SPELMED

Evaluation of the population status and specific management alternatives for the small pelagic fish stocks in the Northwestern Mediterranean Sea

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Contents

I. Introduction

- The ultimate objective of SPELMED (SC NR. 02 - TENDER EASME/EMFF/2016/32) was the evaluation of the population status of *Sardina pilchardus* (European sardine) and *Engraulis encrasicolus* (European anchovy) in the Northwestern Mediterranean Sea, specifically in GSA06 and GSA07, based on the review and generation of key biological and ecological information to support robust management options in the area.
- In this document we provide a detailed description on the activities and achievements of the project. The project was divided in three main tasks: Task 1 - Revision of biological information for both stocks, Task 2 - Revision of the ecological and fisheries information, and Task 3 - Proposal and assessment of fisheries management measures.
- We present the deliverables that were generated under the project, summarizing main results and illustrating them with key figures from several of the deliverables produced.
- We also explain main challenges that arose during the execution of the project and how these were addressed, and the mitigation measures and adjustments resulting from unforeseeable events. All of them were successfully addressed.
- Finally, we provide a description of the project legacy, which include an online folder with all the deliverables sent to EASME and a repository of modelling code and the genomics datasets.

II. EXECUTIVE SUMMARY[1]

Task 1 - Summary of biological results

Genetic/genomic review (**D1.1.1**) **and new genomic study** (**D1.2.1 & D1.2.2**): We reviewed and compiled all available genetic information about European sardine (*Sardina pilchardus*) and European anchovy (*Engraulis encrasicolus*) in GSA06 (Spain) and GSA07 (France). Information on anchovy was more abundant both within and outside the Mediterranean Sea. Regarding anchovy populations, none of the studies identified significant genetic differentiation within GSA06 and GSA07 or between GSA06 and GSA07 samples, with the exception when two different ecotypes were compared (namely the coastal - lagoon or white anchovy- and offshore - marine or blue anchovy- populations). Regarding sardine populations, the available studies showed distinct genetic entities inhabiting the Mediterranean Sea, Alboran Sea, and adjacent Atlantic Ocean. Unfortunately, it was not possible to infer the occurrence of genetic differentiation within or between GSA06 and GSA07 populations. The results from the new genomic study conducted under the SPELMED project showed that the most important component of genetic differentiation among populations occurs between the Atlantic and the Western Mediterranean Sea, whereas the Alboran Sea samples have a distinct status for both species, closer to the Atlantic than the Mediterranean samples. Genetic differentiation in samples from GSA06 and GSA07 was generally not significant, and in both species it was very low when compared to samples taken from the Tyrrhenian and Ionian seas.

Species distributions (**D1.1.2**): Sardine and anchovy occur from the coastal area to the edge of the continental shelf. In GSA06 and GSA07, they generally overlap in their distributions, although sardine is distributed closer to the coast, and it reaches larger sizes and larger maximum ages. For sardine, persistent spawning habitats were identified along GSA06 and GSA07, especially surrounding the river mouth areas of Ebro and Rhone. Persistent nursery habitats were located in the coastal areas and the continental shelf in GSA07 and in the northern part of the Ebro delta in GSA06. For anchovy persistent spawning areas were described along the continental shelf of GSA06 and in GSA07, while persistent nursery habitats were found mainly in the continental shelf of GSA06 and in an area located in the central part of GSA07.

Age, growth and size (D1.3.1.1 & D1.3.1.2): Our review showed that the validation of the age interpretation for both sardine and anchovy is still rather incomplete to date. In the case of anchovy, the adults' age range is between 0 to 4 years old. For sardine, the age range is from 0 to 8 years old. Taking advantage of the availability of large number of otolith readings of anchovy (n= 8054) and sardine (n= 12839) in GSA06 since 2004, we estimated the von Bertalanffy growth parameters (vBGP) of both species. The otolith readings derived from the spawning quarter of juvenile and adult individuals were combined with otolith readings of larvae collected by scientific surveys to build an age-length key (ALK) with a wider representation of individuals of age 0. These ALKs were used as input of a Bayesian vBG model. The updated vBG models of anchovy (Linf=18.1 cm, k=0.684 yr-1 and t0=-0.215) and sardine (Linf=20.5 cm, k=0.985 and t0=-0.142).

[1] Please consider this is a brief executive summary to highlight more relevant SPELMED outcomes. More details can be found in every specific deliverable.

These new estimates led a t0 near age zero, meaning a better biological rationale to this value than too negative current estimates of t0 that implies individuals of age 0 are larger than 10 cm. The growth constants (k) were higher than the current values accepted, indicating the fast growth between ages 0 and 1. These vBGP were used to allocate catch-at-length number to catch-at-age number slice number-at-size to number-at-age ("slicing") for both species in GSA 06 and GSA 07.

Reproductive parameters (D1.3.2.1 &1.3.2.2): We reviewed available data about spawning period, Gonadosomatic index (GSI) and size at first maturity (L50) from sardine and anchovy in GSA 06 and GSA07. Time series analyses of reproduction parameters were very scarce for both species. The reproduction period of sardine in the Mediterranean Sea mainly goes from November to March with peaks of spawning in January and February. The size at maturity of sardine recorded in the literature was highly variable between areas. A time-series analysis was only published in GSA07, where a decline in L50 was observed since 2009. The majority of the studies reported spawning periods of anchovy between April and October with a peak of spawning in June. The L50 of anchovy was highly variable between areas, too. From 2005 a decline of L50 in GSA07 was observed. We also analysed potential historical changes in reproduction parameters with available data from GSA06 and GSA01 and compared with published data from GSA07. For sardine, we observed a latitudinal gradient with GSA07 and GSA06 north (Tarragona and northern areas) showing lower GSI, narrower reproductive period and a decline in L50, while GSA01 had different reproduction parameters. In GSA06 Tarragona a temporal decline in GSI was observed between 2004 and 2013 with an increase in the last period (2014-2017) and a disappearance of individuals of age 4 and 5. For anchovy, we found that the spawning period in GSA01 was the widest of the 3 GSAs followed by GSA06 and GSA07. Changes in the reproductive period were not observed. GSI of anchovy was lower in GSA07 and GSA06 than in GSA01. We observed a progressive disappearance of older individuals (age 3 and 4) in GSA06 and individuals of the same age had lower GSI values in the recent period (2014-2017). L50 of anchovy in GSA06 increased in the beginning of the data analysed (2004-2006) but in 2012 a rapid decline was observed during 3 consecutive years, followed by a recovery in the period 2015-2017. Similar patterns were observed in GSA07, but no recovery of L50 was described. In GSA01 a slight decline in L50 was observed since 2007 but with high inter-annual variability.

Abundance, biomass and recruitment sizes (D1.3.3.1): For sardine a general decreasing temporal trend of biomass and landings was found in both areas. The age and length distributions showed a shift towards younger and smaller individuals in both areas, which was reflected in landings. Limited available data in terms of spatial-temporal changes suggested a local increase in abundance and biomass of sardine in the south of GSA06 (Gulf of Alicante) and a general change from shallower (10-50 m) to deeper areas (50-100 and 100-200 m), particularly in GSA06. For anchovy, a temporal increase of abundance and biomass was found in both areas, which coincided with an increase of catches in GSA06 but not in GSA07. The age and length distributions did not show a clear shift to smaller individuals, although the biomass of larger organism declined in the population and landings. Available spatial-temporal data suggested an increase of abundance and biomass in the GSA06 (Gulf of Alicante, Gulf of Valencia and Ebro River Delta) and a change from shallower (10-50 m) to deeper areas (50-100 and 100-200 m) in both GSAs. Unfortunately, the spatially resolved data from acoustic surveys were not accessible through SPELMED DC neither from National coordinators to be used in these analyses. Spatial-temporal changes need to be further analysed with spatially resolved acoustic surveys. Significant correlations of trends between acoustic surveys, trawl surveys and landings suggested a useful complementary of these sources and particularly for anchovy.

Intra and inter-annual mortality (D1.4.1): We retrieved the current information on natural mortality M (stock assessment model inputs) and fishing mortality F (stock assessment model outputs) for both species, in order to understand the biases that probably are affecting the stock assessment models. Further, new estimates of M and *M-at-age* were proposed through several indirect methods, using the updated vBGP. The M estimated by the *Prodbiom* software was used to set the final assessment models of the two species stocks in both areas, because it meet the biology rationale of these species under the hypothesis of the t_0 occurs near to age 0.

Population body condition (D1.5.1): Sardine is a winter spawner, and acquires and stores energy in spring and summer to be used in the reproductive period. Instead, anchovy spawns in spring and summer and uses the current energy income for reproduction. We analysed the seasonal and inter-annual variability in the body condition of sardine and anchovy of the GSA06 and GSA01 and we compared the results with available published data from GSA07. Sardine had a higher body condition in spring (April-June) in GSA06 north and south. Instead, in GSA01 the peak of body condition was later (July and August), just before the spawning season. In general, the relative condition index (Kr) mean values were higher in GSA06 north than in GSA01. In the case of anchovy, the months with higher body condition were April-May for GSA06 and April to September for GSA01. However, in GSA06 the body condition was higher than GSA01 during the reproduction peak. The intra-annual variability of Kr was lower than in sardine. High inter-annual variability in body condition was observed for sardine in GSA06 north and south and a temporal decline in body condition coincided with the decline observed in GSA07. The decline was observed in all ages. Inter-annual variability in the body condition was also observed for anchovy in GSA06 and GSA07. Overall, the body condition of sardine and anchovy in GSA06 and 07 declined similarly, with a decline of Kr in 2008 in both species and a second decline in 2014 that presented the lower values of Kr. Instead, GSA01 presented different patterns in both species. Attention should be put in the differences in the peak of body condition between GSAs in the case of sardine. In GSA06 the decrease in body condition before three months of the spawning season could indicate that there is less energy available during the reproduction period.

Biological and genetic data related to connectivity and stock identification (D1.2.3): Genetic/genomic data reviewed or generated during this study showed that the differentiation of both species sampled from the study areas were not significant. In addition, both species displayed several similar biological features in both areas such as a declining age distribution, a decline in L50, a decline in GSI index and body condition and changes in length structure of landings. Sardine showed in both areas similar declining changes in abundance, biomass and landing trends. When comparing data available from a latitudinal gradient within GSA06, the abundance and biomass showed similar patterns for both species, while sardine showed a decline in body condition and no change in reproductive period in sub-areas. Both species showed different distribution patterns and responses to environmental variables. These results highlight that biological and ecological differences may be larger than genetic ones and further studies are needed to consider stock identification from a management point of view.

Task 2 - Summary of ecological and fisheries results

Feeding ecology, competitors and predators (D2.1.1 & 2.1.2): We reviewed existing information on feeding ecology and trophic level from stomach content analysis, stable isotopes and ecosystem models. In general, copepods were the most important prey for both species, as well as for their potential competitors round sardinella and European sprat. Sardine and sardinella also presented higher percentages of phytoplankton. Cladocera was also an important prey for sardine, anchovy and sardinella. The trophic niche of round sardinella and European sprat was wider and could be more advantageous for a better adaptation to changes in food availability than that from sardine and anchovy. Available temporal studies regarding feeding behaviour of sardine and anchovy in GSA07 using stomach content and stable isotope documented a reduction in prey diversity and that in periods with higher body conditions these species feed larger copepods and cladocera. In GSA06 there was not enough published data to look at changes in the diets. Overall, information on feeding habits of potential predators of small pelagic fish was scarce. We found that fin-fish species showed the higher weight (%W), followed by seabirds, elasmobranchs, marine mammals, cephalopods and sea turtles. At the geographic level, the importance of sardine in the predators' diets was higher in the studies conducted in the western than in the eastern Mediterranean Sea. In contrast, anchovy contributed more to the diets of predators in the eastern Mediterranean. The main predators were pelagic or bathypelagic organisms. At the species level, the main species preying on sardine were barracudas *Sphyraena* spp., mackerels *Scomber colias*, greater amberjack *Seriola dumerili* and twaite shad *Alosa fallax*. For anchovy, the main predators were *A. fallax*, the pelagic stingray *Pteroplatytrygon violacea*, *Sphyraen*a spp., the false scad *Caranx rhonchus* and mackerel *Scomber scombrus*. There was not enough data to study changes of feeding habits of predators.

Role of environmental fluctuations (D2.3.1): We reviewed existing information on the role of environmental fluctuations and changes for sardine and anchovy in the Mediterranean Sea. Available data was more abundant for anchovy than sardine, and adults were more studied than eggs, larvae and juveniles. There was mostly a negative relationship with depth for both species, thus as depth increases anchovy and sardine biomass, abundance, occurrence and landings tend to decline. In the case of sardine, there was mostly a positive relationship with salinity and primary productivity. Sardine showed mixed results with temperature, although a negative relationship prevailed in literature. On the contrary, the relationship between anchovy and the environmental variables was mixed. Statistical analyses were also performed for both species crossing available datasets regarding presence/absence, abundance, biomass and landings with environmental parameters. Results showed a negative effect between anchovy and sardine variables and primary productivity, especially in GSA06, a positive effect between temperature and anchovy in both GSAs, while contracting results were found for salinity between GSAs. Unfortunately, the spatially resolved data from acoustic surveys were not accessible to be used in these analyses. It is interesting to highlight that high positive correlations were found between MEDITS and MEDIAS anchovy available data (2003-2010, with 2005 as the exception).

Past and current fisheries exploitation (D2.4.1): Sardine and anchovy are the most caught small-pelagic species in the Spanish and French Mediterranean. In fact, 38,528 tons of sardine were landed in 2006 by the fleets of both countries. Currently, landings of sardine are below 11,000 tons, meaning that the catches of this species were reduced by 72%. The landings of anchovy in the French Mediterranean have been reduced along the time series from almost 8,000 tons (2002) to near 1,300 tons (2015-2016). Conversely, this species has been increasingly landed in the Spanish Mediterranean (eight times higher than in 2007). Historical catches indicated that sardine was highly exploited before anchovy in both areas. Currently, anchovy stocks (both GSAs) present a better health status than sardine, which shows quite low stock size with respect to the past. Catch-at-length and catch-at-age revealed that the size of both species seems to be smaller in recent years. Taking into account that no changes in the fishing techniques that could affect selectivity are documented since 2002, it seems that both species are now smaller than ten years ago. Small pelagic fish are mainly caught by purse seine fishery (VL12-24 m) in GSA06 and purse seine (VL12-24 m) and mixed deep-water species (VL 24-40 m) fisheries in GSA07. Although the number of vessels is declining, fishing effort in terms of days at sea seemed to remain stable. The CPUE by fleet vary along the years, months and ports. Most of the fleets were losing net incomes or even were presenting losses. The fleet size of the small pelagic fishery in GSA07 is very small in comparison to GSA06. However, information of GSA07 included several gaps that hampered the performance of a complete analysis.

Task 3 - Summary of management measures

Past and current management measures (D3.1.1 & 3.1.2): We first provided a detailed analysis of the situation on technical measures, following the basis of Council Regulation (EC) No 850/98 as well as other regional, national and autonomic regulations. We discussed those management measures in view of the new Common Fisheries Policy (CFP) objectives and taking into account the regional aspects of the Mediterranean management system, which are mainly based on technical measures. Existing EU technical measures can be found in a wide range of different regulations and contexts. Secondly, we collected information about the fishers and stakeholder perceptions through a series of interviews in relation to five main aspects: 1) Usefulness of the management measures, 2) Compliance, 3) Whose fault is it?, 4) Why is this crisis different from others?, and 5) Possible solutions. The most useful management measures were selected to be “Size limitations”, “Gear Limitations” and “Quota limits”. Regarding the compliance of the management measures (2), results showed that fishers answered that they mostly comply all management measures. Younger fishers were the ones that agreed the most with species limit and quotas. Regarding “Whose fault is it?” (3), fishers did not identify a unique and clear responsible of the depletion situation. They mostly identified managers as the ones to blame, although answers were generally quite balanced. Regarding “Why is this crisis different from others?” (4), most fishers mentioned the small size of the individuals as the main difference to other crisis. Finally, regarding possible solutions (5), all fishers mentioned the need of better and new regulations, co-management and the need of new studies on how environmental factors and water quality could affect the studied species.

Stock assessments (D3.2.1): Overall, the assessment with a4a model highlighted that sardine from GSA06 in 2017 was overexploited (Spawning Stock Biomass, SSB < Blim, limit reference point for spawning stock biomass) and overfishing was occurring (Exploitation rate, E > 0.4, proxy Fmsy). The exploitation trend suggested that overexploitation increased since 2002, and an incipient reduction in fishing mortality occurred since 2014. Sardine from GSA07 in 2016 showed a strong overexploitation, exhibiting a quite depleted SSB and E > 0.80. Given that catches of sardine in GSA06 contributed in more than 90% of catches of combined GSAs, the stock assessment results of sardine GSA06 and GSA07 together was dominated by the trend and status of sardine in GSA06. This means that a less pessimistic overexploitation scenario was perceived when both areas were combined. According to the a4a model, anchovy from GSA06 was overfished (SSB < Blim) and overfishing was occurring (E > 0.4). Overexploitation in 2017 was higher than 2004, meaning that fishing mortality have increased with time. The stock assessment of anchovy GSA07 suggested that fishing mortality was very low in recent years, presumably below E=0.4. However, poor model diagnostics and very high fishing mortality for age 2 avoided providing a reliable advice of the status of anchovy GSA07. Overall, the stock assessment of anchovy showed bigger challenges than in the case of sardine stocks. The final stock assessment of anchovy GSA06 and GSA07 together indicated a sustained status of overexploitation since 2004 (excluding 2005-2007). SSB was depleted and below Blim in 2016. Fishing mortality in recent years was twice Fmsy proxy of E=0.4. Although the stock assessment results indicated that F is decreasing since 2014, the retrospective analysis showed high instability depending on the final year data used to perform the stock assessment.

Management measures to increase sustainability and healthy target stocks (D3.3.1 & D3.3.2): We used a multi-modelling platform to investigate which factors may influence the spatial distribution and abundance of the two species in both areas and which management alternatives could be favoured to promote their sustainable exploitation. Firstly, using a spatial Redundancy Analysis (RDA) we tested 4 main hypotheses as possible causes of historical changes: (1) a high fishing impact, (2) unfavourable environmental conditions, (3) the recovery of Bluefin tuna (*Thunnus thynnus*); and (4) the increase of round sardinella (*Sardinella aurita*). Secondly, we modelled future scenarios considering IPCC projected environmental variables to test different scenarios. Afterwards, we tested possible alternative management scenarios using the Management Strategy Evaluation (MSE) framework with different modelling approach. The spatial RDA findings for sardine in the GSA07 highlighted that its distribution variability may be due to spatial and environmental factors. The importance of the top predator presence was lower than in GSA06, while data regarding sardinella and VMS was not available. For anchovy, results showed that fisheries impact (using AIS intensity) and the environment conditions were the main influencing factors. Future IPCC projections highlighted that both sardine and anchovy will likely undergo a reduction in their spatial distribution in both areas. Future climate refuges areas that will keep a probability of occurrence higher than 0.70 were identified around the Rhone river in GSA07 and the waters around the Ebro River in GSA06 for both species. Food-web models scenarios were developed using GSA06 and GSA07 together. A general reduction of fishing mortality (a 50% reduction of the historical status quo in 2000 or a reduction to 2007 fishing mortality levels from 2008 to 2016) could have contributed to a successful recovery of both species in the present. A Marine Spatial Planning (MSP) approach can provide further insights for these species, considering species-specific measures. We suggest larger spatial-temporal (seasonal) closures for the fisheries targeting small pelagic fish to achieve a reduction of fishing mortality. Depth fishing restrictions are one of the best management measures, and they are based in the MSP approach.

Engaging stakeholders into governance processes (D3.4.1): Feedback from relevant stakeholders was collected through a web-platform with questionnaire, in which the importance of different technical measures in order to progress towards sustainable fisheries should be rank. According to the majority of the stakeholders, the most important measures to be taken into consideration should be: the obligation to carry on board VMS, the prohibition of more than one auxiliary boat per each purse seine, the prohibition of pelagic trawling, big opening trawling gears and semi-pelagic trawling, the limitation of the mesh size , the limitation on the number of fishing days per week, spatial-temporal closures, and the minimum conservation reference size (9 cm or 110 specimens per kg of anchovy and 11 cm or 55 specimens per kg of sardine).

