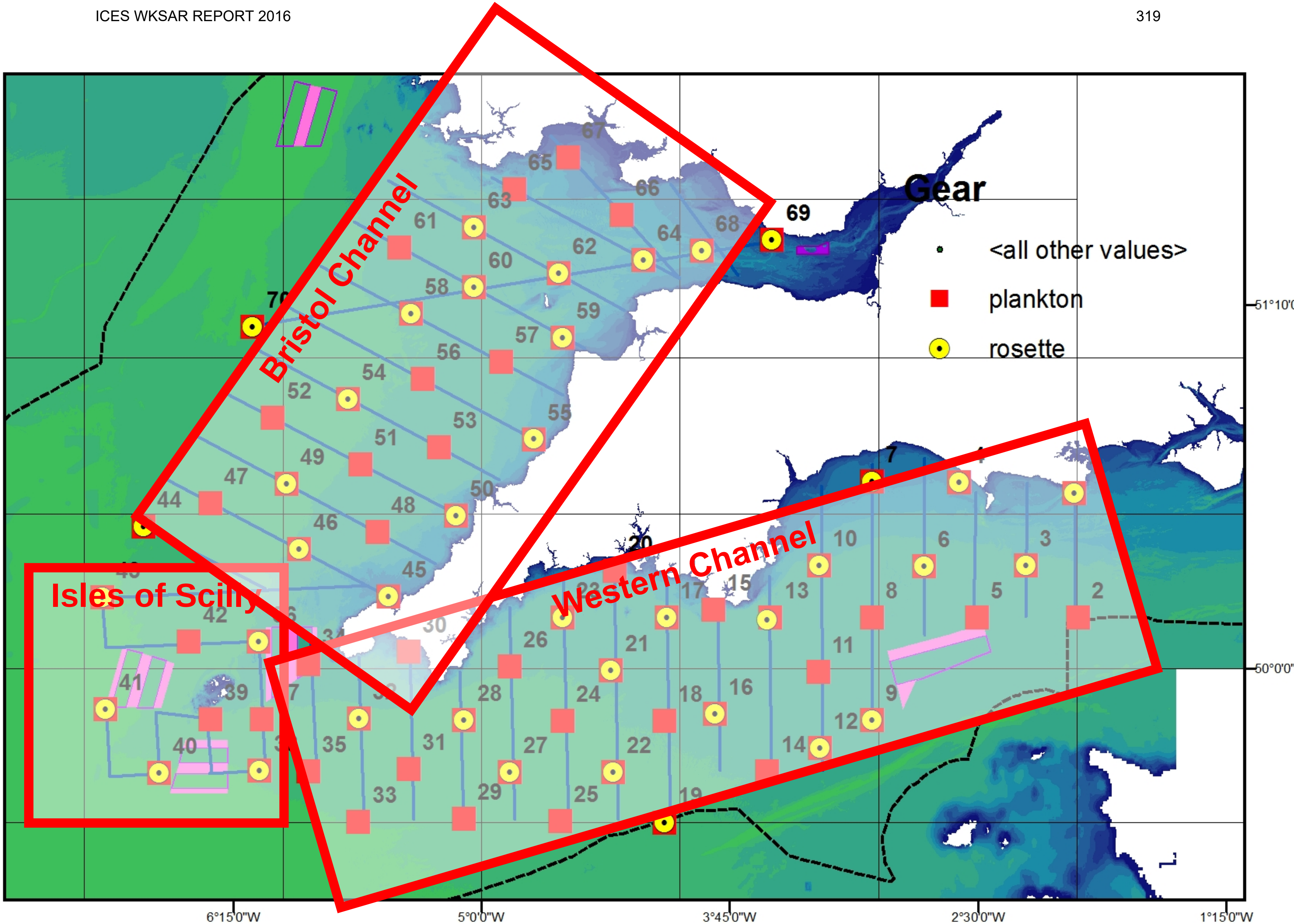


Fig. 3. Summed abundance of summer and autumn spawned sardine eggs by years at station L4.

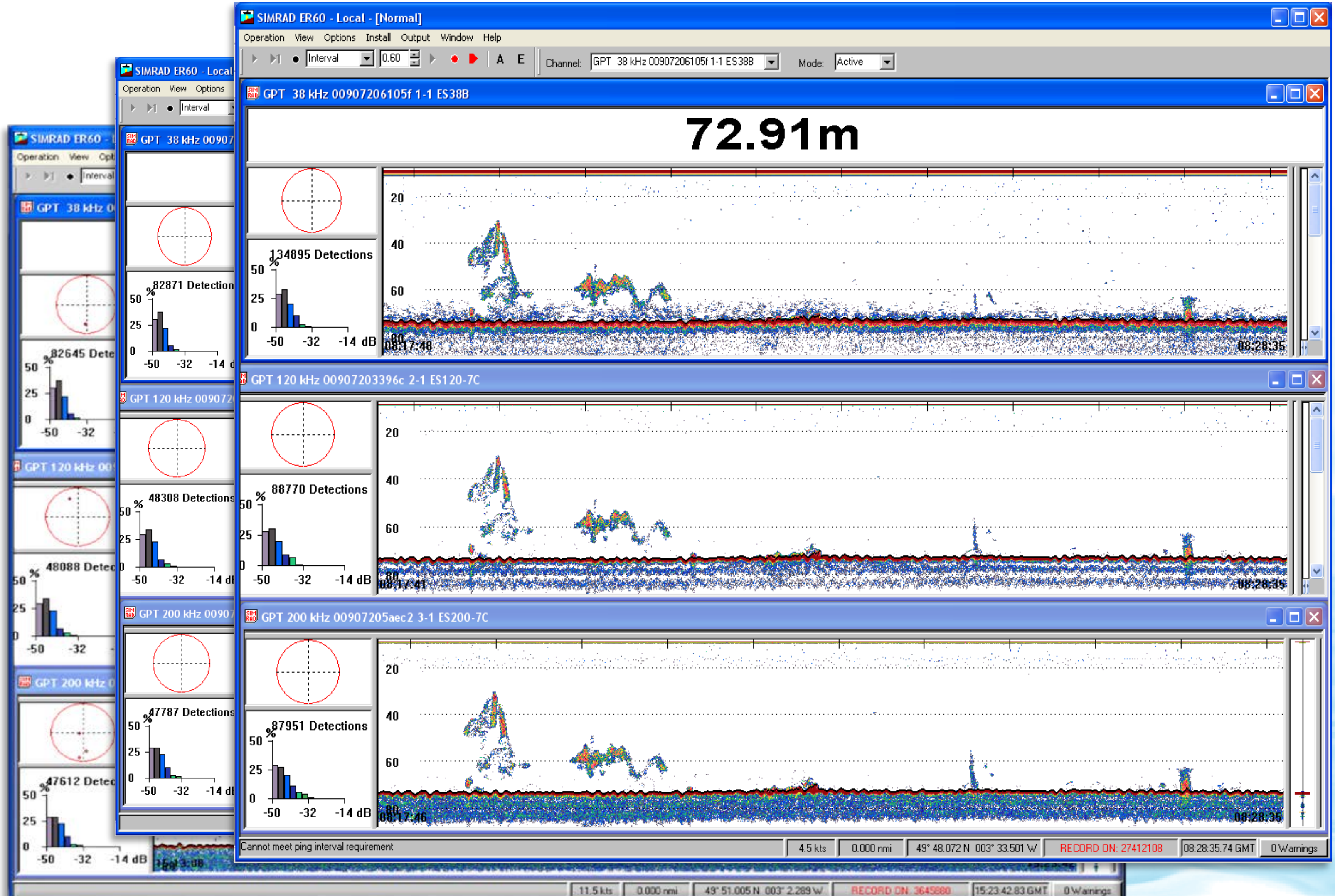
Project Poseidon

- WP2: Integrated monitoring survey on small pelagic fish community and their environment
  - Defra funded (MF1112)
  - 2012-2016 (5 years)
  - Autumn: October (~3 weeks)
  - RV Cefas Endeavour
  - Multidisciplinary (fisheries acoustics + trawl, zooplankton, mammals and birds, oceanography,...)
  - Mackerel box

Cefas

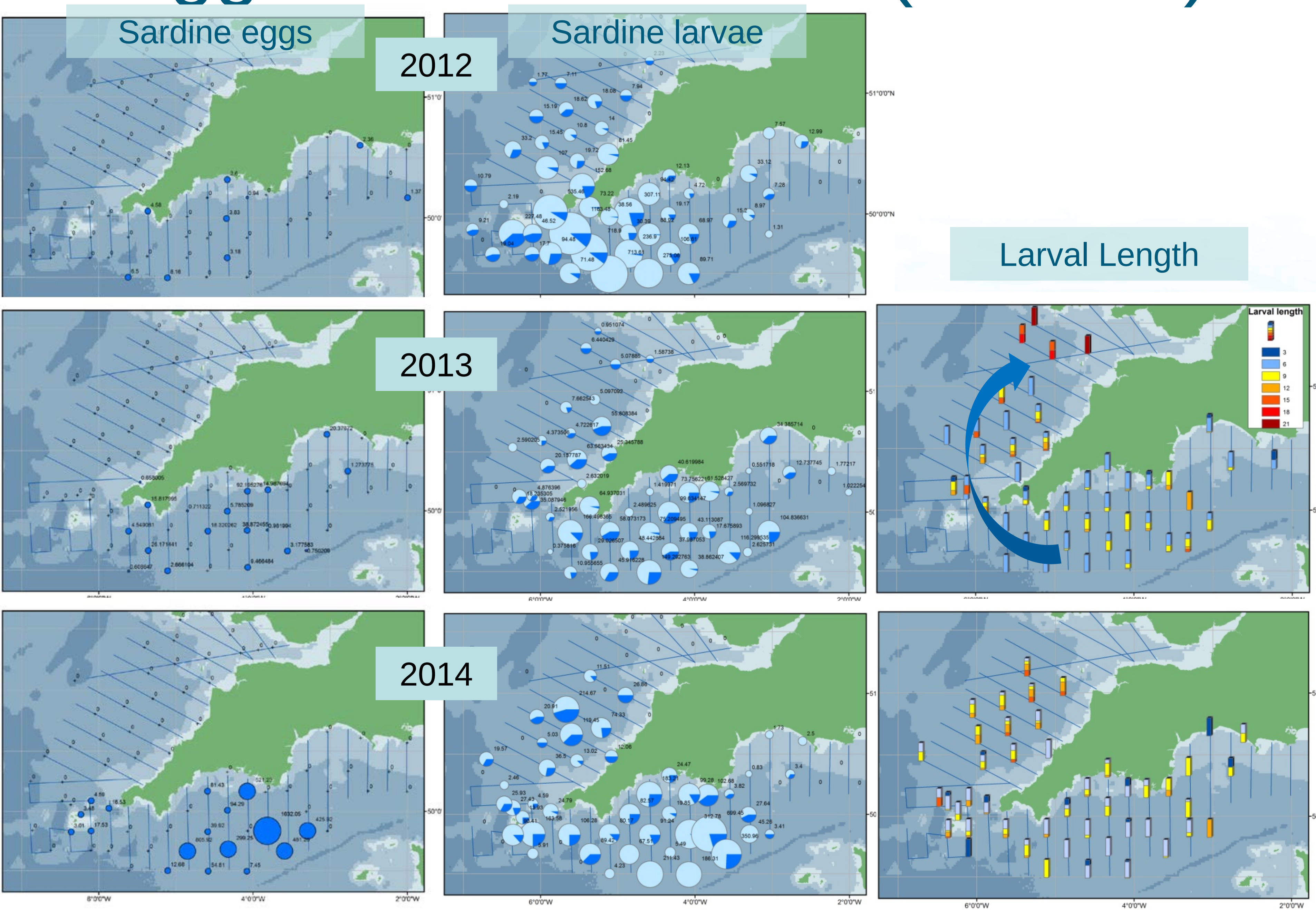

Gear
<all other values>
plankton
rosette
Bristol Channel
Western Channel
Isles of Scilly
51°10'0"
50°0'0"
6°15'0"W
5°0'0"W
3°45'0"W
2°30'0"W
1°15'0"W