III. Background

The small pelagic fish (SPF) species, such as *Sardina pilchardus* (European sardine), *Engraulis encrasicolus* (European anchovy), *Sardinella aurita* (Round sardinella) and *Sprattus sprattus* (European sprat), are key elements of the marine ecosystem in the Mediterranean Sea and are an important bulk of total fishing landings (Cury et al. 2000, Pikitch et al. 2013). Fluctuations of SPF populations in the Mediterranean Sea have been linked with environmental fluctuations and oceanographic conditions changes (Palomera et al. 2007). Causes of recent declines of SPF have also been attributed to high fishing impacts, competition between pelagic organisms or ecosystem effects (e.g., Palomera et al. 2007, Martín et al. 2008, Van Beveren et al. 2014, Brosset et al. 2017, Coll et al. 2018, Saraux et al. 2018). Due to the important biomass, production, and key trophic links, shifts of SPF in the Mediterranean Sea can impact the dynamics of the entire ecosystem, and declining populations can have ultimate consequences for the bulk of commercial catches and economic profit.

Despite their importance, available information about the biological, ecological and management of SPF is still fragmented. Further work is needed to integrate available historical information regarding key aspects of SPF, and to develop robust knowledge to guide the management of these species in the Western Mediterranean Sea. The management of target species can have impacts on other species coexisting in the same exploitation area. Interactions at ecosystem level should be taken into account when defining management measures.

The ultimate objective of SPELMED (SC NR. 02 - TENDER EASME/EMFF/2016/32) was the evaluation of the population status of *Sardina pilchardus* (European sardine) and *Engraulis encrasicolus* (European anchovy) in the Northwestern Mediterranean Sea, based on the generation of key biological and ecological information to support robust management options in the area.

The study had three specific objectives:

1. Revision of biological information for both stocks
2. Revision of the ecological and fisheries information
3. Proposal and assessment of fisheries management measures

The study covered the Geographical Sub-Areas (GSAs) 06 – Northern Spain and 07 – Gulf of Lions, and focused on sardine and anchovy stocks, without forgetting the marine ecosystem and the mixed-fisheries interactions, in these areas.

For this purpose, existing and new information were collected regarding small pelagic fish in North of Spain and the Gulf of Lions (GSA06 and GSA07) and their fisheries, emphasising the information at the sub-regional level within GSA areas. When possible information from other Mediterranean areas was collected during Task 1 and Task 2, too.

A large part of the first objective of SPELMED included a genetic analysis of European sardine and European anchovy in GSA06 and GSA07. Considering the method proposed for such analysis in the request of service, as well as the spatial and sampling coverage requested, the study was challenging given time and budget constraints, in addition with some difficulties in the sampling that are explained below (see section 4).

In this document we provide a detailed summary on the main findings of the project and present the deliverables that have been generated. We also explain main challenges that arose and how these were addressed, and the mitigation measures and adjustments resulting from unforeseeable events.

IV. Work programme, activities carried out and main results of the project

Structure of the project

SPELMED was divided in three main scientific tasks: Task 1, Task 2 and Task 3, divided themselves in several sub-tasks. In addition, Task 0 assumed the coordination of the project:

Task 0. Coordination of the project.

Task 1. Comprehensive review and improvement of the existing biological information for European sardine and European anchovy in GSAs 06 and 07.

Task 2. Comprehensive review of the ecological and fisheries information for European sardine and European anchovy in GSAs 06 and 07.

Task 3. Proposal and assessment of different fisheries management measures for European sardine and European anchovy in GSAs 06 and 07.

TASK 0. Coordination of the project

Lead: Marta Coll (CSIC) and Jose Maria Bellido (IEO). Participant institutions: ALL.

Activities under this task were directed towards a smoothly running of the project and the successful accomplishment of the project goals.

Under Task 0, the following activities were developed:

1) Co-ordination of the WPs activities in collaboration with WP and Task leaders ensuring connectivity among them;
2) Co-ordination of the project meetings with project partners (month 1 - January 2018, month 5 – May 2018; month 12 – December 2018);
3) Preparation of the official kick-off meeting held in Brussels with the contracting Authority (month 2 – February 2018) and mid-term skype meeting (month 10 – October 2018);
4) Preparation and submission of minutes of the first official meeting in Brussels to EASME (February 2018);
5) Preparation and submission of the Inception, Interim, Draft Final and Final reports to EASME (at month 1 – January 2018; month 7 – July 2018; month 12 – December 2018; month 15 – March 2019).

A data call for some specific DCF data, in particular 2015 and 2016 for biological data (fishery dependent information) and for the whole time series of the acoustic and trawl surveys (respectively MEDIAS and MEDITS), was launched after the kick off meeting (12th of February 2018) by means of a specific request to DGMARE. The data requested was made available on the 25th of May 2018.

Project meetings

Three scientific meetings were organised during the project:

• **1st project meeting**, held during the 31st of January to the 1st of February 2018 in Barcelona (Spain) with the aim to discuss project details, plan activities, refine the allocation of duties and tasks, organised all the administrative matters, and discuss the Inception Report. During the meeting focus was put to define protocols and agree on excel files to collect data from different Tasks in a standardized way (See Annex I for the agenda of the meeting).

• **2nd project meeting**, held the 10th and 11th of May 2018 in San Pedro del Pinatar (Spain). The Progress meeting was dedicated to assessing the progress of the project, update activities and tasks, and discuss the Interim Report (See Annex II for the agenda of the meeting).

• **3rd project meeting**, held the 4th and 5th of December 2018 in Barcelona (Spain). This meeting was dedicated to present and discuss results from all deliverables and products, in addition to organise the draft of the Final Report (See Annex III for the agenda of the meeting).

In addition, the project included the organization of four specific 1-day or 2-day workshops: **1) an age-size methodology workshop** (18th and 19th of June, Fuengirola, Spain), **2) a stock assessment workshop** (2nd – 6th of July, Ispra, Italy); 3) **a modelling workshop** (21st- 22nd of August, Barcelona, Spain) and 4) **a genetics workshop** (3rd of December, Barcelona, Spain) (See Annex IV for the agenda of the workshops). These workshops were attended by specific partners of the project that were involved in specific tasks related to the objectives of the workshops. Workshops were essential to create the opportunity to discuss results and improve analyses of specific deliverables.

Additional requested meeting by EASME: During our exchange of communication with EASME and DGMARE, an additional request was sent to SPELMED project to participate in GFCM WGSASP during November 2018 to present results from D3.2.1 (Stock status, including uncertainty). This meeting allowed SPELMED scientists to present new results and important achievements to be incorporated in the GFCM stock assessments. As a result of the participation to the meeting, the assessment of sardine in GSA06 developed with a4a was approved. A summary of the meeting outcomes were provided to the Commission a week after the meeting.

Official meetings with the European Commission

One meeting was held in Brussels with EASME and DGMARE officers:

• **Kick-off meeting**, held the 7th of February of 2018, where the Inception Report and the general work programme was discussed, with a special attention to the genetic analysis. During this meeting we took the final decisions about specificities of the genetic analysis (sampling details and methods), taking into account the suggestions of the Contracting Authority (See Annex V for the agenda and meeting minutes).

• **A second meeting** was held by means of a skype call in October 2018. During this meeting we discussed about the progress of the project, specifically about the genetic study and the stock assessment analyses.

• **A third meeting** was held by phone call in March 2013. During this meeting we discussed final products of the project and dissemination actions.

Official Reports to EASME

Three reports were submitted to EASME prior to this one:

- The corrected version of the **Inception Report** was submitted the 1st of March 2018 and it was accepted the 7th of May 2018 (**Deliverable 0.1**).
- The Interim Report was submitted the 21st of July 2018 and it was accepted in October 2018 (**Deliverable 0.2**).
- The first version of the Draft Final Report was submitted the 31st of December 2018 (**Deliverable 0.3**).

At the end of this document there is the detailed timetable of the project listing milestones and deliverables (Table 1 and Table 2). All milestones and deliverables were successfully completed.

Informative workshops with fishers and administration

In February 2018, a first workshop was held at the Institute of Marine Science (ICM-CSIC) to inform fishers and interested stakeholders about the project aims and activities. Representatives of the Autonomic Government of Catalonia, representatives of fisheries organizations and industry, and several fishers and scientists met during this meeting to discuss the topic of small pelagic fish in the area. During April 2019, we will organize a second workshop with the same stakeholders to present the results of SPELMED and update them on the main findings of the project.

In September 2018, the SPELMED project was introduced in the Scientific Forum organised by University of Alicante (Spain) entitled XI Reunión del Foro Científico sobre la pesca española en el Mediterráneo. The intention is to present a summary of main results in the meeting to be held in September 2019 in the same location.

TASK 1. Comprehensive review and improvement of the existing biological information for European sardine and European anchovy in GSAs 06 and 07

Lead: Manuel Hidalgo (IEO) and Marta Coll (CSIC). Participant institutions: CIBM, COISPA, CONISMA, CSIC, HCMR, IEO.

The aim of the first task of the project was to review and compile the available biological information about European sardine (*Sardina pilchardus*) and European anchovy (*Engraulis encrasicolus*) in GSA06 and GSA07, and complement it with information from other areas of the Mediterranean Sea. In addition, this information was expanded and improved with additional genetic analyses.

Task 1.1. Identify and integrate available past and current information about the distribution and connectivity of the stocks for different age groups

Lead: Rita Cannas (CONISMA) and Marta Coll (CSIC). Participant institutions: CIBM, COISPA, CONISMA, CSIC, HCMR, IEO.

In this task, we integrated available biological and genetic data in order to obtain past and current information and hence a comprehensive picture about what is known regarding the distribution and connectivity of the stocks of European sardine and European anchovy in the study area for different age groups (eggs, larvae, juveniles and adults).

Task 1.1.1. Review of genetic studies

Lead: Rita Cannas (CONISMA) and Manuel Hidalgo (IEO). Participant institutions: HCMR, CONISMA, CSIC, IEO.

We reviewed and compiled all the available genetic information about European sardine and European anchovy in GSA06 and GSA07 (**Deliverable 1.1.1**). The effort was complemented with information from other areas of the Mediterranean Sea, Black Sea and the Atlantic Ocean. The systematic review was based on peer-review papers, grey literature, and data from national and European research activities. All publications/reports that contained information on genetic differentiation/structuring in the investigated species were considered pertinent to this review. The datasets (reports/papers) were subdivided in three categories: a) High Priority (HP), describing at least a sample population in GSA06 and/or GSA07, b) Priority (P), describing at least a sample population in the Mediterranean Sea, and c) Informative (I), with information on the species outside the Mediterranean Sea (i.e., Atlantic Ocean and/or Black Sea).

A total of 62 datasets (including HP+P+I) provided useful information on population genetic differentiation for the target species, 24 of which included information from population samples in GSA06 and GSA07 (HP datasets), other 30 from Mediterranean populations (P datasets), and 8 from outside the Mediterranean Sea (I datasets). In general, results evidenced that information on anchovy was more abundant both within and outside the Mediterranean Sea. Overall, 19 studies deal with anchovy population samples from GSA06 and/or GSA07, and other 19 studies investigated Mediterranean anchovy populations. Contrarily, information concerning GSA06 and GSA07 sardines derived from 5 studies only, while further 11 studies concentrate on Mediterranean sardines.

Regarding European anchovy populations from GSA06 and GSA07, three techniques were the most commonly applied: allozymes, mtDNA markers and SNPs. None of the studies identified significant genetic differentiation within GSA06 and GSA07 or between GSA06 and GSA07 samples, with the exception when two different ecotypes were compared (namely the coastal (lagoon or white anchovy) and offshore (marine or blue anchovy) populations) (Figure 1). In addition, when analysed together, GSA06 and GSA07 tended to appear closer to the

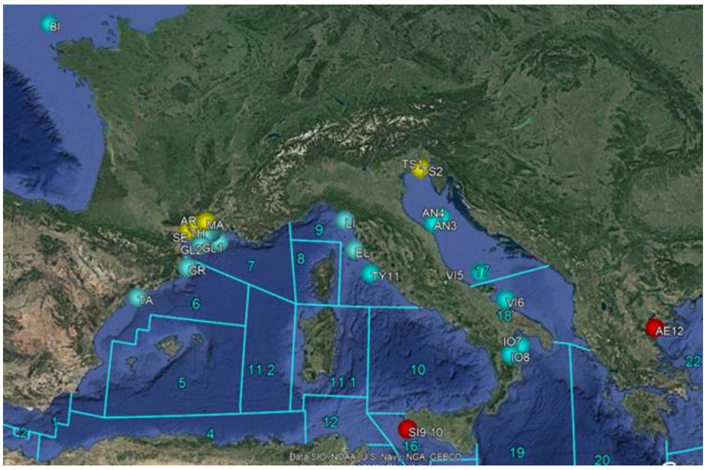

Figure 1. Genetic differentiation and stock structuring of European anchovy within the Mediterranean Sea as inferred by Borsa (Borsa 2002).

eastern areas of the Western Mediterranean Sea (Ligurian and Tyrrhenian seas) than to the Alboran Sea, which in almost all the studies appeared to be significantly different to GSA06 and GSA07 and more similar to the Atlantic samples of the Gulf of Cadiz. In general, distinct genetic entities were found to inhabit the Mediterranean Sea and adjacent Atlantic Ocean.

Regarding European sardine populations, three techniques have been applied so far: allozymes, mtDNA markers and SSRs. Genomic studies were never used before our project in this species, nor have SNP markers. Unfortunately, it was not possible to infer the occurrence of genetic differentiation within or between GSA06 and GSA07 populations because in 4 studies out of 5, only one sample was included from the GSAs of interest.

Results from the only study with multiple samples indicated that the populations from GSA07 (the Gulf of Lions) were homogeneous; they were grouped together but in a different cluster from the samples of GSA06 (Valencia and Catalonia) (Figure 2). However, the bootstrap values supporting this subdivision are very low (i.e., not statistically supported). Comparatively, there was a heterogeneous ability to differentiate Alboran from GSA06 and GSA07 compared with the consistency observed in studies on anchovy. In general, the studies showed distinct genetic entities inhabiting the Mediterranean Sea, Alboran Sea, and adjacent Atlantic Ocean.

Figure 2. Genetic differentiation and stock structuring of European sardine within the Mediterranean Sea as inferred by Ramon and Castro (Ramon & Castro 1997).

Task 1.1.2. Review of other information regarding the distribution of the species

Lead: Marta Coll (CSIC) and Manuel Hidalgo (IEO). Participant institutions: CIBM, CONISMA, CSIC, IEO.

We reviewed available data regarding the distribution of European sardine and European anchovy in the study area (GSAs 06 and 07) for different age groups (eggs, larvae, juveniles and adults), complementary to Task 1.1.1 (**Deliverable 1.1.2**). When available we reviewed information from other areas of the Mediterranean Sea. The used peer-review papers, grey literature, and national and European research activities.

Both European sardine and European anchovy occur from the coastal area to the edge of the continental shelf (approx. 200 m depth). They generally overlap in their distributions in the study area, although European sardine is observed to distribute closer to the coast, and it reaches larger sizes and larger maximum ages (Figure 3).

European sardine spawns from October to March. Persistent sardine spawning habitats have been identified along GSA06 and GSA07, especially surrounding the river mouth areas of Ebro and Rhone, and they reach as far as the southern areas of GSA06. European sardine recruitment period is mainly described in June and July, and the identified persistent nursery habitats are larger in July than in June. These nurseries are located in the coastal areas and the continental shelf of the Gulf of Lions in GSA07 and the northern part of the area directly influenced by the Ebro in the GSA06.

Larger sizes of European sardine specimens, captured during MEDITS EU survey, were observed in GSA06 compared to GSA07, while a higher presence of individuals captured at the MEDITS survey were observed in GSA07 than GSA06, with a trend to increase in the northern area.

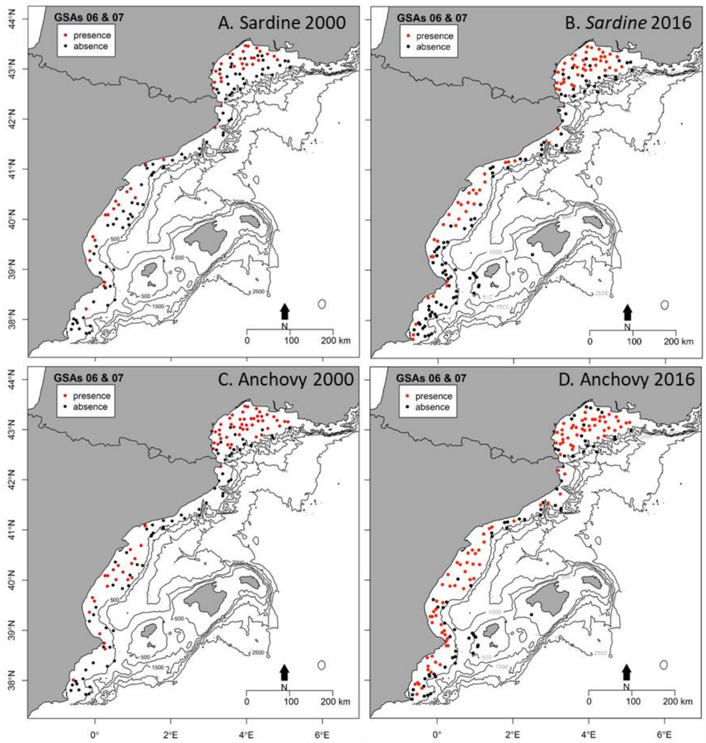

Figure 3. Comparison of presence/absence of European sardine in a) 2000 and b) 2016 and European anchovy in c) 2000 and d) 2016 according to results from the MEDITS survey.

European anchovy spawns from spring to autumn with a peak in June and July, with described persistent spawning areas along the continental shelf of GSA06 and the Gulf of Lions in GSA07. Juveniles of European anchovy are found in high percentages during late autumn and winter, and in late autumn persistent nursery habitats are found mainly in the continental shelf of GSA06 and in an area located in the central part of the Gulf of Lions in GSA07. Larger sizes of specimens captured at MEDITS survey were observed in GSA06 compared to GSA07, too. A larger presence of individuals captured at MEDITS survey are observed in GSA07 than GSA06. However, the presence of anchovy specimens in MEDITS survey conducted in GSA06 seems to increase with time.

Published results did not show clear spatial-temporal changes in the spatial distribution of both species. However, qualitative assessments about presence/absence of the MEDITS survey suggested that there may have been spatial-temporal changes in the presence/absence patterns of individuals captured in the survey (with increasing presence of European sardine in GSA07 and of European anchovy in GSA06) (Figure 3).

Unfortunately, the lack of freely available georeferenced raw data from acoustic surveys (e.g., the MEDIAS survey) impaired the possibility to complement previous published results and the ones developed with MEDITS surveys to fully evaluate potential changes in species distributions over time.

Task 1.2. A genetic population analysis for sardine and anchovy in the Western Mediterranean Sea

Lead: Rita Cannas (CONISMA) and Costas Tsigenopoulos (HCMR). Participant institutions: COISPA, CONISMA, CSIC, HCMR, IEO.

We generated new detailed information on the genetic population status of European sardine and European anchovy in GSAs 06 and 07, and in general for the North-western Mediterranean Sea and wider areas of the Mediterranean Sea (**Deliverable 1.2.2**). The analysis added innovative information to the genetic characterization of the stocks for the Mediterranean Sea, considering previous information, mainly available for anchovy (Tudela et al. 1999, Ardura et al. 2011, Zarraonaindia et al. 2012, Ardura et al. 2013, Catanese et al. 2016, Ruggeri et al. 2016, Catanese et al. 2017, Chahdi Ouazzani et al. 2017, Turan et al. 2017) and the review in Deliverable 1.1.1. This task was performed with an open communication channel to on-going projects SARGEN and TRANSBORAN, led by IEO and covering waters of Portugal, Spain, Morocco, Algeria and Tunisia. The work plan and outcomes of this task are briefly described below:

Sampling procedure: The genetic sampling was conducted following the specificities of the term of reference, in European Mediterranean and Atlantic waters during scientific surveys or commercial hauls, and it was fine-tuned with the final definition of priority locations and involved GSA achieved at the project meeting in Brussels with the Contracting Authority. The final sampling strategy included twelve sampling locations, each with at least 35 fish sampled (Figure 4):

Two and three sampling locations in GSA07 and 06, respectively,

One sampling location in four neighbouring GSAs (GSA01, 05, 09 and 11),

One sampling location in two more distant GSAs (GSA10 and 19),

One sampling location in the Atlantic Ocean (close to the strait of Gibraltar).

Table 1. Summary of sampling achieved for the genetic analysis of each species.