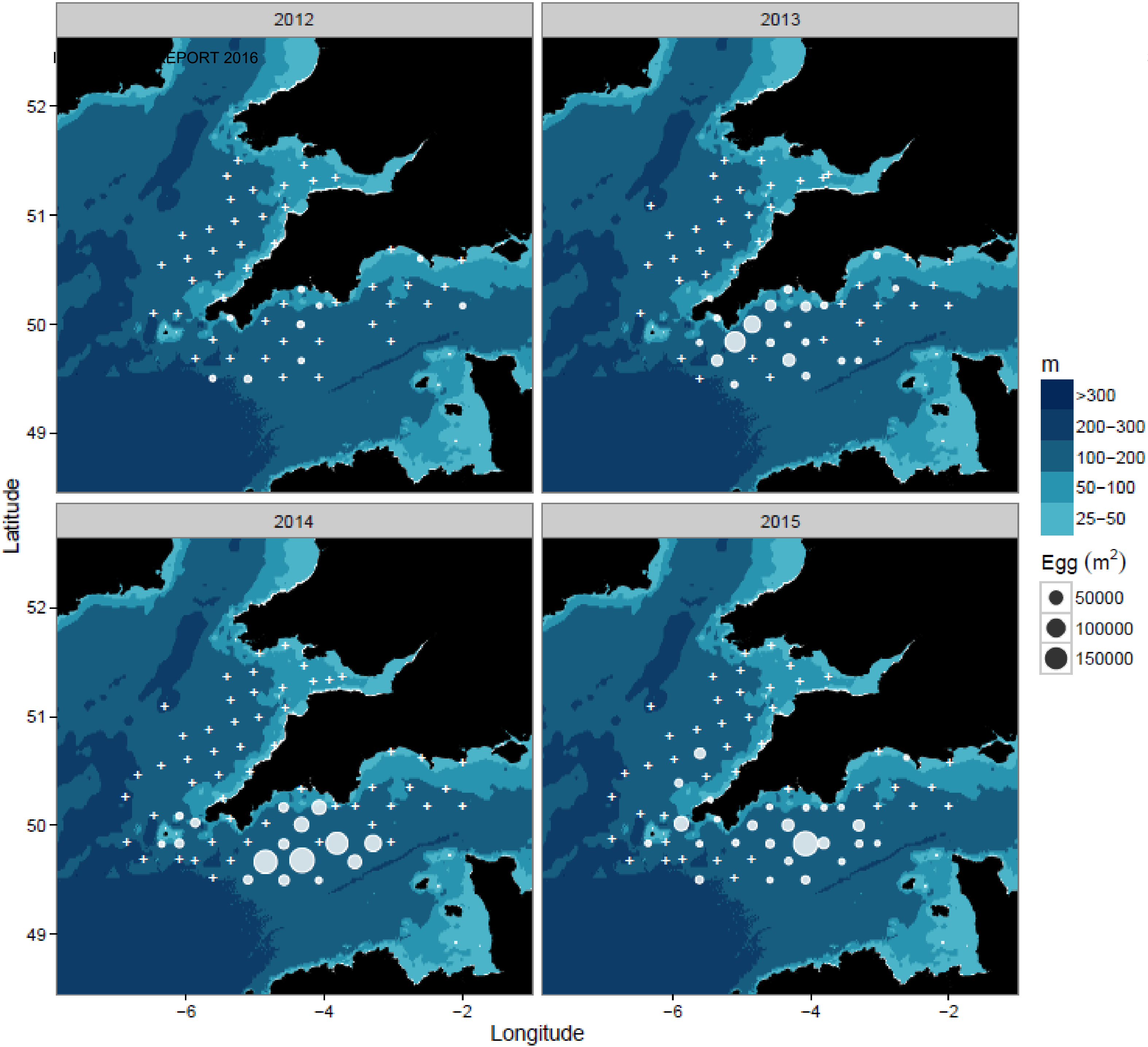
Echogram

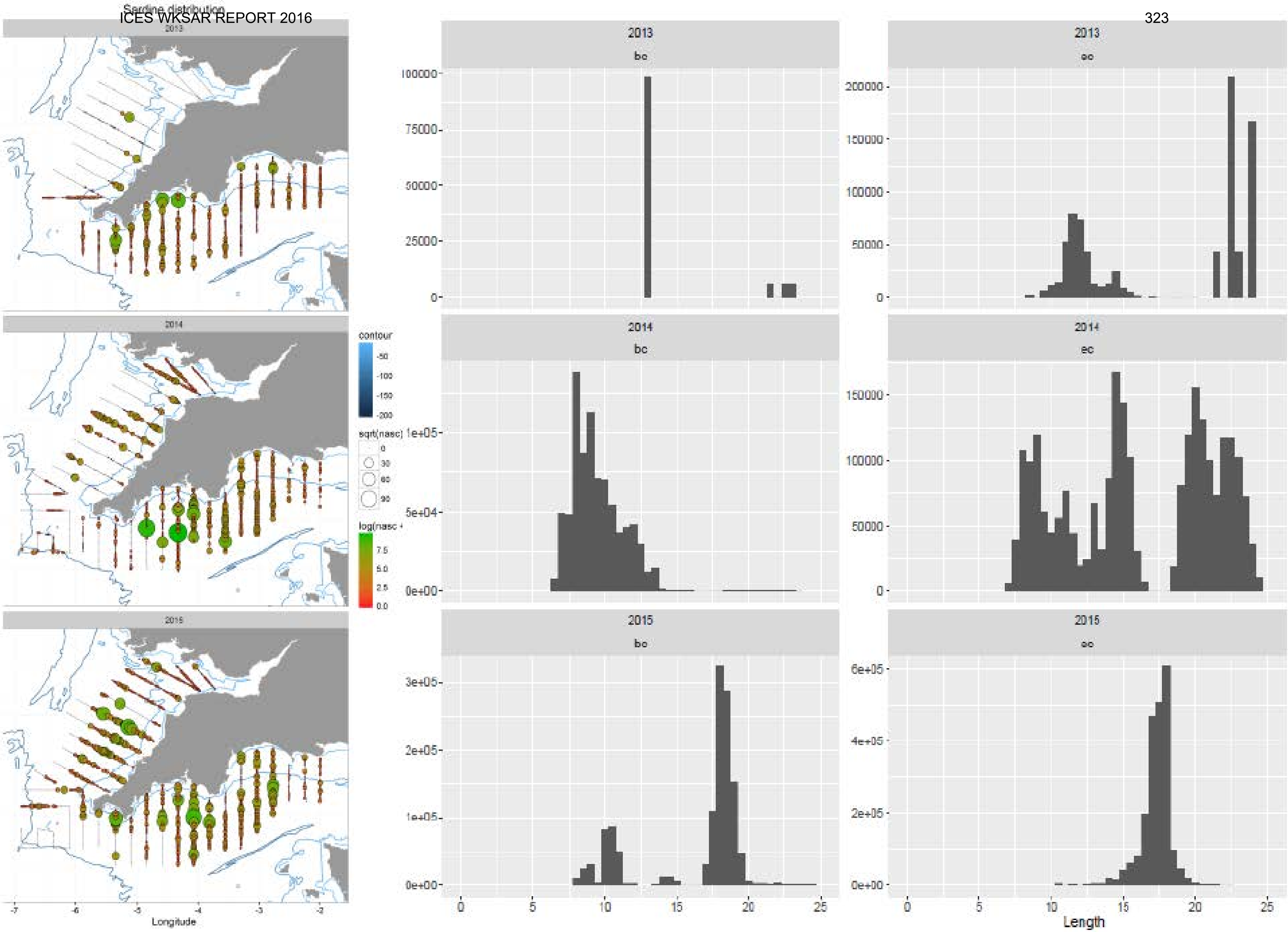


Cefas

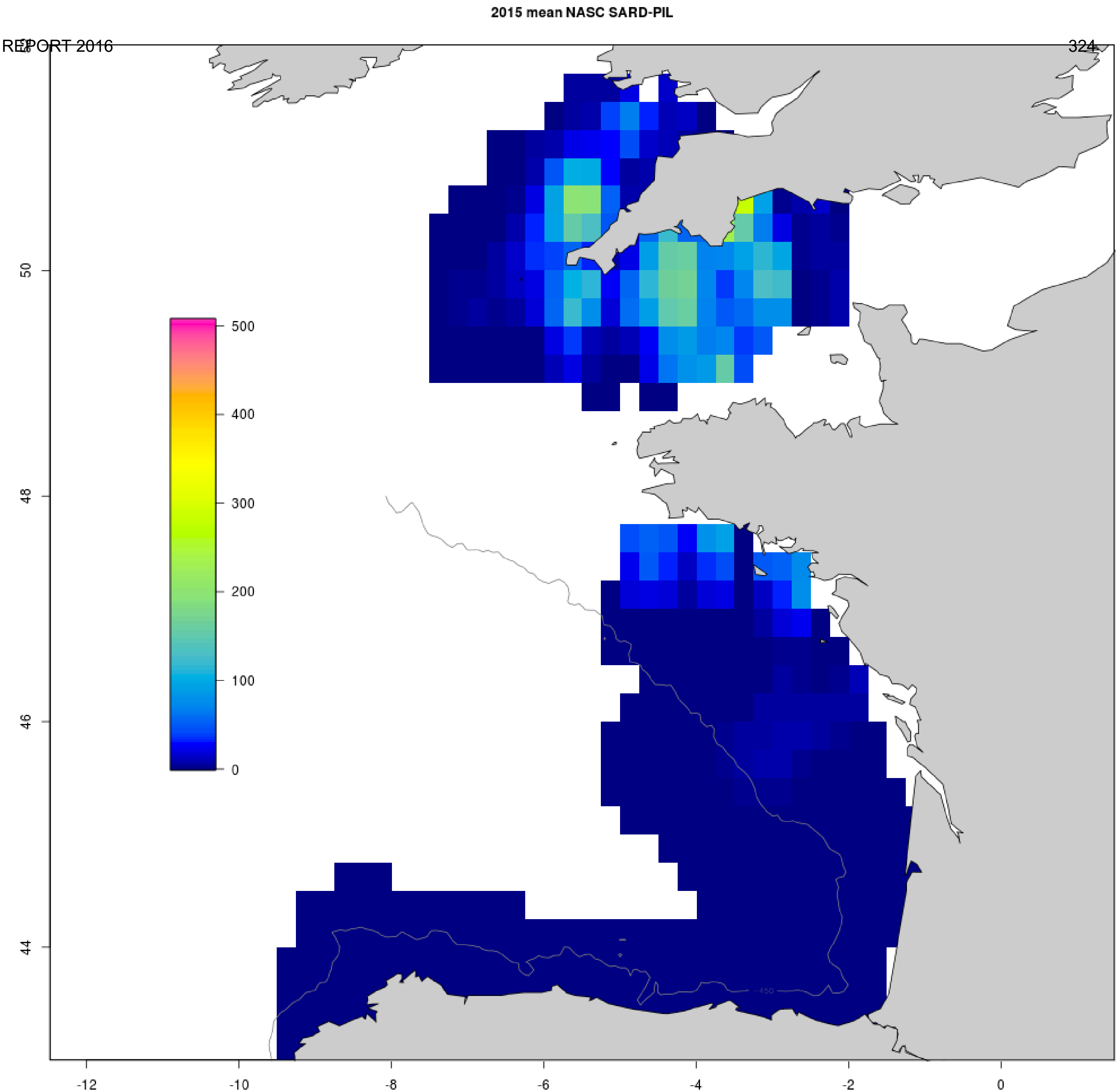
Eggs/larvae 2012-14 (autumn)




2012
2013
2014
2015
Latitude
Longitude
52
51
50
49
-6
-4
-2
m
>300
200-300
100-200
50-100
25-50
Egg (m^2)
50000
100000
150000



Sardine distribution
2013
2014
2015
Longitude
contour
sqrt(nasc)
log(nasc
2013
bc
2013
ec
2014
bc
2014
ec
2015
bc
2015
ec
Length


2015 mean NASC SARD-PIL
500
400
300
200
100
0
50
48
46
44
-12
-10
-8
-6
-4
-2
0

English Channel			
	2013	2014	2015
ANE	1,595	7,459	18,846
BOF	0	0	0
HER	4.9	45.27	56.11
HOM	9,378	53,491	37,882
PIL	56,995	122,277	99,395
SPR	77,039	79,578	56,781

Isles of Scilly			
	2013	2014	2015
ANE	0	0	0
BOF	0	15,777	0.19
HER	0	0	0
HOM	773	201	13,995
PIL	227	553	1,068
SPR	NA	7,646	1,200

Bristol Channel			
	2013	2014	2015
ANE	0	2.91	186
BOF	0	0.69	3.89
HER	969	257	3,931
HOM	2,030	591	14,346
PIL	3,592	5,944	55,754
SPR	24,555	57,232	147,553

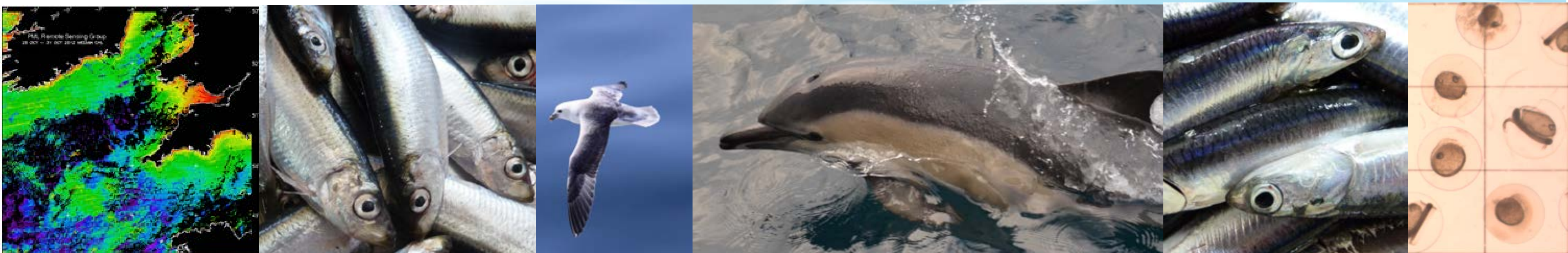
Cefas

Prelim summary

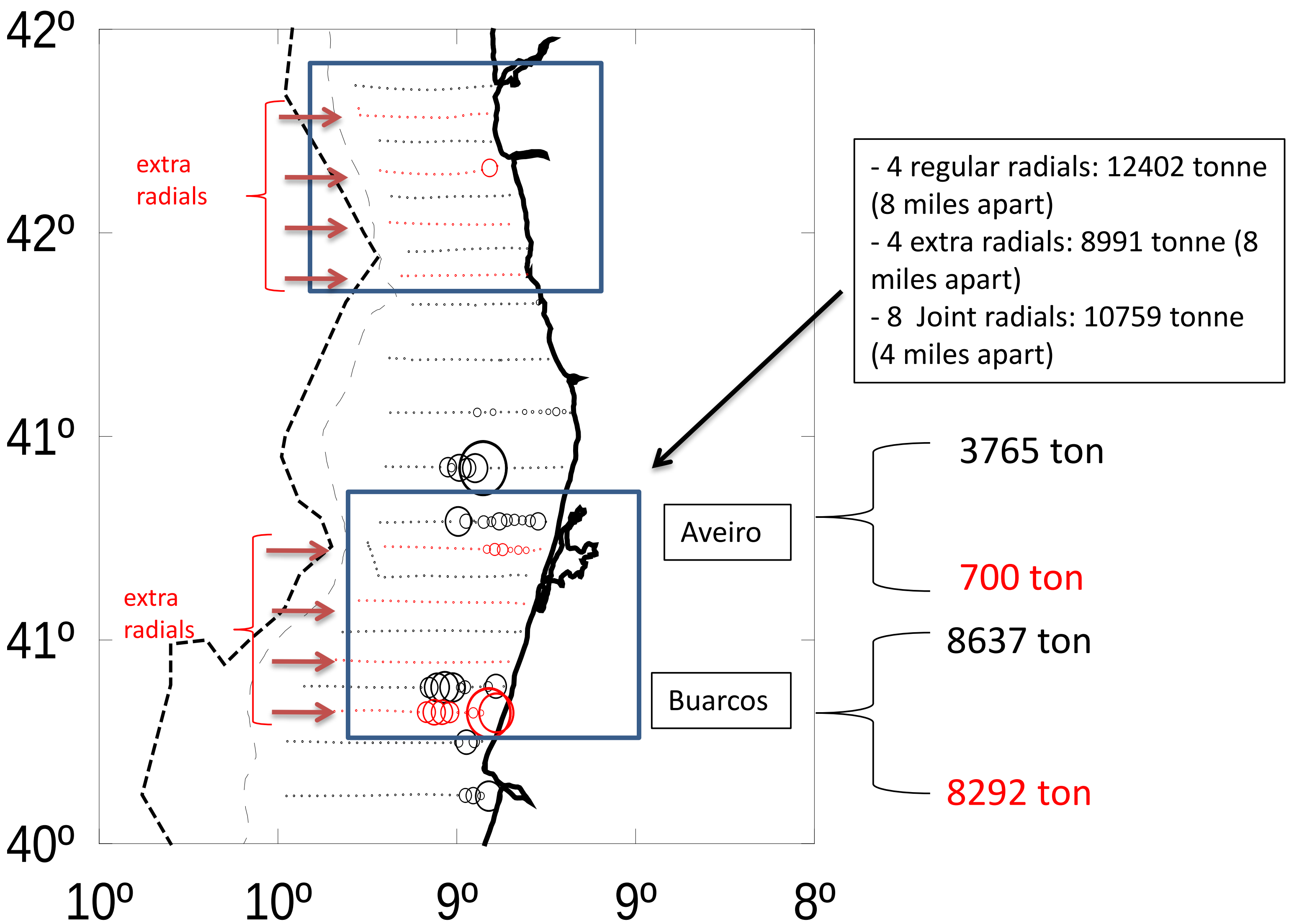
- Spawning south of peninsula mainly
  - No change in distribution
  - No decrease in numbers
  - Peak numbers comparable to Bay of Biscay
  - Increased autumn spawning (BoB?)
- Larvae drift significant distances
- Juveniles (nursery area)
- Increase in numbers
- In autumn: northwards distribution
- Genetically similar