Sampling sites		Minimum n° individuals	Sampling institutions
GSA06	Site 1-3	105	CSIC/IEO
GSA07	Site 4-5	70	CSIC/IEO
GSA01	Site 6	35	IEO
GSA05	Site 7	35	CSIC/IEO
GSA09	Site 8	35	CIBM
GSA10	Site 9	35	COISPA
GSA11	Site 10	35	CONISMA

GSA 19	Site 11	35	COISPA
Atlantic	Site 12	35	IEO

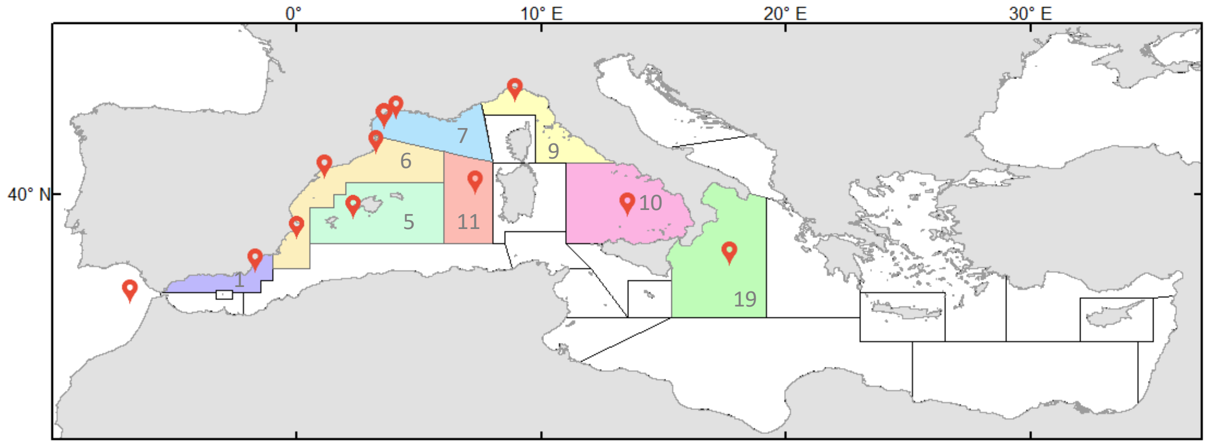

Figure 4. Map of the locations of the sampling sites for the genetic analysis of each species.

Tissue sampling and storage: Following the standardized procedure for the sampling collection, storage and shipping (protocol presented in **Deliverable 1.2.1**), all partners involved in the sampling activities delivered their samples (Table 1 and Figure 1). In Deliverable 1.2.1. the sampling and shipping protocol explained the details of the sampling collection and storage. After completion of the sampling, tissues were collected by ICM/CSIC where they were temporarily stored until laboratory analyses started.

Genotyping by sequencing: The genetic analyses were developed using genotyping through high-throughput sequencing. Total genomic DNA was isolated from tissues using commercial kits. The amount and quality of DNA was quantified using a spectrophotometer. All individual DNAs were digested by a specific high-fidelity Restriction Enzyme (RE), ligated to compatible adapters and size-selected (custom library construction). Fragments were finally sequenced in four lanes of HiSeq 2500 Next-Generation Sequencing machine and using kits for paired-end (PE100) sequencing. Raw reads were used for downstream analyses.

Bio-informatic analyses: Sequenced reads from each of the two species were analysed separately using STACKS v.2.2 pipeline, in order to quality control the reads, identify the genomic loci sequenced, genotype each individual, and conduct basic population genetics analyses. Then, the surviving high quality forward reads of each sample were used for building de novo the loci of that particular sample with the STACKS component ustacks. The parameters used were -M 3 (Maximum distance allowed between loci) and -m 5 (Minimum depth of coverage required to create a locus). Then, a catalogue of loci was built for each species using the STACKS component cstacks with the parameter -n equal to 3 (number of mismatches allowed between sample loci when building the catalogue). Following the catalogue construction, the loci of each individual were matched to the catalogue through sstacks. The next step included the use of gstacks to assemble and merge the second read of each pair, call variant sites and identify the genotype of each sample for each catalogue locus. Finally, populations was executed by keeping only the loci that were sequenced in >80% of the individuals of each population in at least 11 out of the 12 populations of each of the two species, with >0.1 minor allele frequency. For each stacks locus, only one randomly selected SNP was kept. Through STACKS component populations, we extracted the selected SNPs in vcf, genepop and structure format. Additional file formats were obtained with the software PGDSpider version 2.1.1.5. The vcf files were imported in the bioconductor R package SNPrelate were we conducted a principal component analysis (PCA).

Population genetic analyses: Estimates of genetic diversity within samples in terms of observed (Ho) and expected heterozygosity (He) were calculated for each geographical sample with GenAlEx v6.5. Hardy–Weinberg Equilibrium (HWE) was evaluated for each sampling location, using exact tests based on heterozygote deficit as implemented in the software Genepop v4.7. The inbreeding index (FIS) was calculated with Genodive v2.0b27 and the significance tested with 999 permutations. To estimate the level of differentiation among samples, pairwise and global FST values were calculated with Arlequin ver. 3.5.1.2. To correct for multiple testing the Benjamini–Hochberg procedure, controlling for the false discovery rate (FDR), was used as implemented in Myriads. The Analysis of Molecular Variance (AMOVA) was performed again with Arlequin grouping the samples on the basis of a priori hierarchical geographical structure. The statistical significance of the resulting values was estimated by comparing the observed distribution with a null distribution generated by 10,000 permutations, in which individuals were redistributed randomly into samples. The Discriminant Analysis of Principal Components (DAPC) was performed with Adegenet ver. 2.1.1 (R version 3.5.1, R Development Core Team, 2014; http://www.r-project.org). Prior to running the DAPC, an optimum number of principal components were identified using the optim.a.score () function. The DA was then run on the retained principal components using the dapc () function. Finally, after selecting the best number of eigenvalues for the DA analysis, the DAPC results (DAPC scatterplots) were visualized graphically with the scatter.dapc () function. To determine the number of expected genetic clusters (K) present in the dataset, without any a priori population definition, the find.clusters () function included in Adegenet was initially used to run successive numbers of (K)-means clusters of the individuals, across a range of K = 1–20. We identified the best supported number of clusters through comparison of the Bayesian Information Criterion (BIC) for the different values of K. Finally, the structure files were imported in STRUCTURE v 2.3.4 software to evaluate the presence of clusters with the sampled populations. To select the best k parameter representing the number of clusters of the dataset, we used the EVANNO method as implemented in Structure Harvester. In order to summarize variation within and between sampling sites, Principal components analysis (PCA) was performed using the R-package SNPRelate v1.16.

Summary of results: results showed that the most important component of genetic differentiation among populations occurred between the Atlantic and the Western Mediterranean, whereas the Alboran Sea samples have a distinct status in both species, closer to the Atlantic than to the Mediterranean samples. Genetic differentiation in samples from GSA06 and GSA07 locations (Spanish and French coasts, respectively) was generally not significant, and in both species, it was very low when compared to samples taken from the Tyrrhenian and Ionian seas (Figure 5). Therefore, current results provided thorough insights into the extremely weak fine-scale genetic structuring in both high gene

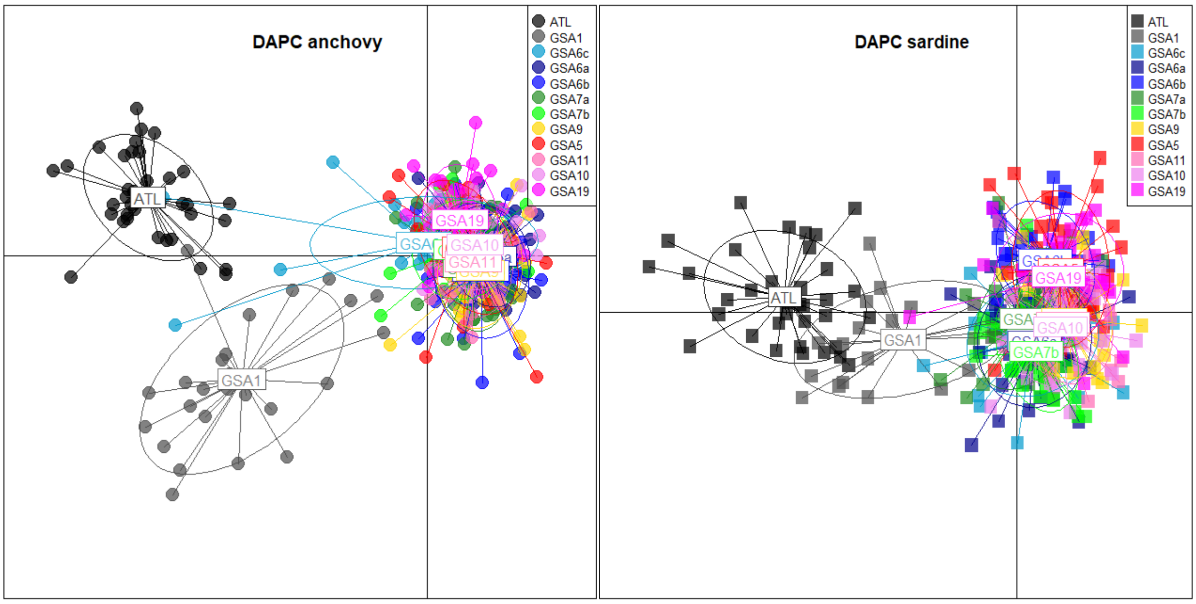

Figure 5. DAPC analysis summarizing the main genetic results: differentiation of the Atlantic (black) and Alboran (grey) samples from the rest of the Mediterranean samples in the two species (in colours).

flow marine fish.

The last deliverable of this task, **Deliverable 1.2.3**, regarding all biological and genetic data related to connectivity and stock identification presented a summary of all results of SPELMED project that can provide information about connectivity and stock identification of sardine and anchovy in GSA06 and GSA07. We summarized results considering their magnitudes, patterns and trends between GSA06 and GSA07 and within regions in GSA06, processing all results generated by SPELMED during Task 1 (biological information), Task 2 (ecological and fisheries information) and Task 3 (assessment and management advice). We also identified gaps of information.

The integration of genetic/genomic data reviewed and generated during this study showed that the differentiation of both European sardine and European anchovy populations sampled from the study area was not significant. Both species displayed several similar biological patterns and changes to stressors in both GSA06 and GSA07 (summarized below): both displayed a declining age distribution with time, mostly a decline in size at first maturity and in body condition, no changes in the reproductive period, similarities in the order of magnitude of abundance and biomass, and both showed changes in length structure of landings. Sardine showed in both areas similar changes in abundance and biomass trends (mostly a decline) and landing trends (mostly a decline, too).

When comparing data available from a latitudinal gradient within GSA06, the abundance and biomass showed similar patterns for both species. Regarding physiological condition and reproduction, sardine showed a decline in body condition. Both species showed different distribution patterns between GSA06 and GSA07 changing with time, as well as different responses to environmental variables. Sardine showed also differences in age class distribution, size at first maturity, gonadosomatic index, reproductive activity by age and reproductive period.

A lack of information to compare GSA06 and GSA07 was identified for growth, gonadosomatic index, reproductive activity by age and mortality parameters. To compare different locations within GSA06 missing information was identified for growth and mortality for both species, and information regarding age class distribution, size at first maturity, reproductive activity by age and body condition was not available for anchovy between sub-areas. In both cases (comparison between GSAs or within GSAs) information was not available from trophic behaviour of the studied species and their competitors and predators.

These results highlight that despite differences between populations from GSA06 and GSA07 or within GSA06 are very small from a genetic/genomic point of view, biological and ecological differences may be larger and further coordinated studies between both GSAs are needed to consider stock identification from a management point of view.

Task 1.3. Identify and integrate available past and current intra and inter-annual biological information regarding growth, reproduction and abundance

Lead: Marta Albo-Puigserver (CSIC) and Jose María Bellido (IEO). Participant institutions: CIBM, COISPA, CONISMA, CSIC, IEO.

In this task we reviewed, collected and integrated available biological data in order to obtain past and current intra and inter-annual information about the growth, reproduction and abundance of European sardine and European anchovy, particularly in the study area, for different age groups (eggs, larvae, juveniles and adults).

Task 1.3.1 Age, growth and size at age of European sardine and European anchovy

Lead: Beatriz Morales-Nin, John Gabriel Ramirez and Marta Albo-Puigserver (CSIC). *Participant institutions*: COISPA, CONISMA, CSIC, CIBM, IEO.

We collected existing information from laboratory studies and field observations on the age, growth, and age structure of European sardine and European anchovy stocks from GSAs 06 and 07 (**Deliverable 1.3.1.1**). Information on the rest of the Mediterranean Sea was included as complementary data. Data was compiled for each species considering sampling year, geographical area, life stage (larvae, juvenile, adult), sex (indeterminate, females, males, all together), age range, and method of age/growth determination (Figure 6). New von-Bertalanffy curves were calculated using raw monitoring data from IEO and ICM-CSIC collected from the past.

Our review showed that the validation of the age interpretation is still rather incomplete to date, only indirect methods have been used and even some studies lack formal precision and accuracy. In some cases, length frequency analyses supported the data for the adults and birthdate distributions for the larvae, In the case of European anchovy, the adults' age range was between 0 to 4 years old, and in most cases the von Bertalanffy growth parameters were determined for both sexes together, without sex differentiation.

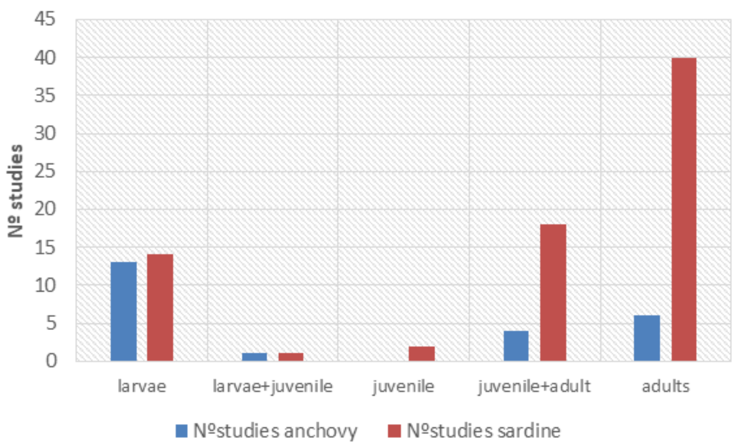

Figure 6. Number of studies about growth by species and life stage.

For European sardine, the age range was from 0 to 8 years old. Available studies targeting larvae were much more limited for this species. Regarding the GSAs of interest, the von Bertalanffy growth parameter varied notably depending from the life phase considered (K=0.42 for juveniles + adults, 0.23 for adults). The Ø parameter ranged from 1.976 to 2.32, indicating a moderate growth rate. From the age-length structure, it was observed a trend in the reduction of the individual size of European sardine since 2010 and European anchovy since 2005 in GSA06. Moreover, older individuals of European anchovy (ages 2+) disappeared from 2010.

Taking advantage of the availability of large number of otolith readings of European anchovy (n= 8054) and European sardine (n= 12839) in GSA06 since 2004, we estimated the von Bertalanffy growth parameters (vBGP) of both species every year. The vBGP of both species led to quite negative t_0, implying that individuals of age 0 were larger than 10 cm. To solve this problem, the otolith readings of juvenile and adult individuals derived from the spawning quarter were combined with otolith readings of larvae collected by scientific surveys to build an age-length key (ALK) with a wider representation of individuals of age 0. These ALKs were used as input of a Bayesian von Bertalanffy growth model. The updated von Bertalanffy growth models of European anchovy (*Linf*=18.1 cm, *k*=0.684 yr^{-1} and t_0=-0.215) and European sardine (*Linf*=20.5 cm, *k*=0.985 and t_0=-0.142) solved the issues related to t_0. The growth constant (k) was higher than the current value accepted until now, indicating the fast growth between ages 0 and 1. These vBGP were used to allocate catch-at-length number to catch-at-age number slice number-at-size to number-at-age ("slicing").

Finally, our results showed that the purse seine fleet removed few age classes of the stock of European sardine and particularly since 2010 only ages lower than 2 were caught (0-1). The harvested stock of European anchovy was represented by four ages (0-3). Given the high variability of vBGP estimates among years, all available otolith readings were merged to find the vBGP that finally were used in the stock assessments of both species (shown in summary of Task 3.2).

The second part of this task was the development of a protocol for age determination for anchovy and sardine to summarize some activities that can solve some of the problems while estimating age when reading otoliths (**Deliverable 1.3.1.2**).

Task 1.3.2. Reproductive parameters of European sardine and European anchovy

Lead: Marta Albo-Puigserver (CSIC). Participant institutions: CIBM, COISPA, CONISMA, CSIC, IEO

Long-term trends in the variation of reproduction parameters can be indicative of a change in the life-history traits of the species and can have consequence for population growth and condition and ultimately affect natural mortality and recruitment success.

In this task, we first reviewed available data about reproductive period, Gonadosomatic index (GSI) and size at first maturity (L50) from European sardine and European anchovy in GSAs 06 and 07. We used published scientific studies, reports submitted to STECF and GFCM, information from surveys at sea and partners' own data (**Deliverable 1.3.2.1**).

Our review showed that the reproduction period of European sardine in the Mediterranean Sea mainly goes from November to March with peaks of spawning in January, February, and it seems stable with time. The size at first maturity of European sardine is highly variable between areas. A time-series analysis was only published in GSA07 where a decline in L50 was observed since 2009 (Brosset et al. 2016b). The GSI (%) increased in the GSA07 in the last 15 years (Brosset et al. 2016b). The increase of GSI% of sardine indicates an increase in the investment of energy to reproduction. The majority of the studies reported spawning periods between April and October with a peak of spawning in June for European anchovy. In the last decade the reproduction period seems to last slightly longer (1 month more), but the GSI index remained steady in GSA07. The L50 of European anchovy was highly variable between areas, too. From 2005 a decline of L50 in GSA07 was observed (Brosset et al. 2016b). However, in GSA01 and 06 declines in L50 were not observed from 2007 and 2002 to date, respectively. In general, our review indicated that time series analyses of reproduction parameters were very scarce for both species. We recommend to reconstruct and analyse time series data on reproduction period, size at first maturity and GSI in order to incorporate this information into stock assessment procedures to complement the evaluation of population trends. Taking into account variability in these demographic parameters could allow an adaptive management that is more realistic than the current assessment / advice framework.

Secondly, we analysed potential historical changes in reproduction parameters developing new analysis with available raw data (**Deliverable 1.3.2.2**). We calculated the reproduction period, GSI and L50 of European sardine and anchovy from GSA06 and GSA01. In the case of European sardine, GSA06 data was divided in two subareas, GSA06 north (data from Tarragona harbour to the boarder with France) and GSA06 south (data from Torrevieja harbour to the southern area). Results were compared with previous historical analysis from GSA07 (Brosset et al. 2016b) and with the information gathered from the review done in deliverable D1.3.2.1.

For European sardine, our new analyses showed that the reproductive period in GSA06 and 01 did not present clear time trends. In GSA07 the reproduction period was narrower in the recent period (2002-2015), beginning one month later than in the 90s (Brosset et al. 2016b). The duration of the reproductive period lasted one month longer in GSA01 and GSA06 south (October-April) than in GSA07 and GSA06 north (October or November-March). GSI (%) of European sardine was generally lower in the northern area of the Western Mediterranean. In GSA06 Tarragona a temporal decline in GSI was observed between 2004 and 2013 with an increase in the last period (2014-2017). When we split the data by age, we observed the disappearance of individuals of age 4 and 5 in recent years in GSA06. In general, GSI was higher in older individuals. However, in the period 2014-2017 age 0 had higher GSI values similar to the GSI values of age 1 and 2. The L50 of European sardine declined in GSA07 and GSA06 north in the same period, with the minimum L50 in 2012 in both areas (Figure 6). Instead, in GSA06 south this decline was not confirmed and in GSA01 there was an increase of the L50 in recent years. The observed decline in the L50 and lower values of GSI of European sardine in GSA07 and GSA06 north can be highly related to the disappearance of older individuals and changes in the age/size structure. All of these changes are probably translated into a lower reproductive capacity in the north than in the south of the Western Mediterranean, since younger females have proportionally lower fecundity and shorter spawning season. Therefore, in general we observed a latitudinal gradient with GSA07 and 06 north showing lower GSI, narrower reproductive period and a decline in L50, while GSA01 had different reproduction parameters. Reproductive parameters and historical variability in GSA06 south were intermediate between GSA06 north and GSA01.