In progress:

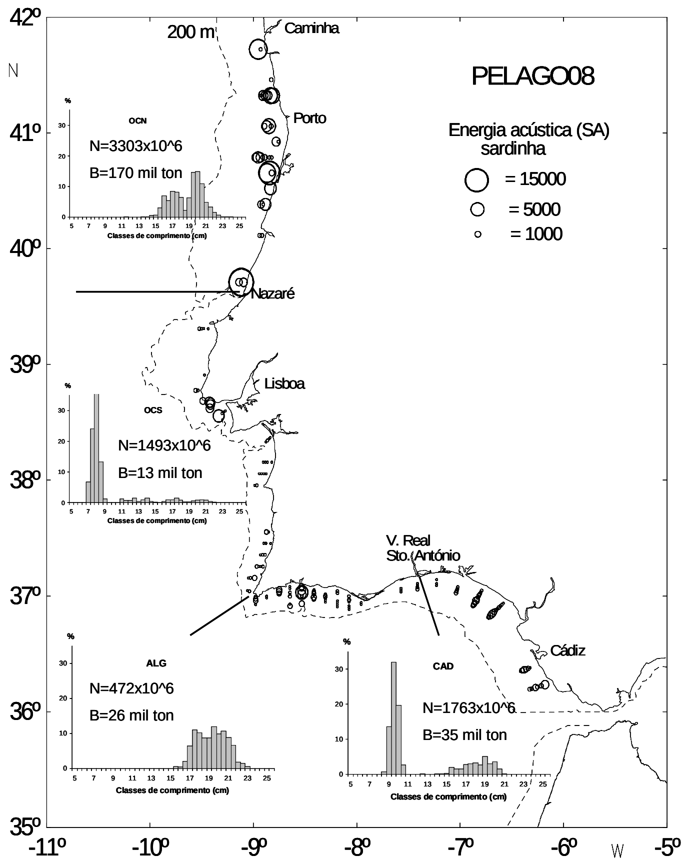
- Spawning habitat
- Drift modelling
- What are the spawning *triggers*?
- Nursery areas?
- Biomass time-series (*but*: only Mackerel box, and can't cover very shallow inshore areas)
- Sardine habitat
- Predators, who eats sardine

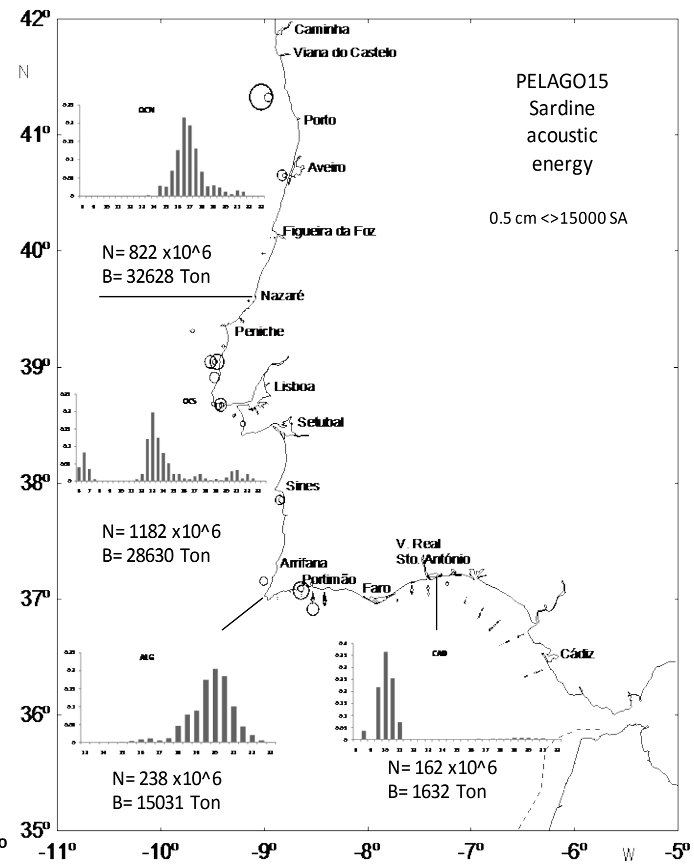


PELAGO16 : Sardine acoustic energy test areas



High and low sardine abundance surveys: Differences between density concentration





PEL08: 18% acoustic energy in 2 miles; 43% in 10 miles

PEL15: 41% acoustic energy in 2 miles; 79% in 10 miles

PIL acoustic energy (NASC) CV (classic)

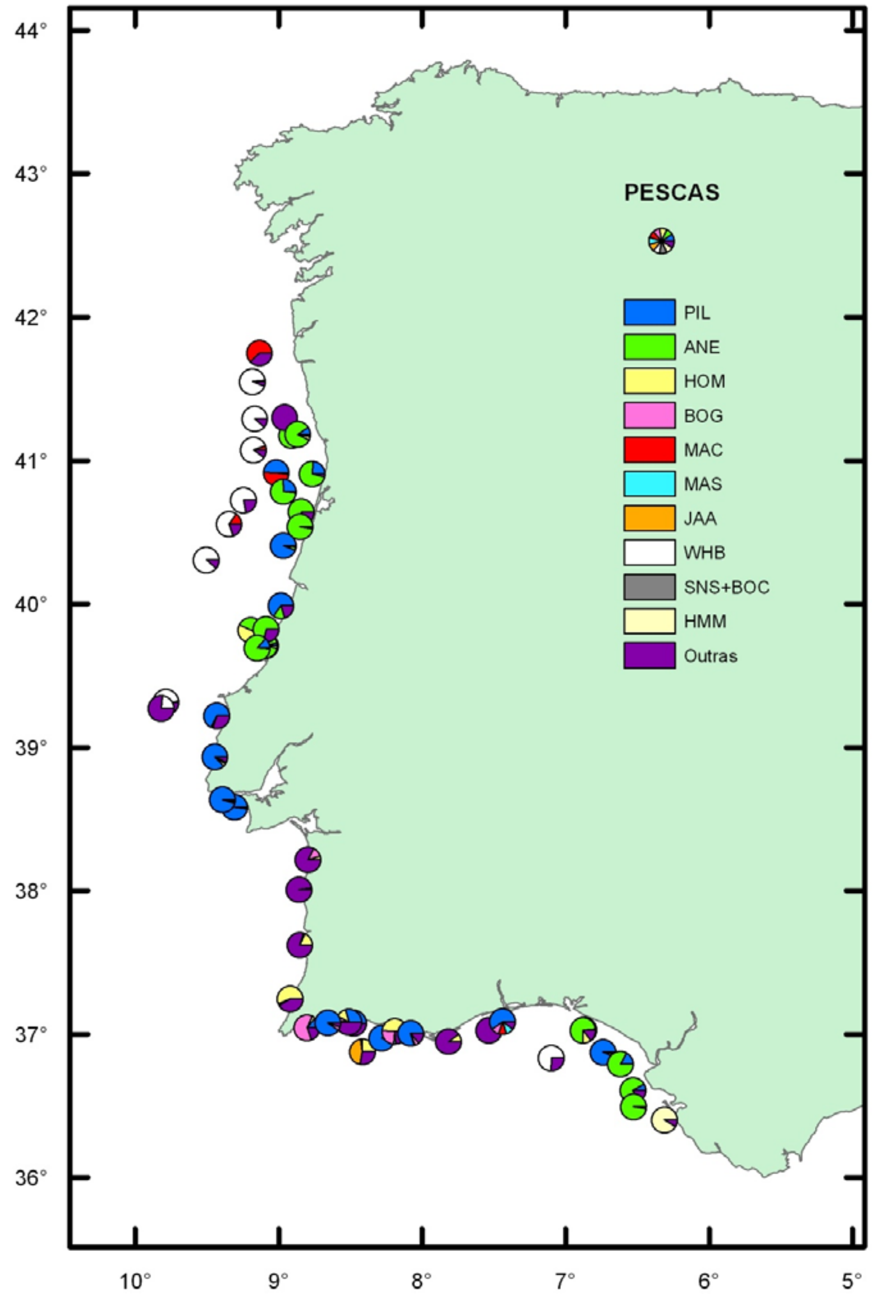
survey	tousand tonne **Biom. All area**	**CV. All area**	**Cv. North Lisboa**
PEL02	615	0.11	0.17
PEL05	587	0.14	0.20
PEL08	244	0.17	0.26
PEL11	127	0.29	0.37
PEL14	101	0.16	0.33
PEL15	78	0.35	0.48
PEL16	172	0.22	0.44

Lower biomass → Higher CV

Tabela 2: Parâmetros dos dados acústicos (N - nº de amostras; m – média e σ^2 – variância) e parâmetros do modelo (pepita + esférico) ajustado ao variograma experimental, para cada campanha acústica (Zona Ocidental Norte). CV% - coeficiente de variação clássico. CV_{geo} – coeficiente de variação atendendo à estrutura espacial.

Cruz.	N	m	σ^2(dados)	σ_E^2	pepita	patamar	r	CV%	CV_{geo}%
Mar97	351	348	2463874	9290	1300000	2560000	3.0	24.0	27.7
Nov97	327	232	359169	1297	290000	385000	3.0	14.3	15.5
Mar98	360	445	3626542	10958	3150000	3800000	6.6	22.6	23.5
Nov98	349	332	1044197	3206	800000	1050000	2.7	16.5	17.0
Mar99	248	418	2692315	11081	2400000	2860000	6.6	24.9	25.2
Ago99	327	132	349559	1248	280000	365000	3.9	24.7	26.7
Nov99	349	195	362016	1218	300000	400000	7.2	16.5	18.0
Mar00	318	215	1165913	4053	870000	1210000	5.7	28.1	29.0
Nov00	318	1542	20348120	69178	13800000	22800000	7.8	16.4	17.0
Mar01	339	767	10833000	34110	8400000	11400000	4.2	23.3	24.0
Nov01	302	610	4996046	17958	4550000	5360000	7.2	21.1	22.0
Mar02	349	497	3875075	13074	3200000	4132000	4.2	21.2	23.0
Fev03	349	340	940399	2787	650000	1050000	9.0	15.2	15.5

PELAGO16 trawl hauls



Biomass comparison in test area

4 regular radials: 12402 tonne (8 miles apart)

4 extra radials: 8991 tonne (8 miles apart)

8 Joint radials: 10759 tonne (4 miles apart)

Sardine maturity ogive in the Bay of Biscay

Lionel Pawlowski

Available datasets

- 18682 qualified samples

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Semester 1	522	1068	748	1120	266	277	1138	1020	1055	1291	1308	1241	1422	1236
Semester 2	444	556	583	365	336	300	900	277	312	339	342		216	

- Cohorts from 1993 and onwards
- Collected during PELGAS survey for semester 1
- Collected from pelagic trawlers and seiners and bottom trawl surveys (FR IBTS) for semester 2

- For each sample: month, age, length, individual weight, sex and maturity stage

Maturity stages

- Stage 1: immature fishes
- Stage 2: maturation. Some fishes starts to spawn
- Stages 3,4,5: spawners
- Stage 6: post-spawning
  - rarely observed in S1, depending on the timing of the survey/stock.
  - more common in S2

Maturity ogive in stock assessment models

- In age structured models (eg XSA), described as the proportion of mature individuals by age

- a sensible set of parameters for XSA:
bias_SSB(related to maturity ogive) =
+/- sum of (bias_prop.mature@age_*y* * n@age_*y* * w@age_*y*)

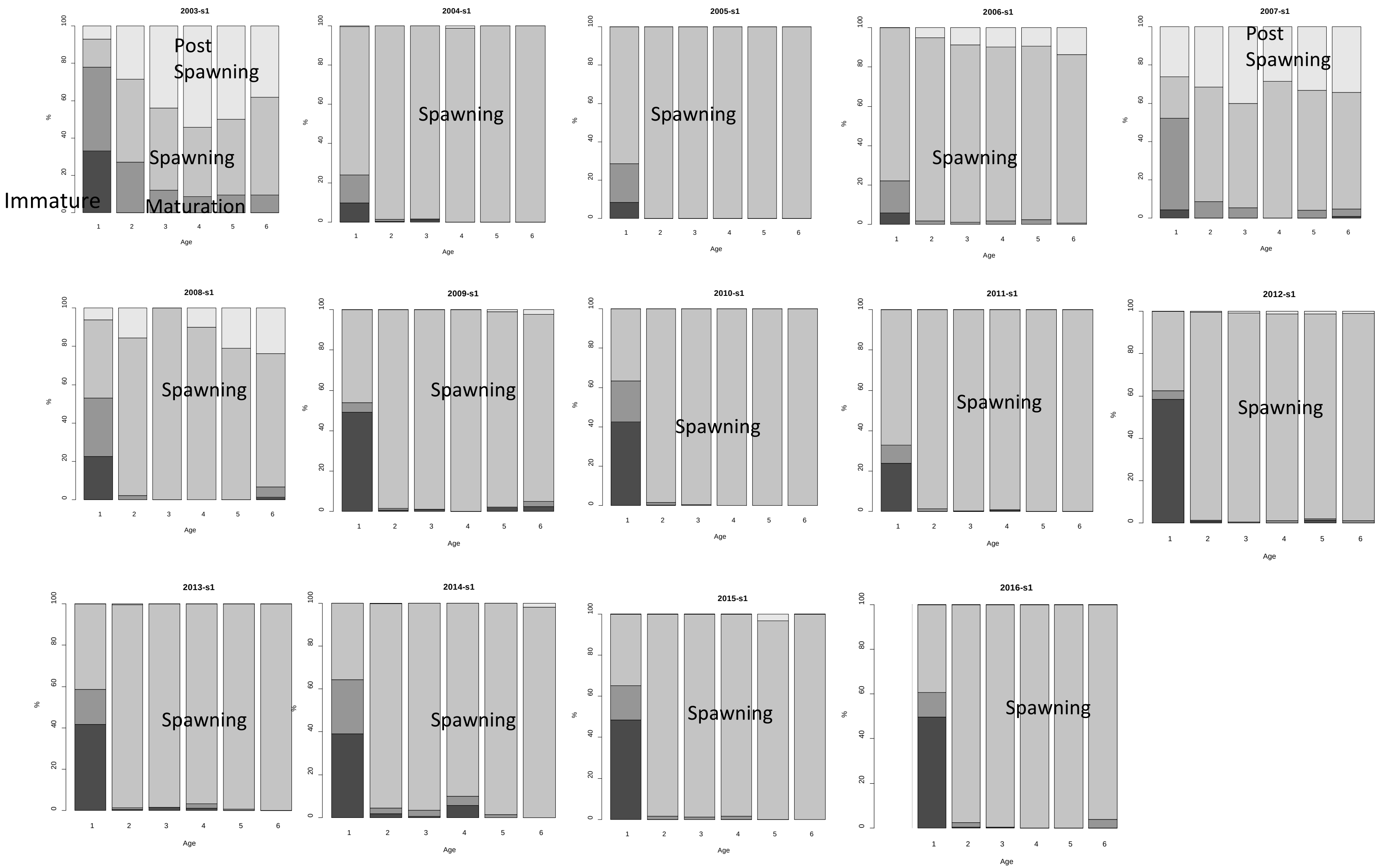
- stage 2: arbitrarily considered to have 50% individuals mature

- Should we use ogive in S1 or S2 or both ?