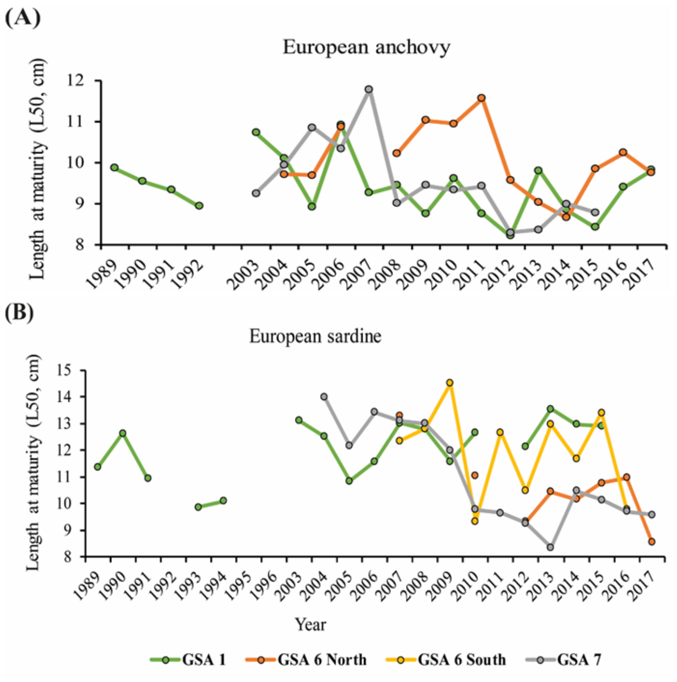

Figure 6. Inter-annual variability on length at first maturity (L50; cm) represented for each GSAs (1, 6 and 7) and for (A) European anchovy and (B) European sardine.

For European anchovy, we found that the spawning period in GSA01 was the widest (April-October) of the 3 GSAs followed by GSA06 (April-September) and GSA07 (April/May-August). Changes in the reproductive period were not observed. GSI of European anchovy was lower in GSA07 and 06 than in GSA01. In the period 2014-2017 the GSI was lower than in previous years. When we split the data by age in GSA06, we observed a progressive disappearance of older individuals (age 3 and 4) and individuals of the same age had lower GSI values in the recent period (2014-2017). L50 of European anchovy in GSA06 increased in the beginning of the data analysed (2004-2006) but in 2012 a rapid decline was observed during 3 consecutive years, followed by a recovery in the period 2015-2017 (Figure 6). Similar patterns were observed in GSA07, but no recovery of L50 was described. In GSA01 a slight decline in L50 was observed since 2007 but with high inter-annual variability. The observed decline in L50 and lower values of GSI of European anchovy in GSA07 and GSA06 can be related to the disappearance of older individuals and changes in the age/size structure affecting the reproductive capacity in the north of the Western Mediterranean Sea. However, the recovery of L50 in the last years could indicate a recovery of the demographic structure of the population. In the following years attention should be given to the age structure and reproductive parameters of European anchovy in GSA06 in order to evaluate if this recovery is consistent with time or is only a temporal fluctuation. We observed that GSA07 and 06 had similar patterns in the reproductive parameters although the recovery of L50 was not observed in GSA07. In the future, it would be key to analyse if the population of both GSAs behave in the same way. Meanwhile, European anchovy of GSA01 presented smaller L50 and different patterns of reproductive parameters.

For both species we identified some methodological limitations in order to understand changes in the reproductive parameters and the comparison between GSAs. As a summary: (1) raw data on GSA07 is not available and due to differences in methodologies the comparison in absolute terms between GSA07 and the rest of the areas is difficult. (2) Samples are collected from commercial vessels. Therefore, the length-structure of the population might be biased. In order to ensure that the collected samples are representative of the population it is necessary to compare this biological dataset with the one obtained in the MEDIAS survey that were not available for analyses during this project. (3) For some years, the size at first maturity could not be calculated because in the commercial sampling juveniles are under-represented, instead the dataset of MEDIAS would be a good complementary data series to calculate the L50 for anchovy. In the case of sardine, a scientific survey on winter is necessary. (4) In order to improve the understanding on how the observed decline in L50 and age structure can affect the stocks of both species, it will be necessary to take into account these changes in the evaluation of the stocks since current stock assessments assume equal reproductive potential and probability of generating the same recruitment level.

Task 1.3.3. Abundance, biomass and recruitment size of European sardine and European anchovy

Lead: Marta Coll (CSIC) and Maria Grazia Pennino (IEO). Participant institutions: IEO, CIBM, COISPA, CSIC.

We reviewed available data regarding temporal trends of abundance and biomass of European sardine and European anchovy in GSA06 and GSA07 for different age groups (eggs, larvae, juveniles and adults) using complementary datasets (**Deliverable 1.3.3.1**). When available, we included information about spatial-temporal patterns.

Regarding changes in European sardine a general decreasing temporal trend of biomass of sardine in both GSA06 and GSA07 was found (Figure 7). This decline coincided with a significant decline in landings in both areas. The age and length distributions of sardine populations with time showed a shift towards younger and smaller individuals in both areas, which are reflected in the composition of the landings. Limited available data in terms of spatial-temporal changes suggested a relative local increase of abundance and biomass of sardine in the southern part of GSA06 (Gulf of Alicante) and a general change of abundance and biomass from shallower (10-50 m) to deeper areas (50-100 and 100-200 m), which is more distinguishable in GSA06 than in GSA07. These changes need to be further analysed with spatially resolved acoustic survey data.

Regarding changes in anchovy abundance and biomass, we identified a general increase in temporal trends of abundance and biomass of anchovy in both GSA06 and GSA07, which coincides with a significant increase of catches in GSA06 (Figure 7). On the contrary, we observed a decline of landings in GSA07. The age and length distributions of anchovy populations did not show such a clear shift to younger and smaller individuals as in the case of sardine, although the biomass of larger organism had declined with time in the population and in the catch. The smaller sizes may have had a negative impact on the incentive of fisheries to target this species from GSA07. As with sardine, available data in terms of spatial-temporal changes suggested an increase of abundance and biomass of anchovy in the southern part of GSA06 (Gulf of Alicante, Gulf of Valencia and Ebro River Delta) and a general change of abundance and biomass from shallower (10-50 m) to deeper areas (50-100 and 100-200 m) that is visible in both GSAs. These changes need to be further analysed with spatially resolved acoustic survey data.

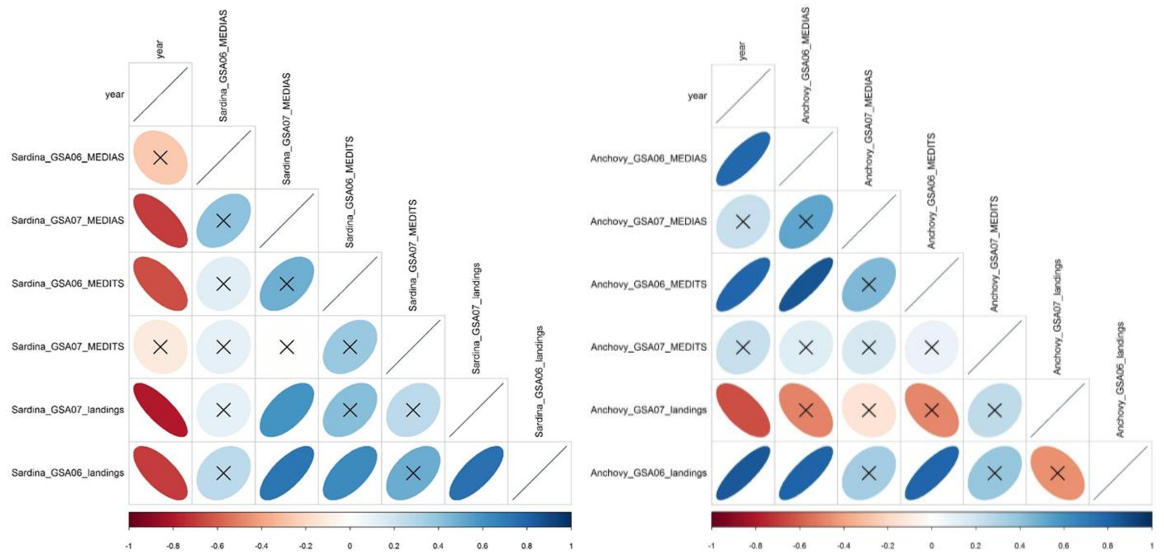

Figure 7. Spearman's rank correlations of a) European sardine and b) European anchovy trends of biomass from MEDIAS, MEDITS and landings of GSA 06 and GSA 07. Blue represents positive correlations, red are negative correlations, a cross indicates a non-significant correlation, the thinner the figure, the highest the correlation.

In general, population indicators for sardine and anchovy, such as biomass, body size and age distributions, and the spatial distributions with depth, showed a change in mid 2000s in both areas (around 2006-2008). Some significant correlations of trends between acoustic surveys, trawl surveys and landings suggested that complementary data to acoustic surveys can be useful (Figure 7). Overall, correlations between datasets were higher for anchovy than for sardine. Acoustic surveys for anchovy were correlated with landings and trawl surveys (MEDITS) in GSA06, and for sardine were correlated with landings in GSA07. Trawl surveys for sardine were correlated with landings in GSA06. In several cases, trends of anchovy and sardine were negatively correlated, such as in landings and trawl surveys in GSA06.

Task 1.4. Intra and inter-annual mortality parameters of European sardine and European anchovy

Lead: John Gabriel Ramirez (CSIC) and Ana Giráldez (IEO). Participant institutions: IEO, CIBM, CSIC.

Among all inputs required to set the stock assessment models, probably the natural mortality (M) is the most important but at the same time the most uncertain parameter. The indirect estimators of M usually use fish life-history information to correlate the value of natural mortality with other life history parameters that comparatively are easier to estimate (e.g. asymptotic length ($L\infty$) and constant growth (k)). This means that if the von Bertalanffy growth parameters (vBGP) are estimated from biased data (e.g. incomplete knowledge on growth of early life stages), these biases will be propagated to natural mortality estimates. Consequently, the estimates of fishing pressure that require information of natural mortality will also be biased. Indeed, these are the cases of European anchovy and European sardine, whose vBG parameters have been lacking full biological sense (i.e., too negative t0, probably underestimating constant growth values).

In this deliverable (**Deliverable 1.4.1**) we retrieved the current information on natural mortality (stock assessment model inputs) and fishing mortality (stock assessment model outputs) for both species, in order to understand the biases that probably are affecting the stock assessment models. Further, new estimates of M and *M-at-age* were proposed through several indirect methods, using the updated vBGP from deliverable 1.3.1.1.

Natural mortality parameters for different age groups reported in scientific articles, reports submitted to STECF and GFCM, grey literature and partners' own data were reviewed and compiled for both species, different life stages and in both GSAs areas (Figure 8). Natural mortality was estimated by implementing several indirect methods based on the von Bertalanffy growth parameters (e.g., Pauly, Then, Jensen) and maximum age (e.g., Then, Hamel, Chen-Watanabe methods) (Kenchington 2014, Then et al. 2014). Additionally, *M-at-age* was estimated by performing the Abella's, and Gislason's indirect estimators (Abella et al. 1997, Gislason et al. 2010, Kenchington 2014). Other relevant scientific information on natural mortality rate vector (M_i) was considered (such as Gulland 1987, Beyer et al. 1999, Gislason et al. 2008). The indirect estimates of natural mortality were introduced in the stock assessment model for sensitivity analyses (i.e., impact on the stock assessment outputs; Task 3.2). The natural mortality estimated by the Prodbiom software was used to set the final assessment models of the stocks of sardine and anchovy in GSA 06 and GSA 07, because it meet the biology rationale of these small-pelagic species under the hypothesis of the t0 occurs near to age 0.

a) b)

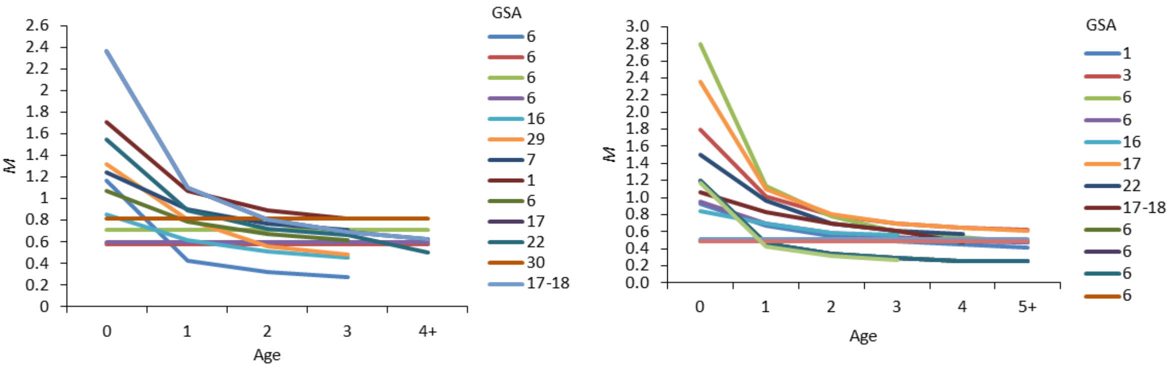

Figure 8. Some vectors of natural mortality at age used as input data in the stock assessment of the a) European anchovy and b) European Sardine in Mediterranean Sea.

Task 1.5. Population body condition and energy content of European sardine and European anchovy

Lead: Marta Albo-Puigsever (CSIC). Participant institutions: CSIC, IEO

Body condition is a proxy of the quantity of energy stored and is dependent of food supply and energy allocation strategies. Population reproductive potential, growth and natural mortality can be affected by body condition. European sardine is a winter spawner with a capital breeding strategy, and acquires and stores energy in spring and summer to be used in the reproductive period. Instead, anchovy spawns in spring and summer and is considered to have an income breeding strategy that uses the current energy income for reproduction. We analysed the seasonal and inter-annual variability in the body condition of European sardine and anchovy of the GSA06 and 01 and we compared the results with available published data from GSA07 (**Deliverable 1.5.1**). To do that we calculated the length-weight relationship for each GSAs and we used the relative condition index (Kr) (Le Cren 1951) as an index of body condition.

Overall, our results showed that length-weight relationships were not notably different between GSAs and could not be used as a character to discriminate between populations or stocks. European sardine had a higher body condition in spring (April-June) in GSA06 north and south. Instead, in GSA01 the peak of body condition was later (July and August), just before the spawning season. In general, Kr mean values were higher in GSA06 north than in GSA01. In the case of European anchovy, the months with higher body condition were April-May for GSA06 and April-September for GSA01. However, in GSA06 the body condition was higher than GSA01 during the reproduction peak. The intra-annual variability of Kr was lower than in sardine.

Inter-annual variability in body condition was observed for European sardine in GSA06 north and south and the temporal decline in body condition coincided with the decline observed in GSA07 (Figure 9). However, in GSA07 the observed decline was more pronounced than in GSA06, which showed a recovery of Kr between 2011 and 2013 with a sharp decline in 2014. In GSA01 the pattern of decline was not clear. When we split the data by age, the decline was observed in all ages. Inter-annual variability in the body condition was also observed for European anchovy in GSA06 and 07 (Figure 9). Instead, in GSA 01 there was a period of body condition decline alternated with a period of increase body condition.

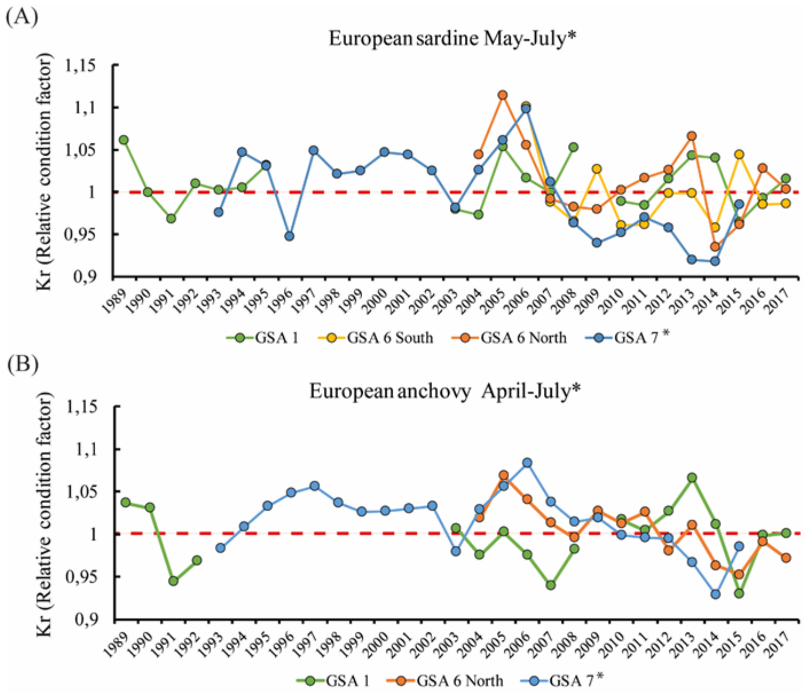

Figure 9. Time series of the mean annual body condition (Kr) of European sardine (A) and anchovy (B). Only months with high body condition were taken into account for the calculation of the annual mean. In the case of GSA 7 data corresponded to MEDIAS campaign representing late June (Brosset et al. 2017).

Overall, the patterns in the three GSAs indicated that the body condition of European sardine and anchovy in GSA06 and 07 declined similarly, with a decline of Kr in 2008 in both species and a second decline in 2014 that presented the lower values of Kr. Instead, GSA01 presented different patterns in both species. The lower values of body condition in the south (GSA01) may be a consequence of higher temperatures, dynamism and mean primary productivity in the south that lead to higher metabolic rates. Moreover, attention should be put in the differences in the peak of body condition between GSAs in the case of European sardine. In GSA06 the decrease in body condition before three months of the spawning season could indicate a partial loss of the capital breeding behaviour of this species.

The decline on body condition observed for both species in GSA06 and 07 could be a consequence of a change in quality or quantity of food (Brosset et al. 2017). Moreover, the disappearance of older individuals may be related with the decline in body condition. The decline in body condition of both species should be taken into account for the evaluation of the stocks since natural mortality may have increased and reproduction potential in combination with the removal of older individuals could be highly reduced.

In future analyses the relationship of these declines with environmental variables such as river discharges or primary productivity should be explored at a monthly time scale since the peak on body condition may vary from year to year and can compromise the spawning success of the following year (Brosset et al. 2015).

TASK 2. Comprehensive review of the ecological and fisheries information

Lead: Marta Coll (CSIC) and Maria Grazia Pennino (IEO). Participant institutions: CIBM, CSIC, IEO, NISEA.

The aim of the second task was to review and compile the available information regarding ecological key factors and fisheries about European sardine (*Sardina pilchardus*) and European anchovy (*Engraulis encrasicolus*) in GSAs 06 and 07, and complement it with information from other areas of the Mediterranean Sea.

Task 2.1. Feeding ecology of anchovy and sardine & Task 2.2. Influence of other SPF and predators on the target stocks of European sardine and European anchovy

Lead: Marta Albo-Puigserver and Joan Navarro (CSIC) and Raúl Laíz (IEO). Participant institutions: CSIC, IEO.

Information about feeding habits and trophic interactions is essential in order to understand the key interactions of species in the ecosystem and ultimately the functioning of the food web. Changes in the feeding habits or in prey quality may influence the body condition of the organism and thus the growth and reproduction potential. Moreover, processes of competition with close related species could also influence the fitness of the species in a context of food limitation.

Existing information on feeding ecology and trophic level from stomach content analysis, stable isotopes and ecosystem models was reviewed following the PRISMA approach for European sardine and European anchovy in GSAs 06 and 07 (**Deliverable 2.1.1**). Information was compiled considering the ontogenetic variation in diet (larval, juvenile, and adult). Additionally, information on the rest of the Mediterranean Sea was collected as complementary data. For each publication selected, the species and geographical sampling location (latitude and longitude, in degrees) was registered, and in the case of stomach content analysis the weight percentage (%W) of the prey and, if not available, the numerical percentage of prey consumed was registered. In case of stable isotopes, the mean, standard deviation and range (when possible) of $\delta^{15}N$, $\delta^{13}C$, and trophic level if calculated, was recorded; and in the case of ecosystem models, such as Ecopath with Ecosim (Christensen & Walters 2004), modelling outputs such as trophic level and omnivory index were retrieved. Data was analysed to explore temporal (annual and seasonal), ontogenetic and geographic variability in the feeding ecology based on different metrics (stomach content, stable isotopes, trophic level and other trophic metrics) of both small pelagic species. Gaps of information were identified for future studies.

In addition, existing information on feeding ecology and trophic level of round sardinella (*Sardinella aurita*) and European sprat (*Sprattus sprattus*) was reviewed following the same methodology. Information was compiled considering the ontogenetic variation in diet (larval, juvenile, and adult). Regarding potential predators of European sardine and anchovy, information on feeding ecology of these predators and proportion of small pelagic fish in their diet was collected as well, in order to evaluate the relevance that sardine and anchovy have for higher trophic levels and mortality due to predation. For each publication selected the species and geographical sampling location was recorded (**Deliverable 2.1.2**).

A total of 35 published papers on stomach content analysis of small pelagic fish comprising European sardine, European anchovy, round sardinella and European sprat were found in the Mediterranean Sea. From those, 12 contained information on sardine or anchovy in GSA06 or GSA07. For stable isotope analysis a total of 30 studies contained information on one of the four small pelagic fish. In general, copepods were the most important prey for the four species (Figure 10). However, sardine and sardinella also presented higher percentages of phytoplankton. Cladocera was also an important prey for sardine, anchovy and sardinella. In addition, the review highlighted that the trophic niche of round sardinella and European sprat was wider and could be more advantageous for a better adaptation to changes in food availability respect to sardine and anchovy.

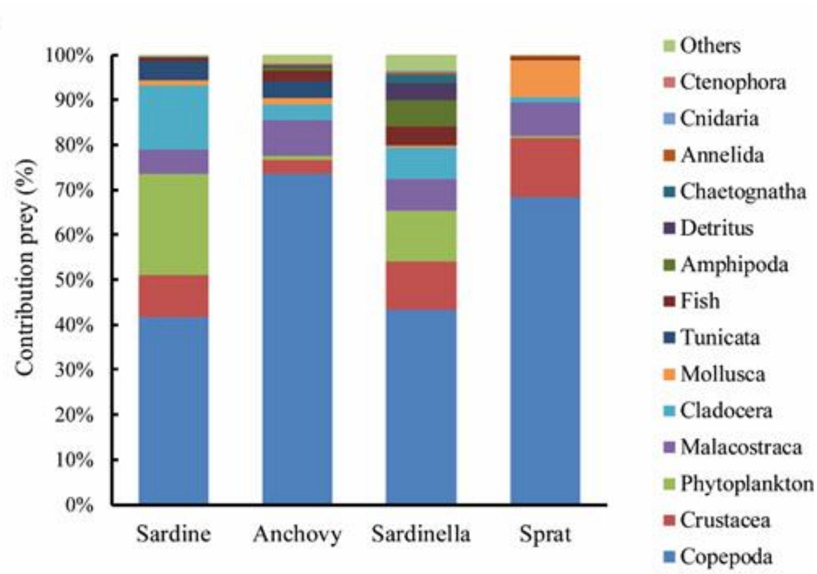

Figure 10. Summary of all diets reported in the Mediterranean Sea for European sardine and anchovy, round sardinella and European sprat from stomach content analysis. Percentages of most important prey categories are represented for each species.

The temporal study of Brosset and co-authors (Brosset et al. 2016a) in GSA07 using stomach content and stable isotope found that there was a reduction in prey diversity and that in the periods with higher body conditions of anchovy and sardine they feed on larger copepods and cladocera. In GSA06 there was not enough data available to look at changes in the diets of small pelagic fish in temporal scale. In order to understand if the observed decline in body condition are due to changes in food quality or quantity we recommend that further studies on temporal stomach content analyses of sardine and anchovy are developed in the future.

A total of 137 published papers were found indicating the presence of sardine and/or anchovy in the diet of a predator from the Mediterranean Sea. From those, 16 studies were from GSA06 and 6 from GSA07. The number of studies in the eastern areas of the Mediterranean Sea was higher than the studies conducted in the central and western part (Figure 11). In general, we found that fin-fish species showed the higher %W of sardine and anchovy, followed by seabirds, elasmobranchs, marine mammals, cephalopods and sea turtles. At the geographic level, the importance of sardine in the predators' diets was higher in the studies conducted in the western than in the eastern Mediterranean Sea. In contrast, anchovy contributed more to the diets of predators in the eastern Mediterranean Sea. At the species level, the main predators were pelagic or bathypelagic organisms. The main species preying on sardine were barracudas *Sphyraena* spp., mackerels *Scomber colias*, greater amberjack *Seriola dumerili* and twaite shad *Alosa fallax*. For anchovy, the main predators were *A. fallax*, the pelagic stingray *Pteroplatytrygon violacea*, *Sphyraen*a spp., the false scad *Caranx rhonchus* and mackerel *Scomber scombrus*.

Overall, our review highlighted that information on feeding habits of potential predators of small pelagic fish was scarce and results might change if more dietary studies are available in the future. Moreover, there was not enough data to study changes of feeding habits of predators in time, thus the potential changes in the importance of sardine and anchovy in the diet of predators due to the decline in the biomass cannot be currently assessed. This limitation evidenced that more effort should be dedicated to the systematic compilation on dietary studies of key species (i.e. mackerel *Scomber* spp.) to detect important changes in pelagic food-web interactions.

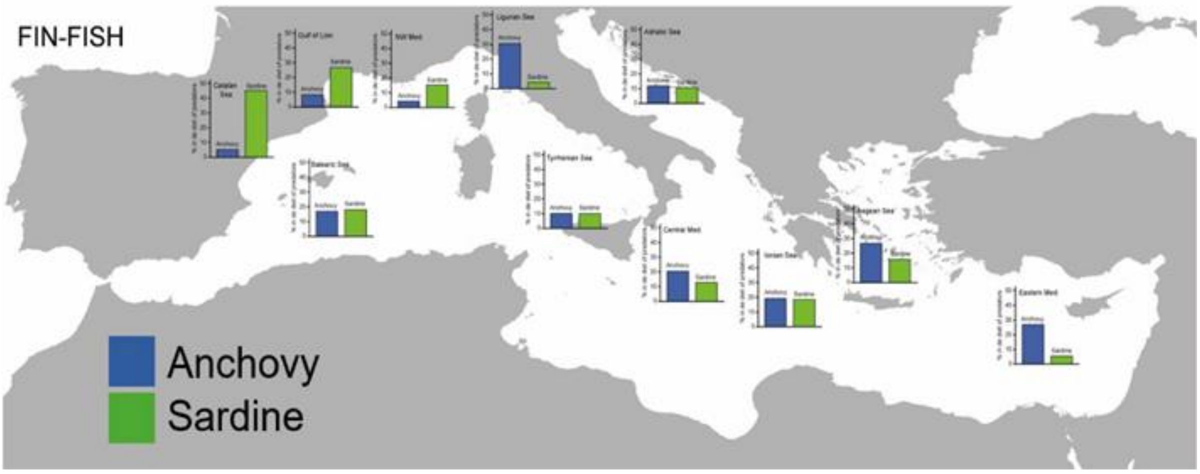

Figure 11. Importance of European anchovy and sardine in the diet of fin-fish predators in the Mediterranean Sea.

Task 2.3. Quantify the potential role of environmental fluctuations and changes in status of sardine and anchovy stocks

Lead: Marta Coll (CSIC) and Maria Grazia Pennino (IEO). Participant institutions: CSIC, IEO.

We first reviewed existing information on available studies regarding the role of environmental fluctuations and changes in the status of European sardine and European anchovy following the PRISMA approach and collected from GSAs 06 and 07, and from the Mediterranean Sea in general (**Deliverable 2.3.1**). Information was compiled considering the ontogenetic variation (larval, juvenile, and adult). All information available was summarized in a database to identify aim of the study, region, time period, species and ontogenetic fraction of the species, environmental factors investigated, and main results found (e.g., sign and shape of the response).

Secondly, statistical analyses were performed crossing available datasets regarding presence/absence, abundance and biomass, and landings of anchovy and sardine (Task 1.1, Task 1.3.3 and Task 2.4) and environmental parameters. We developed two different statistical approaches (1) to explore the effect of the environment from a temporal perspective and (2) to spatially predict the distribution of SPF species and their changes with time from past to present considering environmental fluctuations and changes.

The temporal approach was explored using Random Forests (RFs) (Breiman 2001). RFs were particularly indicated for this task as they do not require any prior assumptions about the data and their classification accuracy is not affected by correlations or interactions between variables (James et al. 2013). The spatial approach to quantify the potential role of environmental fluctuations and changes in the species status was based on the Species Distribution Models (SDMs) framework. The so-called SDMs link spatially and temporally information on the presence/absence or abundance of a species to environmental variables to predict where (and how much of) a species is likely to be present in unsampled locations or time periods. In particular, among the alternative modelling algorithms to perform SDMs, we used Boosted Regression Trees (BRTs) (Elith et al. 2008). Finally, we obtained functional responses from observed species distributions and environmental conditions, and from predictive species distribution maps. These results informed us about the environmental preference of these species and about their suitability habitats, complementing information from the literature review. The selection of the most relevant factors that influence the abundance and distribution of the species can be used to inform the quantitative food-web modelling approaches (Coll et al. 2016, Coll et al. Submitted), such as the one presented in Task 3.3.1.

During the systematic review, more than 1300 studies were evaluated and assessed to extract available information. Despite the numerous studies, only 40 studies provided quantitative information about relationships between anchovy and/or sardine and the environment. Available data was more abundant for anchovy than for sardine, and adults were more studied than eggs, larvae and juveniles (the least studied). Data was also heterogeneously distributed in the Mediterranean Sea. Results evidenced that for both species there was mostly a negative relationship with depth, thus as depth increases anchovy and sardine biomass, abundance, occurrence and landings tend to decline. In the case of sardine, there was mostly a positive relationship with salinity and primary productivity. Sardine showed mixed results with temperature, although a negative relationship prevailed in the literature. On the contrary, the relationship between anchovy variables and temperature, primary productivity and salinity was mixed, with similar prevalence of studies that showed a positive or a negative effect.

Results from the temporal modelling showed mainly a negative effect between anchovy and sardine variables and primary productivity, especially in GSA06, and a positive effect between temperature and anchovy in both GSAs, while contracting results were found for salinity between GSAs. Salinity in both GSAs and temperature in GSA07 we found to have a negative relationship with sardine in GSA07, in line with results from the scientific literature review, while temperature had mixed relationships in GSA06. Another important result was the fact that in GSA06 results were different between zones along the latitudinal gradient from south to north, while anchovy results were similar and consistent within the GSA06 and along the latitudinal gradient (Figure 12). Results highlighted as well that the time lags between the environmental variables and the response variable are important to understand the relationships that may exist.

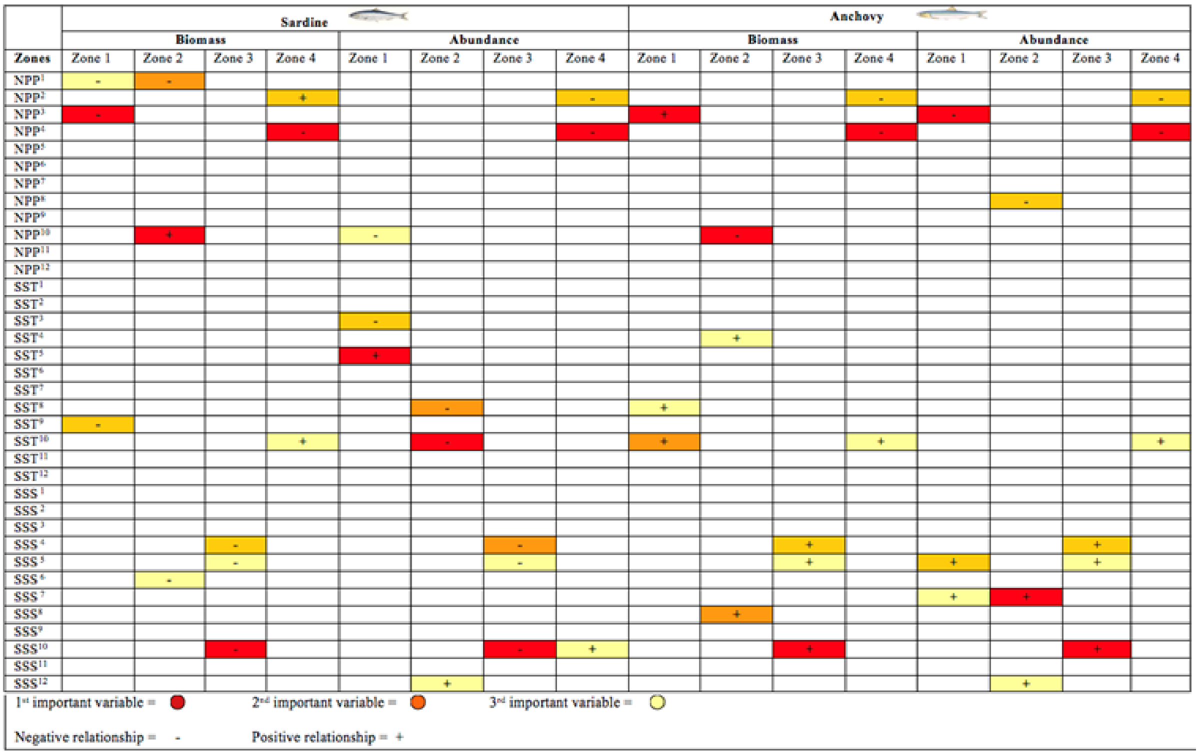

Figure 12. Summary of results from Random Forests applied to sardine and anchovy temporal dependent variables (biomass, abundance, landings) for GSA06 and GSA07. Zone 1: southern part of the study area.

Overall results from the spatial temporal modelling showed contrasting results between anchovy and sardine and between GSA06 and 07. Anchovy mainly showed an expansion of the population with time in GSA06, especially evident from 2009 onwards, while in GSA07 results illustrate changes between coastal and shelf areas, with some lower than average years in 2005-2008. Sardine showed a decrease of prevalence of biomass and abundance in GSA06 with time, with a slight expansion to the south in recent years, while in GSA07 a general decline was also observed with a change in concentration of the species from coastal to deeper waters. The last years of the time series showed a more profound decline. The spatial temporal modelling results coincided to identify a negative relationship between depth and anchovy and sardine, and they captured a mainly positive relationship with primary productivity, while the relationships with temperature and salinity were not linear and showed some thresholds.

Unfortunately, the spatially resolved data from acoustic survey were not accessible through SPELMED DC neither from National coordinators to be used in these analyses. Therefore, we used alternative datasets to complement the description of spatial patterns. However, this information should be further analysed when spatial data becomes available. In this context, it is interesting to highlight that when data was available to test congruence between datasets, the correlation between MEDITS and MEDIAS performed with data for anchovy from 2003-2010 showed high spatial correlation for biomass, abundance and occurrence for most of the years (with 2005 as the exception), in line with previous results from Deliverable 1.3.3.1.

Task 2.4. Evaluate the past and current fisheries exploitation of target stocks

Lead: John Gabriel Ramírez (CSIC) and María González (IEO). Participant institutions: CIBM, COISPA, CSIC, IEO, NISEA.

Existing information regarding past and current fisheries of European sardine and European anchovy was collected from the study area regarding fleet, catches, discards, average effort deployed and economic performance of main fisheries (**Deliverable 2.4.1**). The available information from GSA 06 and GSA 07 was compiled from different sources: (1) Existing information coming from scientific papers and grey literature, in particular those coming from the research and monitoring projects carried out on small pelagic fisheries in the last years; and (2) Data from DCF activities accessed through the SPELMED DC. Gaps of information were identified for future studies.

Our results regarding the analysis of historical catches indicated that European sardine has been exploited to higher levels and started to be highly exploited before European anchovy in GSA06 (and to Spanish Mediterranean level) and GSA07 (and to French Mediterranean level) (Figure 13). Currently, anchovy stocks (both GSAs) present better health than sardine, which reports quite low stock size regarding historical information

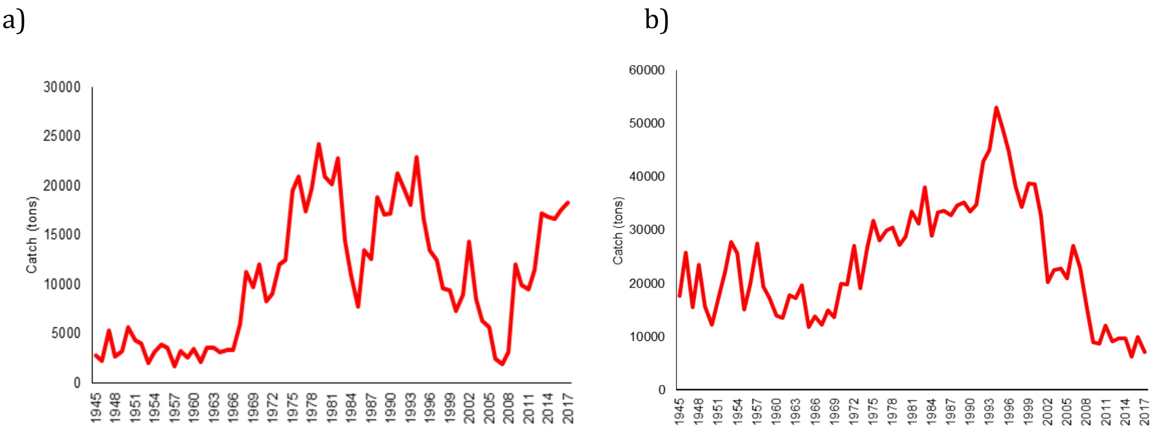

Figure 13. Historic catches of a) European anchovy and b) European sardine recorded by the *Instituto Español de Oceanografía* (IEO) in GSA 06.

of landings and catches. This coincides with results from Deliverable 1.3.3.1 regarding abundance and biomass trends.

According to official fishery data over GSA level, discards were negligible for European sardine and European anchovy. However, the reconstructed catches suggested that discards represented above 7,000 and 20,000 annual tons of European anchovy and European sardine, respectively.

A historic fluctuation of European anchovy suggested that recent declining of landings (2007) and subsequent increasing of landings, may respond to cyclic variation of biomass, without disregarding the strong impact of the fishery in the study areas. Conversely, European sardine looked to be largely affected by fishery pressure in both GSAs. Catch-at-length and catch-at-age of both species revealed that smaller individuals are caught in recent years, in agreement with results from deliverable 1.3.3.1.

The small pelagic fish are mainly caught by purse seine fishery (VL12-24 m) in GSA06 and purse seine (VL12-24 m) and mixed deep-water species (VL 24-40 m) fisheries in GSA07. Although the number of vessels is declining, the fishing effort in terms of days at sea seemed to remain stable. The CPUE by fleet may vary along the years, months and ports. Larger CPUE are also related to good fishery results along years and into different months. This means that fleets with moderate CPUE only produced good CPUE during some months by year. Conversely, fleets that obtained high CPUE were also capable to obtain good CPUE along the whole year. According to the fishing strategy used by fleets in GSA06 (local fishery or searching actively), we observed that the fleets that belong to different ports obtained different “success” regarding catch volume. Additionally, a fleet could obtain good CPUE of one, another or both species.

Most of the fleets were losing net incomes or even were presenting losses during the period with available economic information. Some fleets avoided reaching negative results by reducing the fleet size. The fleet size of the small pelagic fishery in GSA07 is very small in comparison to GSA06. However, catch-at-length, fleet information and economic data of GSA07 included several gaps that hampered the performance of a complete analysis of the fisheries for European anchovy and European Sardine in GSA07.

TASK 3. Propose and assess different fisheries management measures

Lead: Jose Maria Bellido (IEO) and John Gabriel Ramírez (CSIC). Participant institutions: CEFAS, CIBM, COISPA, CSIC, IEO, NISEA.

The final aim of the third and last task was to propose and assess fisheries management alternatives regarding European sardine (*Sardina pilchardus*) and European anchovy (*Engraulis encrasicolus*) in GSAs 06 and 07.

Task 3.1. Summarize the past and current management measures at regional, national and European level and the role of the main stakeholders involved in main fisheries of target stocks, including their interactions

Lead: Jose Maria Bellido (IEO). Participant institutions: IEO, COISPA, CSIC.

The first part of this task was to provide a detailed analysis of the situation on technical measures, following the basis of Council Regulation (EC) No 850/98 as well as other regional, national and autonomic regulations (**Deliverable 3.1.1**). We developed the analysis of the main existing technical measures for the small pelagic fisheries in GSAs 06 and 07. We discussed those management measures in view of the new Common Fisheries Policy (CFP) objectives and taking into account the regional aspects of the Mediterranean management system, which are mainly based on technical measures. Existing EU technical measures can be found in a wide range of different regulations and contexts. Deliverable 3.1.1 was structured into four main sections, following a progressive approach: 1) an introduction to technical measures in the Mediterranean and why they are so important in the Mediterranean management system; 2) An inventory of the main existing regulation on technical measures in areas GSAs 06 and 07 at autonomic, national and European level; 3) A review on the current set of technical measures, and 4) a section of conclusions, assessing the degree of fulfilment and effectiveness of the measures, and some recommendations for management.