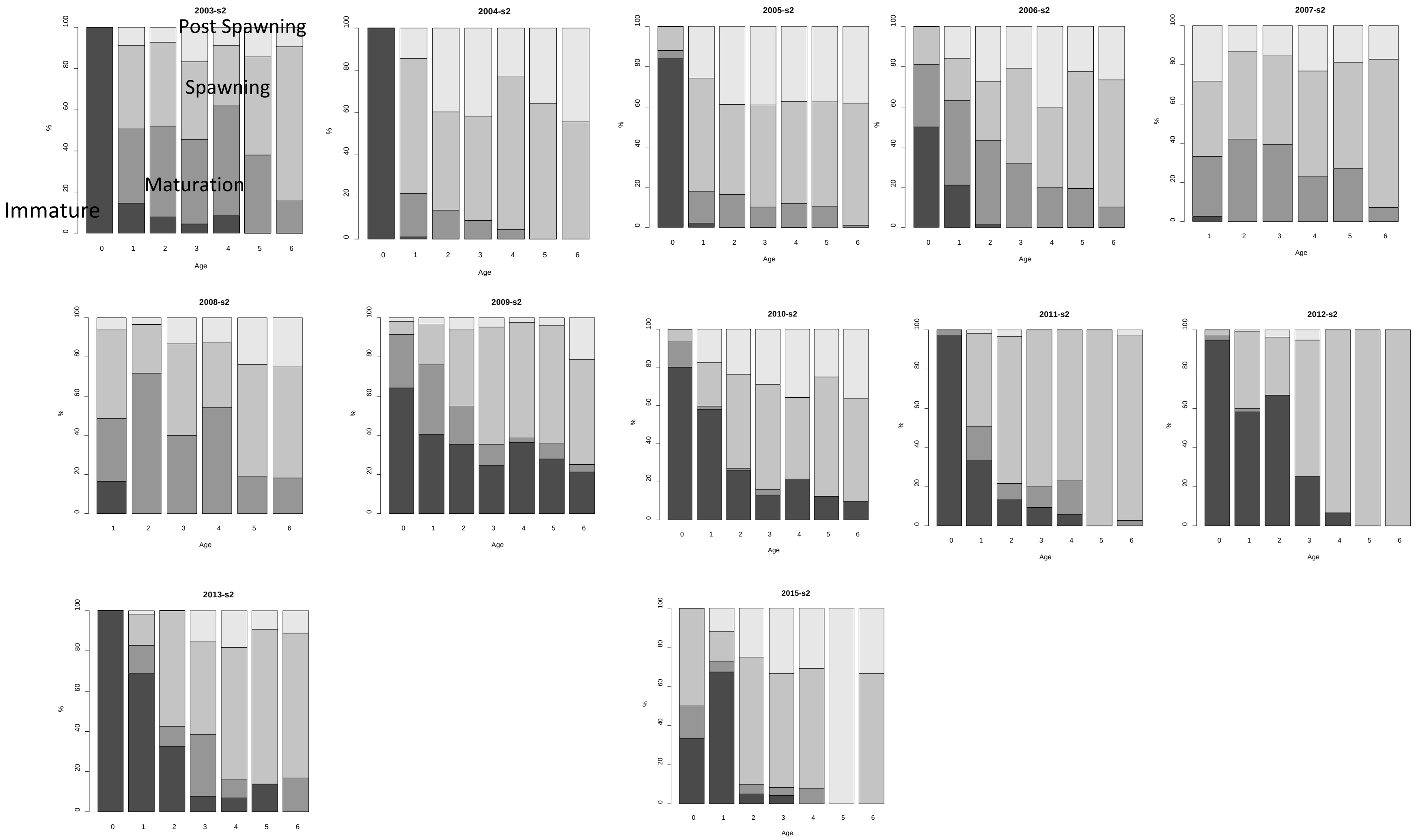
- limited to ages 6+ (age range up to 14 y.o)