Secondly, we assessed the role of the main stakeholders involved in main fisheries of small pelagic fishes (**Deliverable 3.1.2**). We collected information about the fishers and stakeholder perceptions on involvement on technical measures implementation. We performed a series of interviews and facilitated other encounters with fishers and stakeholders to retrieve their opinion on current management measures, how they are impacted by rules and regulations and how to achieve a better stakeholder involvement in development and implementation of management measures. We assessed stakeholder's perception in relation to five main aspects: 1) Usefulness of the management measures, 2) Compliance, 3) Whose fault is it?, 4) Why is this crisis different from others?, and 5) Possible solutions.

We compared survey responses between the categories of fishers, years of experience and geographic distribution, using the Mann–Whitney U test, which is a nonparametric test to assess if there are significant differences among groups. We made use of the "Likert" package of the R software as approach to analyse Likert response items with an emphasis on visualizations (R Core Team 2017). For qualitative responses, we generated different "word clouds" plots. The clouds give greater prominence to words that appear more frequently in the source text. We generated these plots for all the respondents and also for the different analysed categories. We used the "wordcloud" package of the R software.

Regarding the usefulness of the management measures (1), there was a high diversity in answers. The most useful management measures were selected to be Size limitations, Gear Limitations and Quota limits. Vessel limits was quite balanced. None of the management measures suggested appeared to be useless (or mostly disagreed). When separated by groups, fishers with less experience preferred spatial closures, whilst more experienced fishers preferred gear, size and quota limitations. This was also observed when analysing the preferences of fishers north of the Ebro Delta although in the south quota limitations were the most preferred management measures.

Regarding the compliance of the management measures (2), results showed that fishermen answered that they mostly comply to all management measures. Younger fishers were the ones that agreed the most with species limit and TAC (Quotas) and the rest of answers were balanced. Older fishers answers were mostly in agreement with compliance with all measures, with some differences for spatial closures. The same picture emerged when looking at responses of fishers from the north and for the south.

Regarding "Whose fault is it?" (3), fishermen did not identify a unique and clear responsible of the depletion situation. They mostly identified managers as the ones to blame, although answers were generally quite balanced. Regulations emerged as very important as all fishers marked this answer.

Regarding "Why is this crisis different from others?" (4), most fishermen mentioned the small size of the individuals as the main difference to other crisis (Figure 14). They also mentioned that this crisis was area-specific and was being longer than other recent crises. They mentioned the disappearance of sardine, too.

Figure 14. Why is this crisis different from others? Fishers were asked why this crisis is different from the others (Wordcloud graphic, with word dimension meaning frequency).

Finally, regarding possible solutions (5), all fishermen mentioned the need of better and new regulations, as well as co-management of the resource. They also mentioned the need to increase the knowledge and new studies on environmental factors and water quality, and how this can affect small pelagic species. Younger fishers highlighted the need of a strong National Fishers Group to raise their concern to fisheries managers. More experienced fishers also mentioned the Bluefin tuna regulations affecting small pelagic fisheries. Fishers from the northern area also mentioned the need to include adaptive and area-specific regulations (by fisheries ground).

Task 3.2. Development of stock assessment models for anchovy and sardine

Lead: John Gabriel Ramirez (CSIC) and Ana Giráldez (IEO). Participant institutions: CEFAS, CIBM, CSIC, IEO.

Statistical catch-at-age (a4a) and two-stage biomass models were trialled to assess European sardine and European anchovy (**Deliverable 3.2.1**). Stock assessment with a4a was performed with the Fisheries Libraries in R (FLR) (Kell et al. 2007), with the aim to facilitate the uptake of results for the preparation of the Western Mediterranean small pelagic MAP. The development team of FLR based at JRC ISPRA (E. Jardim and other colleagues) was consulted to provide their expertise for these analyses and they provided very useful technical advice and guidelines. The two-stage biomass model originally proposed by Roel and Butterworth (Roel & Butterworth 2000) and recently used for stock assessment of small pelagics in GSA 07 in GFCM working groups (2015, 2016) was explored, too.

Input data: Life-history parameters of both species were reviewed and new estimates of the von Bertalanffy growth parameters (improving the value of t0) were used based on results from previous deliverables. The input data for the stock assessment model were updated as required (including the natural mortality parameter, M). The new estimates for the growth parameters were for sardine: Linf = 20.1 cm TL, k = 0.817 yr-1, t0 = -0.246 yr, and for anchovy: Linf = 18.0 cm TL, k = 0.984 yr-1, t0 = -0.255 yr).

Since 2002, the average annual catch of sardine in the combined GSA 06 and 07 was 19949 tons. Catches have been declining along the time series with the highest value in 2006 (38528 tons) and lowest value in 2015 (6771 tons). Additionally, catches of sardine in GSA 06 contributed on average 79% to the total catches obtained in both areas. Historically, catches of anchovy represented two thirds of the catches of sardine in GSA 06 and GSA 07 (average of 13616 tons). Until 2008, the contribution of catches in each GSA was near 50%. However, since 2009 the catches in GSA 07 dropped to near 1000 tons per year (2015 and 2016), while catches in GSA 06 have been increasing to reach around 19000 tons in recent years (2013-2016).

The length structure of sardine landings indicated a reduction of the size of individuals landed of around 2 cm during the time series. Before 2010, most of the harvested length classes were 14.5-15 cm. Since 2010 the modal length of landed sardine was 12.5 cm. As for the sardine stock, the length structure of the anchovy landed in GSA 06 decreased from around 14 cm (before 2010) to 12 cm (since 2011). This same trend was observed in GSA 07 but showed higher variability in the length structure among years. No changes in the fishing techniques or fishing practices that could affect selectivity were documented for these small pelagic fisheries in the study period.

Because the value of the von Bertalanffy growth parameters (vGBP) have a strong influence on assessment results, different sets were considered in the analyses. A single set of vBGP for the entire time series or by period, or two sets according to apparent change in length at age (2004-2010 and 2011-2017), were used to transform catch-at-length data into the catch-at-age number ("slicing"). Additionally, the age-length keys (ALK), by year, merged by periods or merged for all period, were used to estimate the catch-at-age number.

Stock assessment: Stock assessments using the catch-at-age a4a model for sardine and anchovy in GSA 06 and GSA 07 have either never been performed in recent working groups of STECF or GFCM, or tried but the assessment results were not accepted. In our project, the performance of a4a method was affected by the availability and quality of data, finding the best results for sardine in GSA 06 and sardine GSA 06 and 07, according to the model diagnostics. The assessment models that were set with catch-at-age data obtained from the slicing of a single vBGP for the whole period offered better diagnostics, more internal consistence (when achieved) as well as meeting the rationale of the species biology and fisheries.

Overall, the assessment highlighted that sardine from GSA 06 in 2017 was overexploited (SSB < Blim) and overfishing was occurring (E > 0.4, proxy Fmsy). The exploitation trend suggested that overexploitation has been increased since 2002, and an incipient reduction in fishing mortality has occurred since 2014. Sardine from GSA 07 in 2016 showed a strong overexploitation, exhibiting a SSB quite depleted and E > 0.80. Despite the diagnostics of the a4a model (including residuals, data fitting and retrospective analysis) were acceptable, fishing mortality of age 1 after 2009 was outstandingly high. Given that catches of sardine in GSA 06 contribute in more than 90% of catches of combined GSAs, the stock assessment results of sardine GSA 06 and 07 was dominated by the trend and status of sardine in GSA 06. This means that a less pessimistic overexploitation scenario was perceived when both areas were combined (SSB 2014-2016 = 36% of Bpa, E=0.70) (Figure 15) than when compared with the single assessment of GSA 07 (SSB 2014-2016 = 3.41% of Bpa, E=0.83).

Anchovy from GSA 06 was overfished (SSB < Blim) and overfishing was occurring (E > E=0.4). Overexploitation in 2017 was higher than 2004, meaning that fishing mortality have increased along the time series. The stock assessment of anchovy GSA 07 suggested that fishing mortality was very low in recent years, presumably, below E=0.4. However, poor model diagnostics and very high fishing mortality to age 2 avoided providing a reliable advice of the status of anchovy GSA 07. Overall, the stock assessment of anchovy showed bigger challenges than in the case of sardine stocks. The final stock assessment of anchovy GSA 06 and 07 indicated a sustained status of overexploitation since 2004 (excluding 2005-2007) (Figure 15). SSB was depleted and below Blim in 2016. Fishing mortality in recent years was twice Fmsy proxy of E=0.4. Although the stock assessment results indicated that F is decreasing since 2014, the retrospective analysis showed high instability depending on the final year data used to perform the stock assessment.

a) b)

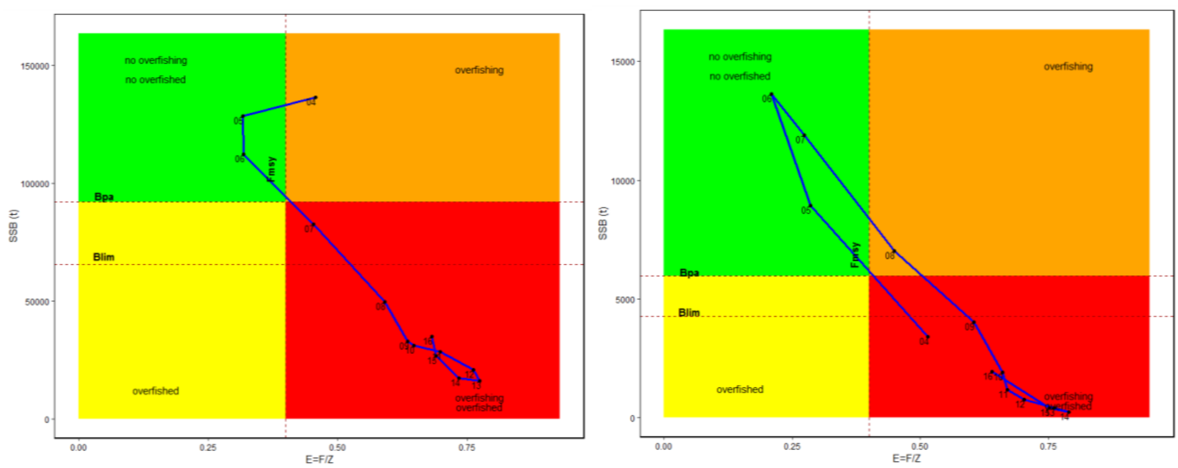

Figure 15. Kobe plot to the a) European sardine and b) European anchovy stocks in GSA 06 and 07 assessed together.

Given that 1) the fishery of sardine and anchovy are focused on ages 0 and 1, 2) both species reach sizes near asymptotic length in the first two years and 3) older ages are either poorly harvested or depleted, a two-stage biomass model was also tried. This model assumes a population structured in two stages: a recruit phase (age class 0 in our study) and an adult phase (age classes 1+). A peak of exploitation rate larger than 70% in 2007 was observed for sardine in GSA 06 and GSA 07. These results suggested that the fishery took advantage of the high biomass available in early years of the time series to produce the largest catches, matching the results found by a4a. After dropping, the biomass did not recover in later years, even when exploitation rates remained below 20%. This would mean that stocks have not been capable to recover despite exploitation rates being low in recent years. This result would be consistent with the important decrease in fishing effort (number of vessels) reported for the last 10 years in the study areas. In comparison terms, a4a indicated that fishing mortality on sardine in GSA 06 and 07 is above the Fmsy proxy (E) for most of the years. Conversely, the two-stage biomass model suggested that exploitation rate has been most of time below 40%.

The two-stage biomass model indicated that anchovy in GSA 06 presented high exploitation rates in 2011 and 2017 (> 40 %), corresponding to high landings and depletion of the biomass for the adult fraction of the stock. Anchovy in GSA 07 also showed very low levels of adult biomass but exploitation rate since 2012 was below 40%. The assessment performed for anchovy for combined GSAs indicated an exploitation rate between 20% and 40%, suggesting that overfishing has not occurred since 2009 (excluding 2016). Conversely, a4a indicated strong overfishing as well as an overfished status since 2009. For these reasons, it was not possible to achieve a consensus on the status of sardine and anchovy in GSA 06, GSA 07 and 06 and 07 combined based on the two-stage biomass model and a4a. However, both models agreed in estimating the size of both stocks as very depleted.

Advice: The very low catches of the two species in GSA 07 reported during recent years may induce high uncertainty in the stock status assessed with VPA methods. The most plausible explanation is stock depletion due to excessive removals (catches) in recent decades, leading to overfishing. The truncated age structure of the small pelagics populations and the low recruitment observed on recent years are consistent with this explanation. The two stock assessment methods did not provide the same message, probably because of the different model assumptions underlying their application. According to our results, scientific advice for sardine and anchovy in GSA 06 can be done considering a single-management stock area. However, a more reliable advice of the stocks in GSA 07 may be obtained when both areas are combined. The results of genetic analysis do not support separate stocks of sardine or anchovy between GSA06 and GSA07 (or in the Western Mediterranean, except the Alboran sea GSA 01). Sardine and anchovy stocks in GSA 06 and 07 are subjected to overfishing (E > 0.4) and SSB is strongly depleted (SSB < Blim). Harvest rates of the two species have been slightly reduced since 2013, but this reduction has not been translated into recovering of SSB yet.

Data gaps: The catch-at-age stock assessment of anchovy and sardine in GSA 06 and 07 have been affected by a too negative t0. This project solved this gap, making it possible to obtain acceptable stock assessment outputs for providing advice to management them. Prodbiom was used as an indirect estimator of natural mortality because the M-at-age vector relies on the trade-off between loss of biomass in younger ages and production of older ones. Thus, this estimator produced a reasonable vector of M and avoided too high values of M for ages 0 and 1 when t0 is near zero (if Gislason's estimator is used). The fishery-independent data series (acoustic surveys) showed problems to follow the trends in the fishery-dependent data (landings), among other reasons because each piece of information holds different temporal information of the stock. Finally, only data from MEDIAS was used to fit the model because stock assessment produced poor results if ECOMED index was included. Official data on catch-at-age number and weight-at-age of sardine and anchovy in GSA 07 included several gaps as well as some incongruent information, which affected the performance of the stock assessment models.

Task 3.3. Explore management measures integrating biological and ecological data available that could modify the fisheries exploitation pattern to increase sustainability and ensure healthy target stocks

Lead: Maria Grazia Pennino (IEO) and Jose Maria Bellido (IEO). Participant institutions: CEFAS, COISPA, CSIC, IEO.

In this task we used a multi-modelling platform to investigate which factors may influence the spatial distribution and abundance of European sardine (*Sardina pilchardus*) and European anchovy (*Engraulis encrasicolus*) in GSA06 and GSA07 and which management alternatives could be favored to promote sustainable exploitation of SPF, under a climate change context (**Deliverable 3.3.1**).

Firstly, using a spatial Redundancy Analysis (RDA) we tested four main hypotheses as possible causes of European sardine and European anchovy observed historical changes: (1) a high fishing impact, (2) unfavourable environmental conditions, (3) the recovery of Bluefin tuna (*Thunnus thynnus*) using feeding habitat occurrence; and (4) the increase of round sardinella (*Sardinella aurita*) presence. Secondly, we modelled future scenarios including IPCC projected environmental variables (IPBES 2012, IPCC 2013) using Species Distribution Models (SDM) to test different pessimistic and optimistic environmental future scenarios. Afterwards, we tested possible alternative management scenarios using the Management Strategy Evaluation (MSE) framework (Punt et al. 2016) with FLR and recovery simulations using the *Ecopath with Ecosim* food-web modelling approach (Christensen & Walters 2004).

Overall, the spatial RDAs highlighted that the variability in the distribution of European sardine in GSA06 was due to a combination of effects that included environmental conditions (bathymetry, sea surface temperature, net primary production and sea surface salinity), fishing factors (considering AIS and VMS intensity), an expansion of the occurrence of Bluefin tuna feeding habitat, as well as the round sardinella expansion. Similar results were found for the biomass of this species although in this case the fishing factors were the most important ones and similar results were found for the European anchovy in the area.

Spatial RDAs highlighted that the variability in the distribution of European sardine in GSA06 was due to a combination of effects that include environmental conditions (bathymetry, Sea Surface Temperature, Net Primary Production and Sea Surface Salinity), fishing factors (considering AIS and VMS intensity), an expansion of the occurrence of predators (included as bluefin tuna feeding habitat), as well as competitors (the round sardinella increase). Similar results were found for the biomass of this species although in this case the fishing factors were the most important ones. And similar results were found for European anchovy in GSA06. The spatial RDA findings for European Sardine in the GSA07 highlighted that its distribution variability in the area may be due to spatial and environmental factors. The importance of the top predator presence was lower than in GSA06, while data regarding sardinella was not available and VMS data was not accessible. For European anchovy, results of the RDAs showed that this species was mostly affected by fisheries impact (using AIS intensity) and the environment conditions.

Future IPCC projections for both species highlighted that both sardine and anchovy will likely undergo a reduction in their spatial distribution in both GSA06 and GSA07 (Figure 16). Areas that will keep a probability of occurrence higher than 0.70 were identified around the Rhone river in GSA07 for both species; the waters around the Ebro river in GSA06 for both sardine and anchovy, and the Gulf of Alicante for anchovy. These areas could be seen as potential special areas to manage due to their nature as "future climate refuges". Unfortunately, the spatially resolved data from acoustic survey were not accessible through SPELMED DC neither from National coordinators to be used in these analyses. Therefore, we used alternative datasets to complement the description of spatial patterns. However, this information should be further analysed when spatial data becomes available.

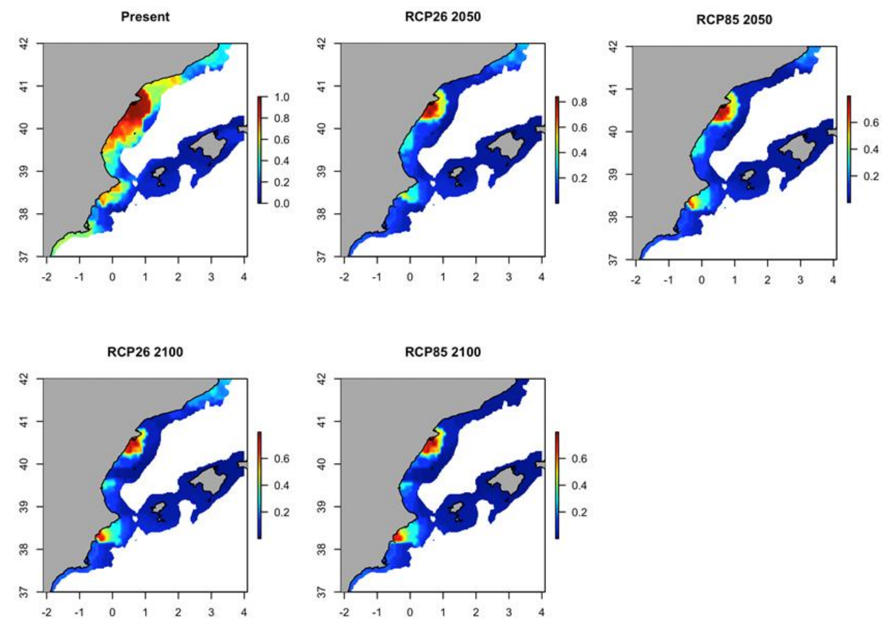

Figure 16. Predicted probability of occurrence of the European sardine (*Sardina pilchardus*) in GSA06 using IPCC scenarios.

MSE results from the FLR framework were computed with inputs from the a4a stock assessment of GSA06 and 07 together. For sardine, in addition to the historical status quo, we tested an additional scenario where fishing mortality was reduced. However, results showed that this option may not be ideal for sardine since the stock was always below

Blim with a high probability (*Blim* is the stock size below which there is a high risk of reduced recruitment). For anchovy, no reliable results were obtained due to a lack of data and time constrains.

Scenarios of European anchovy and European sardine recovery using a food-web temporal and spatial-temporal modelling approach using *Ecopath with Ecosim* were also developed using GSA06 and 07 together. Results highlighted that a general reduction of fishing mortality (a 50% reduction of the historical status quo in 2000 or a reduction to 2007 fishing mortality levels from 2008 to 2016) could have contributed to a successful recovery of both species. The establishment of a Marine Protected Area (MPA) in coastal waters of GSA06 and 07 with restrictions to all fishing fleets except artisanal and recreational fisheries could have partially compensated the negative impacts of high historical fishing mortalities for both species. These simulations took into account species interactions (including prey-predation and competition relationships) and historical changes in temperature, salinity and primary production. These temporal and spatial-temporal dynamic food-web models developed in SPELMED represent the baseline to further explore hindcasting and forecasting temporal and spatial-temporal scenarios following established procedures (Mackinson et al. 2018). Both models will be used in future iterations of this work to test alternative simulations of management advice with the aim to further analyse alternative options to recover and sustainably exploit small pelagic fish in the Northwestern Mediterranean Sea in the future, considering climate variability and future climate change.

The second deliverable of this task (**Deliverable 3.3.2**) on recommendation of management measures for small pelagic fisheries in the study area presents a summary of main technical and management measures recommended according to the main results of the project.

Task 3.4. Engaging stakeholders into governance processes towards sustainable fisheries of target stocks

Lead: Giuseppe Lembo (COISPA). Participant institutions: COISPA, IEO, CSIC, NISEA.

The main objective of this task was to enhance the industry-science partnership ensuring more coherent information and a progressive implementation of sustainable management measures, by improving the stakeholder awareness of the evaluation processes and by incorporating their knowledge into research-based advice (**Deliverable 3.4.1**). Participatory management is widely recognized as a working method of paramount importance, based on the principles of knowledge sharing, accountability and legitimacy, for addressing the sustainable development of the fishery sector.

Feedback from relevant stakeholders in this project was collected through a participatory action, research and learning process. This included preference modelling methods, such as Multi Criteria Decision Analysis (MCDA) techniques to address and finally consent on complex issues among many participants, with different background, knowledge and, sometimes, conflicting objectives or preferences. A web-based platform was established in order to interact with the stakeholders, who were requested to answer anonymously to a questionnaire, ranking the importance of different technical measures in order to progress towards sustainable fisheries of the stocks of European sardine and European anchovy in GSAs 06 and 07.

Overall, and according to the majority of the stakeholders who participated to the survey, the most important measures to be taken into consideration in order to support the sustainable management of the small pelagic fishery should be based on the characteristic of the fishing vessels (Figure 17). This measure was prioritized to consider the obligation to carry on board VMS and the prohibition of more than one auxiliary boat per each purse seine. The prohibition of pelagic trawling, big opening trawling gears and semi-pelagic trawling, as well as limitation of the mesh opening (i.e. min 14 and max 24 millimetres) were considered by stakeholders the most appropriate measures, based on the characteristic of the fishing gears. The limitation on the number of fishing days per week was considered the most appropriate measure based on the fishing effort by time limitations. The prohibition of fishing with purse seine in some periods and areas in order to protect nursery areas and sensitive habitats was considered the most appropriate measure based on the fishing effort by spatial limitations. The enforcement of maximum, daily, weekly or annual catch quotas per species, vessel and fishing ground, as well as the minimum conservation reference size (MCRS) of 9 cm or 110 specimens per kg of European anchovy and 11 cm or 55 specimens per kg of European sardine, were considered relevant measures in order to support the sustainable management of the small pelagic fishery.

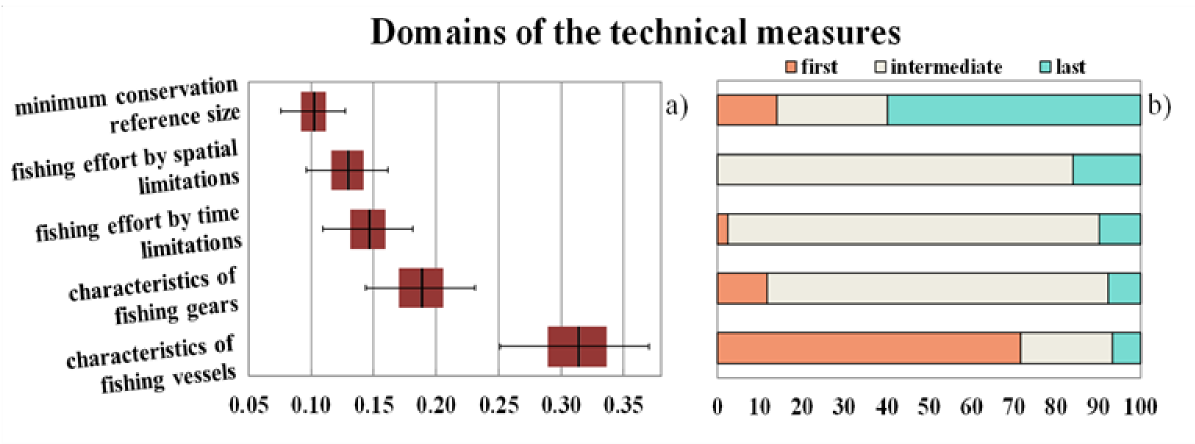

Figure 17. Box Plot (percentile 0.05, 0.25, 0.5, 0.75 and 0.95) with the ranking of the preferences expressed by each stakeholder.

V. Limitations of knowledge and future priorities of research

During the SPELMED project, we identified several limitations in the current knowledge about the biology, ecology and management of European sardine and European anchovy. These limitations highlight future priorities of research:

1. In general, less information about juveniles, larva and eggs distribution, abundance and biomass is available, both for anchovy and sardine, and historic time series of data of these life stages is mostly missing. Future data collection should include monitoring these life stages and integration with historical patchy data. In addition, an effort to collect and harmonized all available information is needed. The icthyoplankton database collected during SPELMED can be a starting point for this endeavour.
2. Available data and models revealed that both sardine and anchovy may have changed their distributions longitudinally (from coastal to deeper areas) and latitudinal (northern and southern). These results need to be confirmed with spatially-resolved data from acoustic surveys.
3. The validation of the age interpretation for both sardine and anchovy is still incomplete, indirect methods were mostly used, and even some studies lack formal precision and accuracy. Further time series about age, growth and length are needed.
4. Intra-annual and inter-annual information about population body condition is patchy. Future data collection should include monitoring these biological parameters, considering the latitudinal gradient of the study area and changing conditions of northern and southern populations.
5. Temporal data about the Gonadosomatic index (GSI), size at first maturity (L50) and spawning period from sardine and anchovy in GSA06 and GSA07 is patchy. Future data collection should include monitoring these biological parameters, considering the latitudinal gradient of the study area and changing conditions of northern and southern populations.
6. Historical information on feeding ecology and trophic from GSA06 is not available to date. This information could be informative to investigate possible changes in data availability related to changes in plankton composition, to be compared with available datasets in GSA07. Available preserved samples from historic collections (in GSA06) should be analysed.
7. Trophic information in GSA06 following the latitudinal gradient of the study area is also missing and could inform about differences in plankton composition, environmental impacts and connectivity effects between GSA06 and GSA07. Additionally, this study could allow the investigation of plastic and other pollutants in stomachs and tissues of organisms.
8. Historical information and information from a latitudinal gradient on feeding ecology of predators is not available. This lack of data impairs the assessment of the impact of changes of the importance of sardine and anchovy in the diet of predators due to the decline in the biomass.

9. The role that environmental factors play in the distribution, abundance and biomass of anchovy and sardine is complex and shows thresholds that may be different in different sub-areas of the Mediterranean. Future data collection should include monitoring key environmental parameters, considering the latitudinal gradient of the study area and the different responses of northern and southern populations in the study area. A transcriptomic study should be developed in this context to identify if the expression of some gens is associated with specific environmental conditions (e.g. gradient of temperature from north to south).
10. Results from the project highlighted that even the differences between populations from GSA06 and GSA07 or within GSA06 are very small from a genetic/genomic point of view, biological and ecological differences may be larger between GSA06 and GSA07, or even within GSA06 following a latitudinal gradient. Therefore, further studies are needed to consider stock identification from a management point of view.
11. The fishing industry plays a key role to explain the historical variability of abundance and biomass of sardine and anchovy in GSA06 and GSA07. A rigours monitoring of the fishing fleets is needed in order to assess as objectively as possible its current and future impact on both species. Current official data misses historical and current assessments of discards, which may contribute to underestimate historical and current fishing mortality.
12. The stock assessments developed under SPELMED represent an important progress regarding previous assessments of European sardine and European anchovy performed in the study areas. However, future iterations of the assessments will be needed to keep progressing on the stock evaluation when new biological and ecological data becomes available. Specifically, data from GSA07 needs to be improved, growth parameters need to be revisited and mortality assessments need to be further explored.
13. The collection of fishers and stakeholder perceptions on technical measures implementation can provide key information to propose alternative management measures of small pelagic fish exploitation. SPELMED results evidenced that while some measures may be widely accepted, others could be favoured by different age groups or geographic groups (following a latitudinal gradient). These differences need to be further investigated and differences between geographic groups following a latitudinal gradient need to be explored in complementarity with the biological and ecological differences found during the project.
14. The multi-modelling platform developed under SPELMED is now available to further investigate which factors may influence the spatial distribution and abundance of sardine and anchovy in GSA06 and GSA07 and which management alternatives could be favoured to promote their sustainable exploitation under a climate change context. These tools can be used in the future to further assess alternative scenarios. Future scenarios should be informed with the involvement of relevant stakeholders. In this context, the feedback from the European Commission, and National, Regional, and local bodies can be extremely relevant to make SPELMED results operational.

VI. Deviation of the work plan and remedial actions

During this project we encountered three main challenges that put the objectives of the project in jeopardy:

1. Availability of data through the Data Call

A data call for some specific DCF data was launched after the kick-off meeting of SPELMED with EASME and DGMARE (12th of February 2018) by means of a specific request to DGMARE. The data requested was made available on the 25th of May 2018. The wait for the data to arrive delayed analyses in the first set of deliverables.

2. Completion of the genetic sampling

The initial estimates to complete the sampling for the project was two months (January – February 2018). However, it was impossible to complete the sampling during this time period because of bad weather conditions in sampling areas (thus several samples of anchovy and sardine were not available) and because we were not able to obtain any reliable samples from the Gulf of Lions on time.

These challenges were communicated to EASME and DGMARE, with the possibility to complete the SPELMED sampling of the Gulf of Lions through the MEDITS France scientific trawl survey during June in agreement with IFREMER. However, MEDITS France did not collect enough samples for SPELMED. The MEDIAS France then accepted to further collect extra samples for SPLEMED. Finally, the sampling scheme for the project was completed on the 3rd of July 2018.

This large delay in obtaining the genetic samples seriously delayed the genetic analyses for SPELMED, and subsequent analyses.

3. Access to spatially-resolved data on abundance and biomass from acoustic surveys

Georeferenced data from the MEDiterranean International Acoustic Survey (MEDIAS)[2] project were not available through the Data Call and were not accessible when contacting MEDIAS coordinators of GSA 06 and GSA 07 by SPELMED coordinators. Therefore, we could only in the project use published spatial results from acoustic surveys.

To solve the problem of accessibility to spatially-resolved data from acoustic surveys, we have made the suggestion in several of our deliverables about the need to complement the requirements of the European Data Framework Collection in the future to include spatially-resolved acoustic surveys information in the data that States provide to the European Commission.

[2] http://www.medias-project.eu/medias/website/

The three main challenges encountered during the first six months of SPELMED were all overcome:

1. Availability of data through the Data Call

Despite the long wait for the results of the Data Call, remaining analyses were performed immediately after necessary data was accessible. Using in house expertise and analytical tools, the DC data was analysed as soon as it arrived and deliverables were updated. Therefore, the first challenge was solved.

2. Completion of the genetic sampling

After a long wait, the genetic sampling was completed. Genetic samples were efficiently analysed, and we accelerated laboratory and bioinformatics analyses to obtain results as soon as possible. This delay postponed some deliverables of SPELMED to the end of 2018 (Table 2 and Table 3 shows proposed changes to milestone and deliverables accounting for these changes in the schedule of the genetic analyses). These proposed changes to the time schedule were already communicated to the EASME and DGMARE the 4th of June 2018 and were accepted.

3. Access to spatially resolved data on abundance and biomass from acoustic surveys

To overcome the lack of access to spatially-resolved data on abundance and biomass from acoustic surveys, we used published available datasets from acoustic surveys (Bellido et al. 2008, Ospina-Álvarez et al. 2013) and complementary datasets to compare results, both in terms of raw data (Tasks 1 and 2) and in terms of outputs of temporal-spatial modelling (Task 3). In particular, we used data from the MEDIterranean Trawl Survey (MEDITS)[3] project (Bertrand et al. 2002). We also used landings as complementary time series datasets.

The first attempt to compare MEDITS temporal estimates with commercial catches of European sardine and European anchovy in GSA 09 showed that MEDITS survey could be a promising descriptor of anchovy abundance at sea (because it is the main targeted species by the fisheries sector in GSA 09), while a larger divergence was found for European sardine (Sbrana et al. 2010). Our results in Deliverable 1.3.3.1 (Report on abundance and biomass data) supported the findings of Sbrana and co-authors. The last stock assessment of European anchovy and European sardine in GSA 09 done by STECF in 2017 (STECF 2017) used both MEDITS relative abundance, in addition to MEDIAS total abundance, as tuning information in the assessment model. The two surveys provided similar estimates of stock abundances (STECF 2017).

In Deliverable 1.1.2, our results showed that some correlations of trends between acoustic surveys, trawl surveys and landings suggested that complementary data to acoustic surveys can be useful. Overall, correlations between datasets were higher for anchovy

[3] http://www.sibm.it/SITO%20MEDITS/principalemedits.htm

than for sardine. Acoustic surveys for anchovy were correlated with landings and trawl surveys in GSA 06, and for sardine were correlated with landings in GSA 07. Trawl surveys for sardine were correlated with landings in GSA 06.

In Deliverable 2.3.1., our results showed that when data was available to test congruence between spatial-temporal datasets regarding biomass, abundance and occurrence, the correlation between MEDITS and MEDIAS performed with data for anchovy from 2003-2010 showed high spatial correlation for biomass, abundance and occurrence for most of the years (with 2005 as the exception).

Table 2. List of milestones. Text in red highlights a change from the initial list accepted by the Commission in the Inception Report, which was accepted in the Interim report.

Milestone N.	Milestone name	Month	Task	Person/s in charge of monitoring	Partner/s
M0.1	1st Plenary meeting	January	0	M.Coll/J.M.Bellido	CSIC
M0.2	Data sharing agreement	February	0	M.T.Spedicato	COISPA
M0.3	Kick-off meeting	February	0	M.Coll/J.M.Bellido	CSIC
M0.4	2nd Plenary Meeting	May	0	M.Coll/J.M.Bellido	CSIC
M0.5	Progress meeting	August	0	M.Coll/J.M.Bellido	CSIC
M0.6	3rd Plenary Meeting	October	0	M.Coll/J.M.Bellido	CSIC
M0.7	Final meeting	November	0	M.Coll/J.M.Bellido	CSIC
M1.1.1	Database of previous genetic studies	February	1.1	R.Cannas	CONISMA
M1.1.2.	Database of available information about distribution	February	1.1	M.Coll/M.Hidalgo	CSIC/IEO
M1.2.1	Definition of the sampling and shipping protocol for tissue collection	January	1.2	R.Cannas/ C.Tsigenopoulos	CONISMA/ HCMR
M1.2.2	All samples shipped to the central location for storage before analyse	February	1.2	M.Coll/M.A.bo-Puigserver	CSIC
M1.2.3	Samples sent to the subcontractor for Genotyping-by-Sequencing	March	1.2	M.Coll/M.A.bo-Puigserver	CSIC
M1.2.4	Raw sequencing results for SNP detection and analysis	September	1.2	R.Cannas/ C.Tsigenopoulos	CONISMA/ HCMR
M1.2.5	Integration of genetic data with those coming from other tasks during a 2-day workshop	December	1.2	R.Cannas/ C.Tsigenopoulos	CONISMA/ HCMR
M1.3.1.1	Common excel sheet agreed to collect data	January	1.3	B.Morales-Nin	CSIC
M1.3.1.2	Review of studies on age, growth and age-composition and protocol on age determination	May	1.3	B.Morales-Nin	CSIC

	developed during a 2-day workshop				
M1.3.1.3	One day workshop on studies on age, growth and age-composition.	May	1.3	B.Morales-Nin	CSIC
M1.3.2.1	Common excel sheet agreed to collect data	January	1.3	M.Albo-Puigserver	CSIC
M1.3.2.2	Database on GSI and size at first maturity	May	1.3	M.Albo-Puigserver	CSIC
M1.3.2.3	Analysis of time series of GSI, size at first maturity	July	1.3	M.Albo-Puigserver	CSIC
M1.3.3.1	Common excel sheet agreed to collect data	January	1.3	M.Coll/M.G.Pennino	CSIC/IEO
M1.3.3.2	Database on abundance, biomass and recruitment size	May	1.3	M.Coll/M.G.Pennino	CSIC/IEO
M1.4.1	Common excel sheet agreed to collect data	January	1.4	A.Giraldez	IEO
M1.4.2	Database on natural mortality	May	1.4	A.Giraldez/J.G.Ramírez	IEO/CSIC
M1.5.1	Common excel sheet agreed to collect data	January	1.5	M.Albo-Puigserver	CSIC
M1.5.2	Database on body condition and energy content	May	1.5	M.Albo-Puigserver	CSIC
M1.5.3	Analysis to identify temporal trends and season variation in condition and energy content	July	1.5	M.Albo-Puigserver	CSIC
M2.1.1	Common excel sheet agreed to collect data	January	2.1	M.Albo-Puigserver	CSIC
M2.1.2	Database on diets information	May	2.1	M.Albo-Puigserver	CSIC
M2.2.1	Common excel sheet agreed to collect data	January	2.2	M.Albo-Puigserver	CSIC
M2.2.2	Database on diet of round sardinella, European sprat and predators	May	2.2	M.Albo-Puigserver	CSIC
M2.3.1	Common excel sheet agreed to collect data	January	2.3	M.Coll/M.G.Pennino	CSIC/IEO
M2.3.2	Review available studies on the role of environmental fluctuations and changes in status of target stocks	May	2.3	M.Coll	CSIC
M2.3.3	Geo-referenced database on relevant environmental parameters	June	2.3	M.G.Pennino	IEO
M2.4.1	Common excel sheet agreed to collect data	January	2.4	M.González	IEO
M2.4.2	Database on catches, discards, average effort and	May	2.4	M.González /J.G.Ramírez	IEO/CSIC

	economic performance of main fisheries				
M3.1.1	Collection of information on technical measures of anchovy and sardine fisheries in the study area	February	3.1	J.M.Bellido	IEO
M3.1.2	Compilation about fishers and stakeholder perception on technical measures implementation	May	3.1	J.M.Bellido	IEO
M3.2.1	Stock status analysis with two stage biomass method	June	3.2	J.G.Ramírez	CSIC
M3.2.2	Stock status analysis with a4a	July	3.2	J.G.Ramírez	CSIC
M3.2.3*	Stock status analysis with integrated model (Stock Synthesis) and comparison with previous methods	Cancelled	3.2	J.G.Ramíerez	CSIC
M3.2.4	2-day workshop on stock assessment methods with external experts	July	3.2	J.G.Ramírez /A.Giráldez	CSIC/IEO
M3.3.1	2-day workshop on modelling techniques: developing future scenarios of environmental and anthropogenic change for small pelagic fish in the Mediterranean	August/September	3.3	M.G.Pennino /J.M.Bellido	IEO
M3.3.2	Stakeholder workshop: definition of future management scenarios	September	3.3	M.G.Pennino /J.M.Bellido	IEO
M3.4.1	Multi-actors platform established	June	3.4	G.Lembo	COISPA
M3.4.2	Develop decision tree	July	3.4	G.Lembo	COISPA
M3.4.3	Develop routine in R to implement the MCDA model and online questionnaires	July	3.4	G.Lembo	COISPA
M3.4.4	Distribute questionnaires	September	3.4	G.Lembo	COISPA

*This milestone was cancelled after discussing stock assessment priorities with EASME and DGMARE during the kick-off meeting (see ANNEX IV kick-off meeting minutes).

Table 3. List of deliverables. Text in red highlights a change from the initial list accepted by the Commission in the Inception Report, which was accepted in the Interim report.