Building a maturity ogive

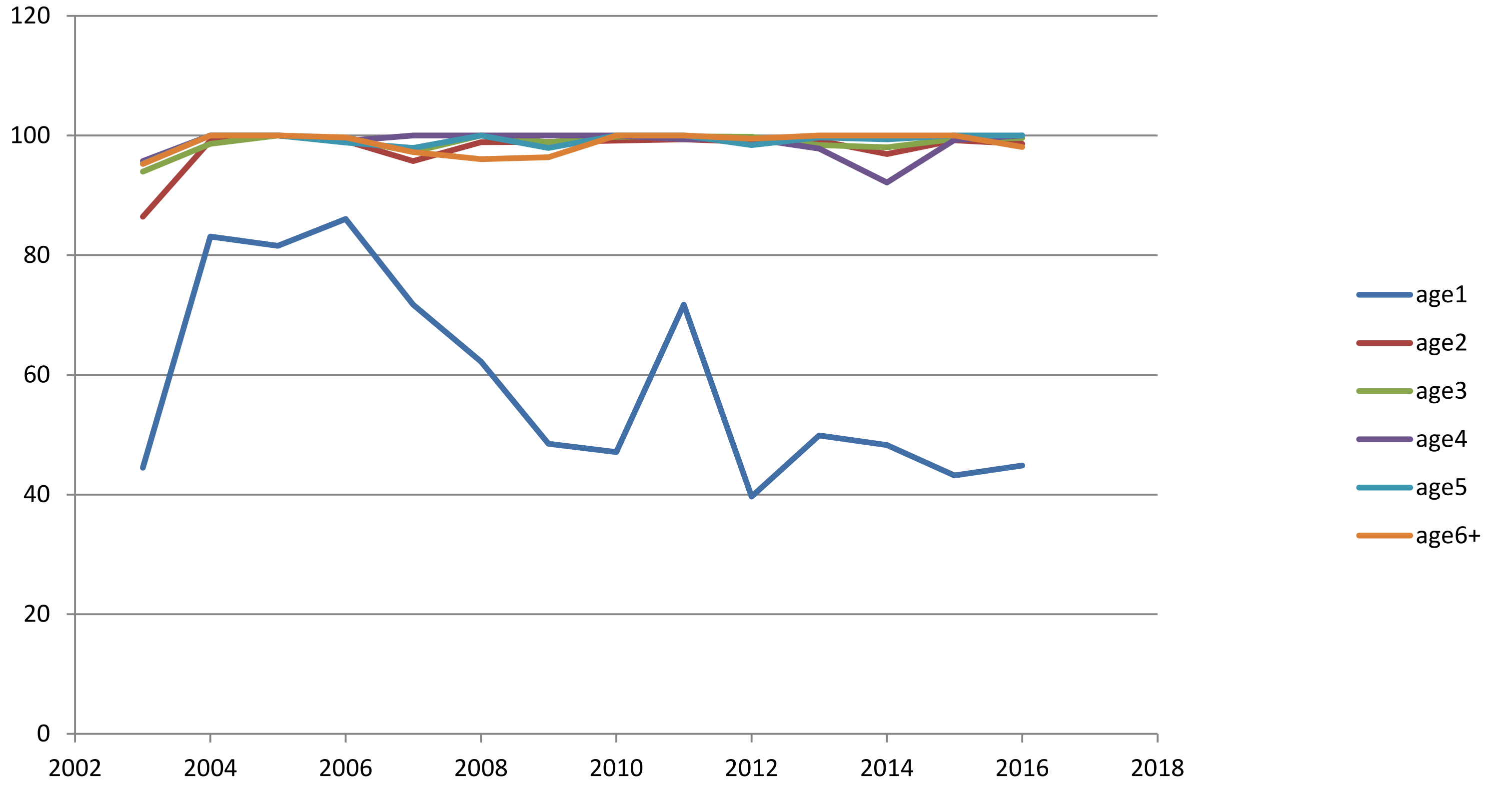
Maturity stage – Semester 1



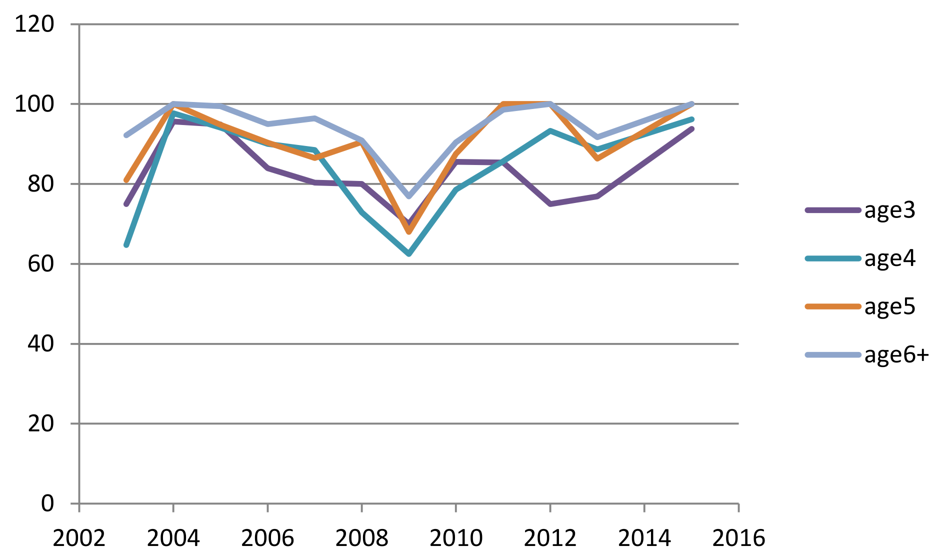
Maturity stage – Semester 2



A drifting maturity ogive ? Semester 1



A drifting maturity ogive ? Semester 2



Conclusion

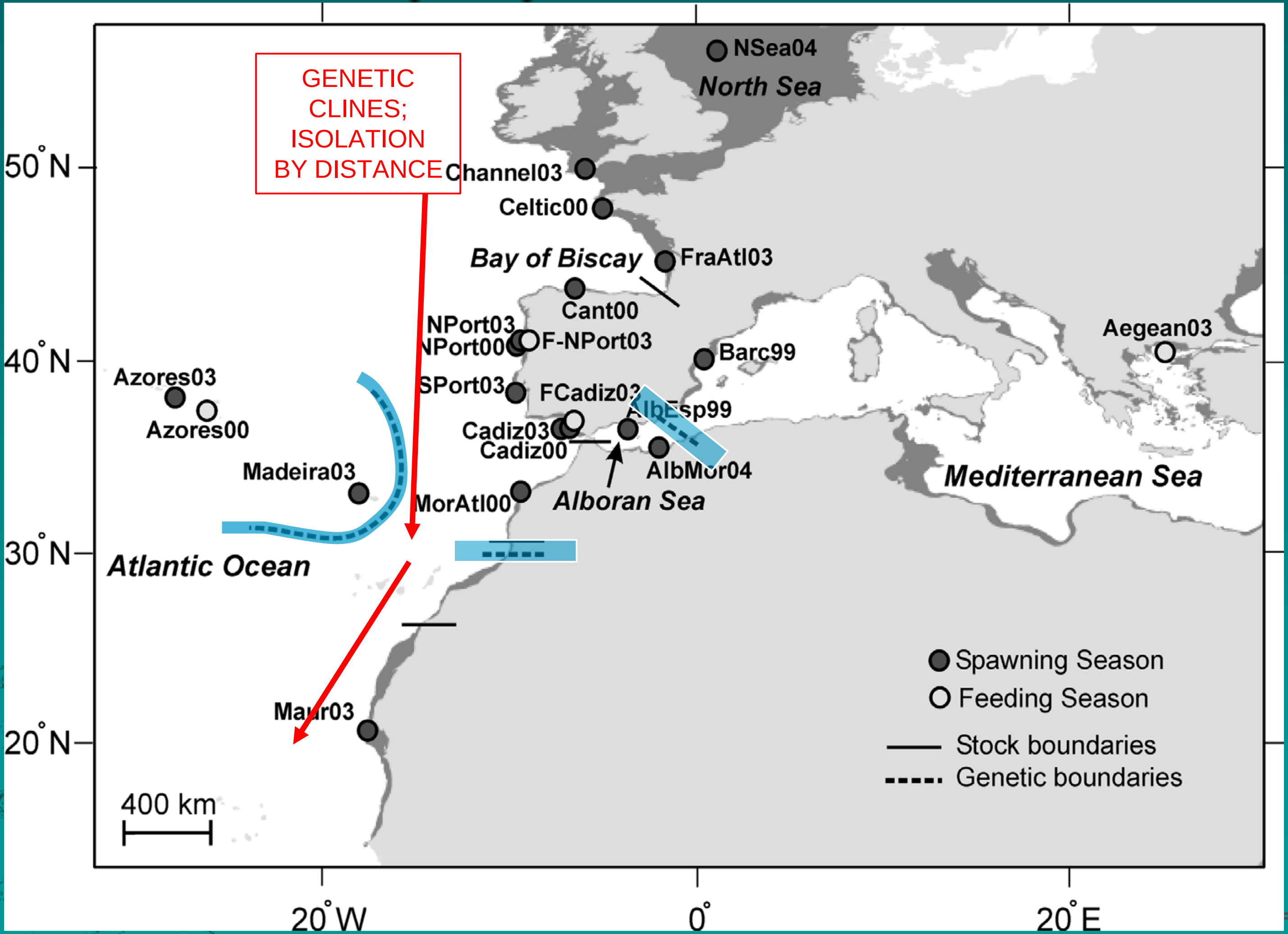
- Relatively stable ogive for Semester 1 but prop mature decreasing for age 1
- Proportion of mature decreasing for Age 1 and fluctuating for age 2 for Semester 2
- Likely to be linked with the decrease of individual size
- Unknown external causes. Consequences for management ?
- How to treat that into stock assessment models requiring ogive (set vs variable ogive ?)
- Other areas/stock needs to be investigated

WKSAR- Lisbon 26-30 September 2016

Sardine stock structure: SARDYN project and update

Alexandra Silva

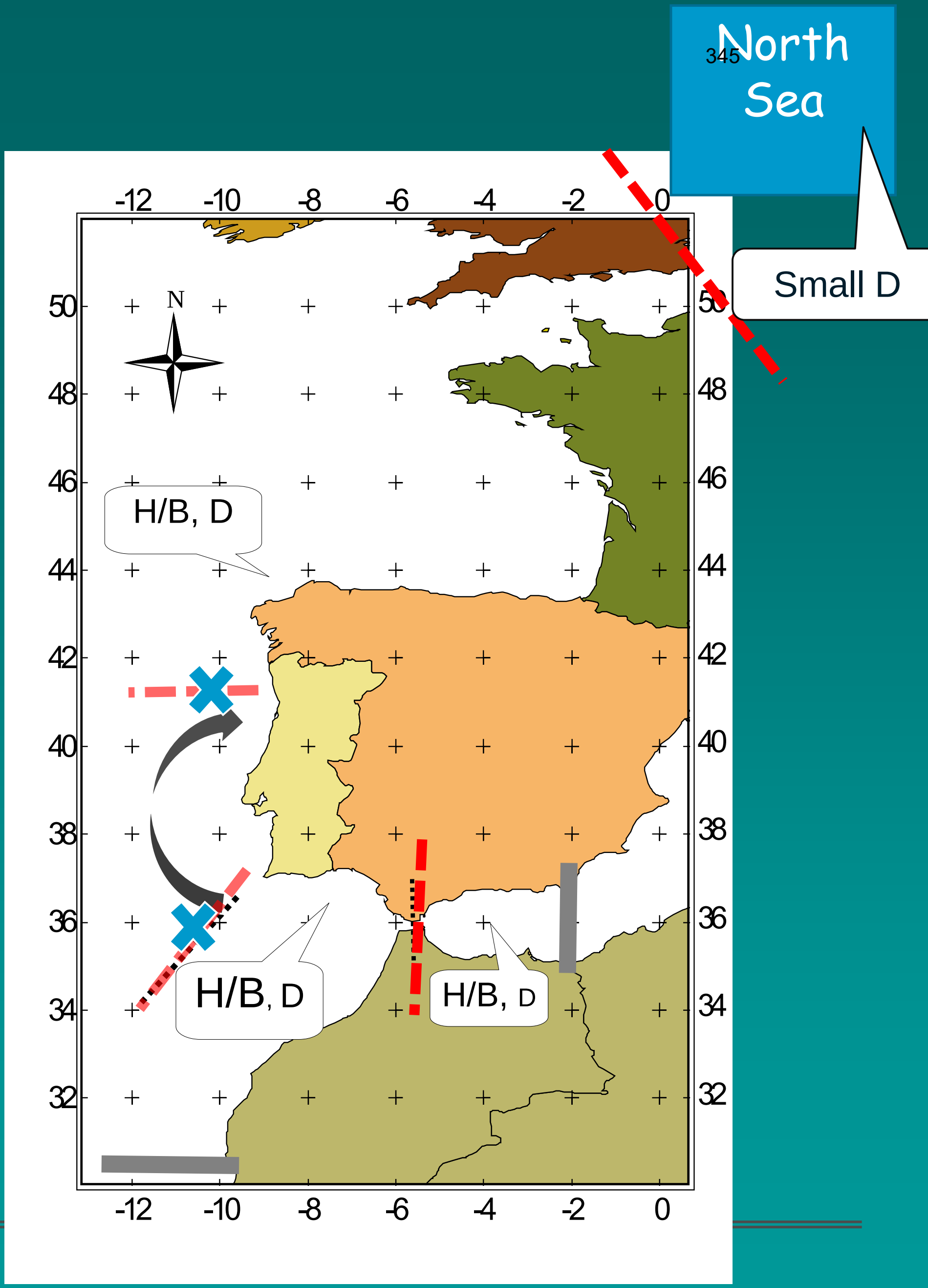
Genetic population structure



Kasapidis, 2014 (review)

Body morphometrics

- H/B – Head to body ratio
- D- eye diameter
- Cape St. Vincent boundary changed over time

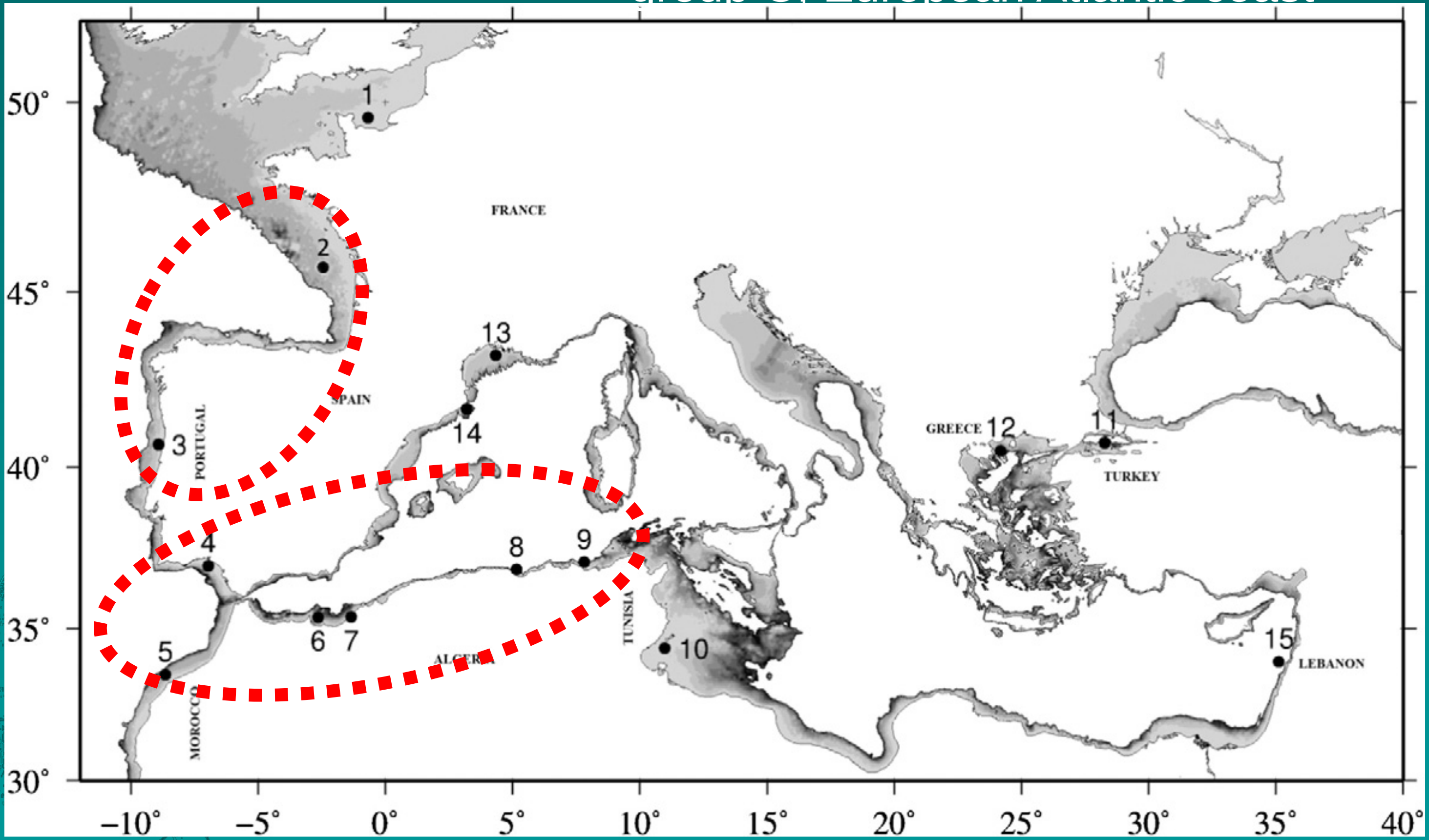


Silva, 2003; Silva et al. 2012

Otolith shape

Three distinct groups could be discerned:

- group A, northern Mediterranean Sea and Gulf of Gabès;
- group B, northern Atlantic Morocco to south Alboran–Algero-provençal coasts;
- group C, European Atlantic coast

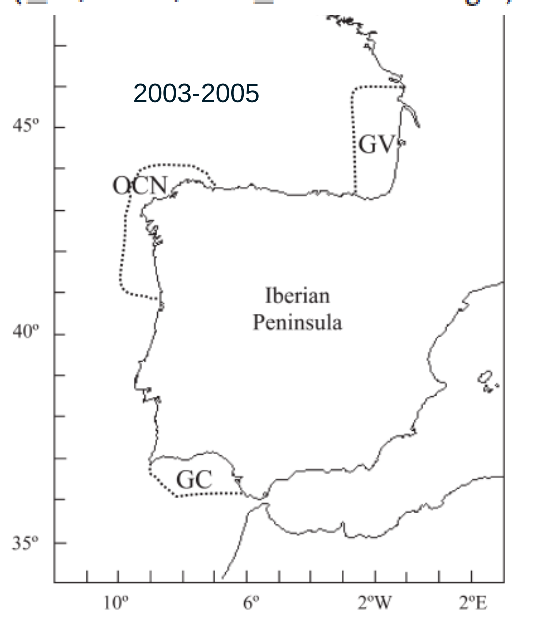


Jemaa et al, 2015

Otolith chemistry

- Higher % discrimination for small (86%) than large (67%) sardines
- "Net balance of migration from OCN towards GC and GV"

(≤15, 16 – 18, and ≥21 cm total length).



SARDYN (Castro, 2007)

- "Follow" the 2004 strong yearclass
- Significant diferences between recruits from north, Lisbon and Cadiz
- Differences between recruits born in diferente seasons
- The north supplied over 80% of the 2004 cohort adults collected across Portugal and Cadiz waters 3 years later

Table 4
Contributions (%) of the recruitment areas/seasons (i.e. Gulf of Cadiz – South 1+ and Occidental North Coast – North 0+ and 1+) of this study to the adults stocks (age 3+) obtained through a MLA. For more details see Section 2.

Adults	Recruits		
	North 0+	North 1+	South 1+
North	0%	85%	15%
Centre	45%	29%	26%
South	28%	65%	7%
Portugal	21%	67%	12%

Correia et al, 2014

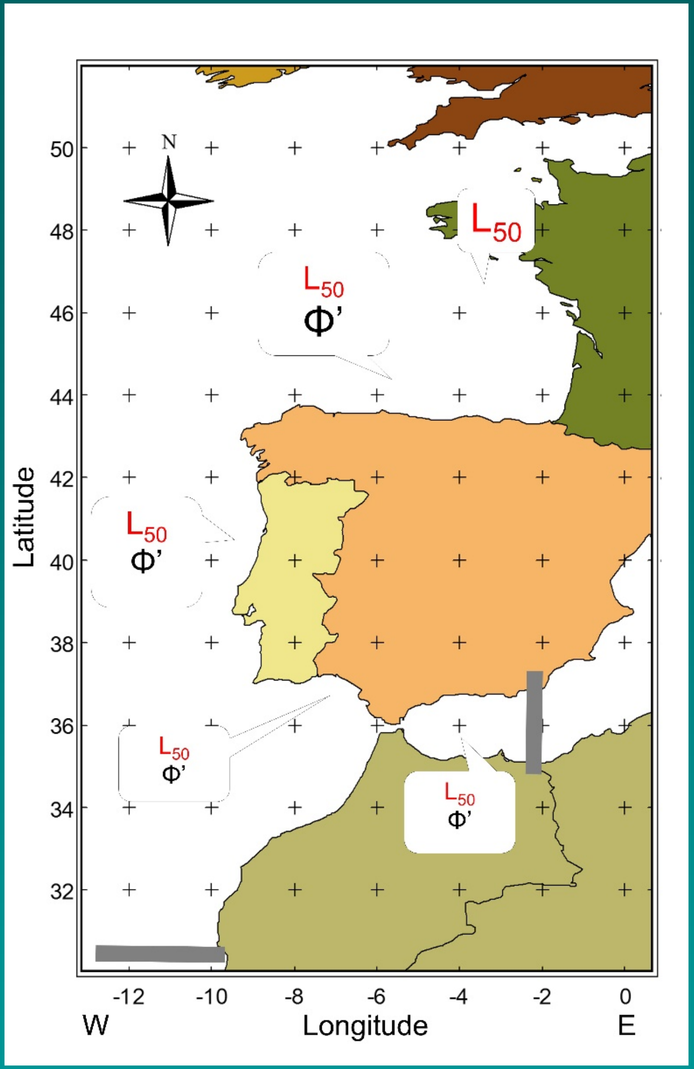
Life-history traits

SARDYN

- Φ' Growth index
- L_{50} – Length-at-first maturity

- Growth performance and length-at-first maturity increase from south to north

- Differences in growth between south, west and north Iberian coast are persistent



Some further update on following presentations !

Annex 5: Terms of Reference

WKSAR– Workshop on Atlantic Sardine

2015/2/ACOM42 The **Workshop on Atlantic Sardine** (WKSAR), chaired by Alexandra Silva (Portugal) and Lionel Pawlowski (France), will work by correspondence during 2016 and meet 26–30 September 2016, Lisbon, Portugal, to:

a) Review information on sardine stock identification, connectivity and migrations within European Atlantic waters (Subarea 7 to Subdivision 9.a);

b) Collate, standardize and analyse survey, fishery and biological data (egg abundance, abundance-at-age, catch biomass, catch-at-age, weight-at-age and maturity-at-age) at the lowest possible geographical and temporal level;

c) Based on ToRs a) and b) propose scenarios of sardine stock structure and dynamics;

d) Develop guidelines for stock assessment and when possible identify methods/models appropriate to handle scenarios proposed in ToR c).

e) Produce a working document compiling the population structure and stock dynamics information available. To be reviewed by SIMWG.

WKSAR will report by 30 November 2016 for the attention of ACOM.

Supporting information

Priority	This workshop will provide ICES with knowledge of the best possible approach to assess the status and provide management advice for sardine in the ICES area taking into account the most recent knowledge of stock structure and dynamics. It will also provide the necessary data with the appropriate spatial and temporal resolution. Consequently, the work is considered to have a very high priority.
Scientific justification	Two sardine stocks are currently assumed in Atlantic European waters: Sardine in Divisions 8.a,b,d, and 7 and Sardine in Divisions 8.c and 9.a. There is strong evidence that sardine has a complex population structure and dynamics in the Northeast Atlantic and that mixing takes place between the two stocks. The current assessment and management units may not be consistent with real biological/dynamic units. The last review of this issue was carried in the last benchmark for Sardine 8.c and 9.a (WKPELA, 2012) based on results from the EU project SARDYN. Since then, new work has been carried out and more data have been compiled, especially in Divisions 8.a,b which justifies revisiting the issue of stock structure and dynamics, both to re-evaluate the two stock assumption and to evaluate the need to consider additional complexity in stock dynamics at substock level. WGHANSA recommended a Benchmark for both sardine stocks in 9.a, 8.c and in 7, 8.abd should be carried out simultaneously in 2017. WGHANSA considered the joint approach for the two sardine stocks will require a longer data compilation/mining workshop made at least 6–7 months before the benchmark meeting to allow timely decisions about assessment approaches and models to be explored in the benchmark. WKSAR will provide (i) the basis for assumptions about stock structure and dynamics (ii) the databases needed to perform assessment with alternative scenarios of stock structure and dynamics and (iii) guidelines on appropriate stock assessment methods, for the joint benchmark of Sardine stocks in 9.a, 8.c and in 7, 8.abd.
Resource requirements	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	The Workshop will be attended by 15–20 members, including experts in DEPM and acoustic surveys and stock assessment (mostly members of WGACEGG and WGHANSA). Participation (e.g. half a day) may be extended to stakeholders (e.g. SWWAC representative).
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	The Workshop has links to ACOM.
Linkages to other committees or groups	The Workshop was recommended by WGHANSA and has linkages to WGACEGG. The Workshop will provide key information for the joint benchmark workshop of the two Atlantic sardine stocks: Sardine in Divisions 8.a,b,d and Subarea 7 and Sardine in 8.c and 9.a. A joint benchmark of the two stocks has been proposed for 2017.
Linkages to other organizations	Not applicable.