Deliv. N.	Deliverable name	Task	Partner/s	Responsible person	Deliv. date (month)
D0.1	Inception Report	0	CSIC/IEO	M. Coll/JMBellido	January
D0.2	Interim Report	0	CSIC/IEO	M. Coll/JMBellido	July
D0.3	Draft Final report	0	CSIC/IEO	M. Coll/JMBellido	December
D0.4	Final Report	0	CSIC/IEO	M. Coll/JMBellido	January 2019
D1.1.1	Report of available genetic information	1.1	CONISMA	R.Cannas	March
D1.1.2	Report of available information about distribution	1.1	CSIC	M.Coll/M.G. Pennino	March
D.1.2.1	Sampling and shipping protocol	1.2	CONISMA/ HCMR	R.Cannas/ C.Tsigenopoulos	January
D.1.2.2	Report on bioinformatic analyses of the GBS data and report of the population genetic analyses	1.2	CONISMA/ HCMR	R.Cannas/ C.Tsigenopoulos	December (November, first draft for one species)
D1.2.3	Report of all biological and genetic data related to connectivity and stock identification	1.2	CONISMA/ HCMR/CSIC	R.Cannas/ C.Tsigenopoulos/ M.Coll	December
D1.3.1.1	Report on age, growth and age-composition	1.3	CSIC	B.Morales-Nin/ J.G.Ramírez/M.Albo-Puigserver	May
D1.3.1.2	Protocol for age determination	1.3	CSIC	B.Morales-Nin	June
D1.3.2.1	Report on GSI and size at first maturity	1.3	CSIC	M.Albo-Puigserver	May
D1.3.2.2	Report on historical reproductive pattern	1.3	CSIC	M.Albo-Puigserver	August
D1.3.3.1	Report on abundance and biomass data	1.3	IEO	M.Coll/M.G.Pennino	June
D1.4.1	Report on mortality parameters	1.4	IEO/CSIC	J.G.Ramírez/ A.Giraldez	June
D1.5.1	Report on available body condition and energy content	1.5	CSIC	M.Albo-Puigserver	August
D2.1.1	Report of the dietary habits of anchovy and sardine	2.1	CSIC	M.Albo-Puigserver	July
D2.2.1	Addition to D2.1.1 information about trophic overlap of SPF and predators information	2.2	CSIC	J. Navarro/M.Coll	July
D2.3.1	Report on the potential role of environmental	2.3	CSIC/IEO	M.Coll /M.G.Pennino	July

	fluctuations and changes in status of studied species				
D2.4.1	Report on past and current catch and effort by stock in the study area and economic performance of main fisheries	2.4	IEO/CSIC	J.G.Ramírez/ M.González	June
D3.1.1	Review on the past and current management measures of anchovy and sardine fisheries	3.1	IEO	J.M.Bellido	April
D3.1.2	Review on fishers and stakeholder perceptions on involvement in technical measures implementation	3.1	IEO	J.M.Bellido	July
D3.2.1	Report on stock status (including uncertainty) and referent points for each stock performed by a4a and two stage biomass model	3.2	CSIC/IEO	J.G.Ramírez /A.Giráldez	December (November first draft, including genetic results from one species)
D3.2.2*	Report on stock status and referent points for each stock performed by Stock Synthesis	3.2	CSIC/IEO	J.G.Ramírez /A.Giráldez	Cancelled
D3.3.1	Report on modelling options developing future scenarios of environmental and anthropogenic change for small pelagic fish in the Mediterranean Sea	3.3	IEO	M.G.Pennino/ J.M.Bellido	December
D.3.3.2	Report on recommendation of management measures for small pelagic fisheries in the study area	3.3	IEO	M.G.Pennino/ J.M.Bellido	December
D3.4.1	Report on the feedback process with stakeholders	3.4	COISPA	G.Lembo	December

*This milestone was cancelled after discussing stock assessment priorities with EASME and DGMARE during the kick-off meeting (see ANNEX IV kick-off meeting minutes).

VII. Final products and project legacy

Project legacy

Final versions of all deliverables from SPELMED are available in the dropbox folder shared with EASME.

In addition, this dropbox contains the code used for the stock assessments and other modelling products resulting from SPELMED.

Indications on where to find the genetics raw data and the genetic samples stored as a back-up for the project are provided below:

- The raw data from the genomic analyses will be stored at the Hellenic Centre for Marine Research (HCMR) facilities and will be available from Dr. Costas Tsigenopoulos (email: tsigeno@hcmr.gr).
- The back-up biological samples collected during the project to perform genomic analyses will be kept at the Institute of Marine Science (ICM-CSIC), stored at -20ºC in a freezer, under Dr. Marta Coll (email: mcoll@icm.csic.es).

A list of tentative scientific publications was discussed during the third scientific project meeting (Annex III). Permission to publish results of SPELMED in peer-review journals and to present them in scientific conferences will be requested in due time.

Finally, in January 2019, a new committee of co-management of small pelagic fish in the northern part of GSA06 (*Pla de gestió del peix blau de l'Empordà nord*[4]) was created with the aim to support the recovery of the resources in the area of the Gulf of Roses and Pals Bay. In this co-management committee, the scientific community will be represented by the Institute of Marine Science (ICM-CSIC) and results from SPELMED project will be very useful to contribute to the starting point of the technical commission in charge of developing the management plan.

[4] http://www.canal10.cat/video/16910-comit-de-cogesti-del-peix-blau-de-les-badies-de-roses-i-pals

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ANNEX I: First scientific project meeting

SPELMED Kick-off meeting

Barcelona, Institute of Marine Science (ICM-CSIC)

31st January - 1st February 2018

AGENDA

Wednesday 31st January 2018 – meeting in room B92b

13.00 – 13.30	**Arrival of participants and welcome coffee**
13.30 – 13.45	**Presentations and logistics** *Marta Coll*
13.45 – 14.30	**Summary of project aims, tasks and timetable** **Presentation and discussions:** presentation of project and aims *Marta Coll & Jose María Bellido*
14.30 – 15.00	**Task 0. Project coordination** **Presentation and discussions:** organization of the project *Marta Coll & Jose María Bellido & Maria Teresa Spedicato*
15.00 – 15.30	**Coffee Break**
15.30 – 16.00	**Task 1. Review and improvement of information** **Presentation and discussions:** planning activities, protocols and organization *Manuel Hidalgo & Marta Coll*
16.00 – 17.00	**Task 1.1 & 1.2. Distribution, connectivity and genetic analyses** **Presentation and discussions:** planning activities and sampling, protocols and organization *Rita Cannas & Costas Tsigenopoulos*
17.00 – 18.00	**Task 1.3. Growth, Reproduction and Abundance** **Presentation and discussions:** planning activities, protocols and organization *Magdalena Iglesias & Marta Albó-Puigserver*
18.00	**End of the session**

20.00: Dinner

Thursday 1st February 2018 – meeting in room B92b

09.00 – 10.00	**Task 1.4. Mortality parameters** **Presentation and discussions: planning activities, protocols and organization** *Ana Giráldez & John G. Ramírez*
10.00 – 10.30	**Task 1.3. Body condition and energy content** **Presentation and discussions:** planning activities, protocols and organization *Marta Albó-Puigserver*
10.30 – 11.00	**Coffee break**
11.00 – 11.30	**Task 2. Ecological and Fisheries Information** **Presentation and discussions:** planning activities and organization *Marta Coll & Maria Grazia Pennino*
11.30 – 12.00	**Task 2.1 & Task 2.2. Feeding ecology, predators and competitors** **Presentation and discussions:** planning activities, protocols and organization *Marta Albó-Puigserver & Raúl Laíz*
12.00 – 12.30	**Task 2.3. Environmental fluctuations and change** **Presentation and discussions:** planning activities, protocols and organization *Marta Coll & Maria Grazia Pennino*
12.30 – 13.30	**Lunch break**
13.30 – 14.00	**Task 2.4. Fisheries** **Presentation and discussions:** planning activities, protocols and organization *María González & John G. Ramírez*
14.00 – 14.30	**Task 3. Fisheries management measures** **Presentation and discussions:** planning activities and organization *Jose María Bellido & John G. Ramírez*
14.30 – 15.00	**Task 3.1. Current management measures** **Presentation and discussions:** planning activities, protocols and organization *Jose María Bellido*
15.00 – 15.30	**Task 3.2. Stock assessment models** **Presentation and discussions:** planning activities, workshops and organization

	John G. Ramírez & Ana Giráldez
15.30 – 16.00	**Coffee break**
16.00 – 16.30	**Task 3.3. Ecological models** **Presentation and discussions:** planning activities, workshops and organization *Maria Grazia Pennino & Jose María Bellido*
16.30 – 17.00	**Task 3.4. Stakeholder engagement** **Presentation and discussions:** planning activities, workshops and organization *Giuseppe Lembo*
17.00 – 18.00	**General discussion & organization** Overview of sampling and protocols, workshops and activities, organization of next meetings and deliverables
18.00	**End of the session**

List of people attending the meeting

Name	Institute	Email
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ANNEX II: Second scientific project meeting

SPELMED 2nd project meeting

Centro Oceanográfico de Murcia - Instituto Español de Oceanografía (IEO)

10th - 11th May 2018

AGENDA

Thursday 10th May

09.00 – 09.30	**Arrival of participants and welcome coffee**
09.30 – 10.00	**Presentations and logistics** *Marta Coll*
10.00 – 10.30	**Updates on project aims, tasks and timetable** *Marta Coll & Jose María Bellido*
10.30 – 11.00	**Task 0. Project coordination** Updates on the organization of the project *Marta Coll & Jose María Bellido*
11.00 – 11.30	**Task 1. Review and improvement of biological information** Updates on tasks, timings and planning *Marta Coll*
11.30 – 12.30	**Task 1.1 & 1.2. Distribution, connectivity and genetic analyses** Updates on deliverables **D1.1.1 & D1.1.2** and sampling, planning of new activities *Rita Cannas & Marta Coll*
12.30 – 13.30	**Lunch break**
13.30 – 14.00	**Task 1.3. Age, growth and size & Reproduction** Updates on deliverables **D1.3.1.1 & D1.3.2.1**, planning of new activities *Marta Albo-Puigserver (first part on behalf of Beatriz Morales-Nin)*
14.00 – 14.30	**Task 1.3. Abundance & biomass** Updates on deliverables **D1.3.3.1**, planning of new activities *Jose Maria Bellido (on behalf of Magdalena Iglesias)*
14.30 – 15.00	**Task 1.4. Mortality parameters** Updates on deliverables **D1.4.1**, planning of new activities *John G. Ramírez*
15.00 – 15.30	**Coffee break**
15.30 – 16.00	**Task 1.5. Body condition and energy content** Updates on deliverables **D1.5. 1**, planning of new activities *Marta Albó-Puigserver*
16.00 – 16.30	**Task 2. Ecological and Fisheries Information**

	Updates on tasks, timings and planning *Marta Coll & Maria Grazia Pennino*
16.30 – 17.00	**Task 2.1 & Task 2.2. Feeding ecology, predators and competitors** Updates on tasks, timings and planning *Marta Albó-Puigserver & Raúl Laíz*
17.00 – 17.30	**Task 2.3. Environmental fluctuations and change** Updates on tasks, timings and planning *Marta Coll & Maria Grazia Pennino*
18.00	**End of the session**

20.00: Dinner

Friday 11th of May

09.00 – 09.30	**Task 2.4. Fisheries** Updates on deliverables **D2.4.1**, planning of new activities *John G. Ramírez*
09.30 – 10.00	**Task 3. Fisheries management measures** Updates on tasks, timings and planning *Jose María Bellido & John G. Ramírez*
10.00 – 10.30	**Task 3.1. Current management measures** Updates on deliverables **D3.1.1**, planning of new activities *Jose María Bellido*
10.30 – 11.00	**Coffee break**
11.00 – 11.30	**Task 3.2. Stock assessment models** Updates on tasks, timings and planning *John G. Ramírez*
11.30 – 12.00	**Task 3.3. Ecological models** Updates on tasks, timings and planning *Maria Grazia Pennino & Jose María Bellido*
12.00 – 12.30	**Task 3.4. Stakeholder engagement** Updates on tasks, timings and planning *Jose María Bellido (on behalf of Giuseppe Lembo)*

12.30 – 13.30	**Lunch break**
13.30 – 16.00	**General discussion & organization** Overview of future deliverables, workshops and activities, organization of Interim Report (July) and next meeting (October)
16.00	**End of the session**

List of people attending the meeting

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Andrea Massaro	CIBM	andrea.massaro@aplysia.it
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ANNEX III: Third scientific project meeting

SPELMED 3rd project meeting

Instituto de Ciencias del Mar (ICM), CSIC, Barcelona, Spain

4th – 5th December 2018

AGENDA

Tuesday, Dec 4th – SPELMED Final Meeting

09.00 – 09.30	**Arrival of participants**
09.30 – 10.00	**Updates on project aims, tasks and timetable** Marta Coll & Jose María Bellido
10.00 – 10.30	**Task 0. Project coordination** Updates on the organization of the project Pending tasks, timings and planning Marta Coll & Jose María Bellido & Maria Teresa Spedicato
10.30 – 11.00	Coffee break
11.00 – 12.00	**Task 1. Review and improvement of biological information** Updates and discussion on tasks 1.1 - 1.5. Integration of new genetic results. Task and subtasks leaders
12.00 – 12.30	**Task 2. Ecological and Fisheries Information** Task 2.1 & Task 2.2. Feeding ecology, predators and competitors Updates on tasks, timings and planning. Integration of new genetic results. Marta Albó-Puigserver & Raúl Laíz
12.30 – 13.30	Lunch break and group photo
13.30 – 14.00	Task 2.3. Environmental fluctuations and change Updates on tasks, timings and planning. Integration of new genetic results. Marta Coll & Maria Grazia Pennino
14.00 – 14.30	Task 2.4. Fisheries Updates on tasks, timings and planning. Integration of new genetic results. María González & John G. Ramírez
14.30 – 15.00	**Task 3. Fisheries management measures** Task 3.1. Current management measures Updates on tasks, timings and planning. Integration of new genetic results. Jose María Bellido
15.00 – 15.30	Task 3.2. Stock assessment models Updates on tasks, timings and planning. Integration of new genetic results. John G. Ramírez & Ana Giráldez
15.30 – 16.00	Coffee break
16.00 – 16.30	Task 3.3. Ecological models Updates on tasks, timings and planning. Integration of new genetic results. Maria Grazia Pennino & Jose María Bellido
16.30 – 17.00	Task 3.4. Stakeholder engagement Updates on tasks, timings and planning. Integration of new genetic results. Giuseppe Lembo
17.00 – 18.00	**Wrapping up – Discussion** Genetic results in the light of the ecological implications
18.00	End of the session

20.00: Dinner

Wednesday, Dec 5th – SPELMED Final Meeting

09.30 – 10.30	**General discussion** Overview of ecological results and discussion related to genetic results Overview of final deliverables and deadlines
10.30 – 11.00	Coffee break
11.00 – 12.30	**Desk work** Organization and production of Final Report

12.30 – 13.30	Lunch break
13.30 – 16.30	**Desk work** Production of Final Report
16.30	**End of the session**

List of people attending the meeting

Name	Institute	Email
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ANNEX IV: Project workshops

Otoliths and vBGP workshop

Centro Oceanográfico de Málaga - Instituto Español de Oceanografía (IEO)

18th - 19th June 2018

AGENDA

Thursday 18th May

11.00 – 11.30	Arrival of participants and welcome coffee
11.30 – 12.00	**Presentations and logistics** *Ana Giráldez*
12.00 – 14.00	**Revision of ways to obtain number-at-age from number-at-size of anchovy and sardine** *Ana Giráldez*
15.00 – 17.30	**Issues related to otolith readings and approaches to solve them** Pedro Torres
18.00	End of the session

Friday 19th of May

09.00 – 10.30	**Age-length keys including otolith readings of larvae** *John G. Ramírez and Alberto Garcia*
10.30 – 11.00	**Coffee break**
11.00 – 14.00	**Updating of vBGP for sardine and anchovy in GSA6** *John G. Ramírez & Ana Giráldez &* Pedro Torres
15.00 – 16.00	**Slicing of landings applying the updated vBGP** *John G. Ramírez*
16.00 – 16.20	**Coffee break**
16.20 – 18.00	**Stock assessment of sardine and anchovy using a4a**

	John G. Ramírez

List of people attending the workshop

Name	Institute	Email
Ana Giraldez	IEO-Malaga	agiraldez@ieo.es
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Alberto Garcia	IEO-Malaga	agarcia@ieo.es
John Ramírez	CSIC-ICM	j.gabriel@icm.csic.es

Stock Assessment with a4a workshop

Joint Research Center JRC, Ispra, Italy

02th - 06th July 2018

AGENDA

Monday 2nd July

10:30 – 12:00	**Presentation of the working plan to assess anchovy and sardine in GSA6 using a4a. Particular discussion on von Bertalanffy growth parameters estimates** John Ramírez, Ernesto Jardim, Paris Vasilakopoulos, Cecilia Pinto, Alessandro Mannini
13:00 – 18:00	**Setting the FLstock and FLindex objects to assessment of sardine** John Ramírez, Paris Vasilakopoulos
18.00	End of the session

Tuesday 3rd July

8:30 – 12:00	**Improving the script to slice length to age number and estimating natural mortality** John Ramírez, Paris Vasilakopoulos
13:00 – 18:00	**Setting the FLstock and FLindex objects to assessment of anchovy** John Ramírez, Paris Vasilakopoulos
18.00	End of the session

Wednesday 4th July

8:30 – 12:00	**Running stock assessment and fitting the anchovy model** John Ramírez, Paris Vasilakopoulos

13:00 – 16:00	**Running stock assessment and fitting the anchovy model** John Ramírez, Paris Vasilakopoulos
16:00 – 17:30	**Plenary to discuss preliminary results and next steps** John Ramírez, Ernesto Jardim, Paris Vasilakopoulos, Cecilia Pinto, Alessandro Mannini
18.00	End of the session

Thursday 5th July

8:30 – 12:00	**Running stock assessment and fitting the sardine model** John Ramírez, Paris Vasilakopoulos
13:00 – 16:00	**Running stock assessment and fitting the sardine model** John Ramírez, Paris Vasilakopoulos
16:00 – 17:30	**Plenary to discuss stock assessment outputs for sardine and anchovy and introduction to uncertainty in a4a** John Ramírez, Ernesto Jardim, Paris Vasilakopoulos, Cecilia Pinto, Alessandro Mannini
18.00	End of the session

Friday 6th of July

8:30 – 12:00	**Introducing uncertainty in estimates of von Bertalanffy growth parameters in stock assessment with a4a** Ernesto Jardim, John Ramírez,
13:00 – 16:00	**Retrospective analysis, referent points and plots comparing different assessments** John Ramírez, Ernesto Jardim, Paris Vasilakopoulos
16:00 – 17:30	**Remarks and next steps to improve the stock assessment of sardine and anchovy**

	John Ramírez, Ernesto Jardim, Paris Vasilakopoulos, Cecilia Pinto, Alessandro Mannini
18.00	End of the session

List of people attending the workshop

Name	Institute	Email
Ernesto Jardim	JRC	Ernesto.JARDIM@ec.europa.eu
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Modelling workshop

Institute of Marine Science (ICM-CSIC), Barcelona, Spain

21st – 22nd August 2018

AGENDA

Tuesday 21st August 2018

10.00 – 10.30	**Arrival of participants and organization**
10.30 – 12.00	**State of the art and aims of the modelling work in Spelmed** *Marta Coll*
12.00 – 14.00	**Revision of ways to model abundance and biomass data with SDM** *Maria Grazia Pennino*
14.00 – 15.00	**Lunch**
15.00 – 17.00	**Environmental response from SDM** *Maria Grazia Pennino*

Wednesday 22nd August 2018

09.00 – 10.30	**Integration of SDM results into Ecosystem models** *Marta Coll*
10.30 – 11.00	**Coffee break**
11.00 – 14.00	**Development of scenarios** *Marta Coll & Maria Grazia Pennino*
14.00 – 15.00	**Lunch**
15.00 – 16.00	**Linking ecological modelling with stock assessment models** *Marta Coll, Maria Grazia Pennino & John G. Ramírez*
16.00 – 17.00	**Work plan and final discussions**

List of people attending the workshop

Name	**Institute**	**Email**
María Grazia Pennino	IEO-Vigo	grazia.pennino@mu.ieo.es
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Genetics workshop

Instituto de Ciencias del Mar (ICM), CSIC; Barcelona, Spain

3rd December 2018

AGENDA

Monday, Dec 3rd - Genetics Workshop

10.00 – 10.30	**Arrival of participants and welcome coffee**
10.30 – 10.45	**Presentations and logistics** *Marta Coll*
10.45 – 11.15	**Genetics WK aims, tasks and timetable** *Rita Cannas & Costas Tsigenopoulos*
11.15 – 12.30	**Genetics Results** *Rita Cannas & Costas Tsigenopoulos*
12.30 – 13.30	**Lunch break**
13.30 – 17:00	**Integration of genetic data with results from other tasks** All participants
15.30 – 16.00	**Coffee break**
17.00	**End of the session**

List of people attending the workshop

Name	Acronym	Institute	Email
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ANNEX V: First meeting with EASME and DGMARE

Brussels, 07/02/2018

Meeting minutes of the Kick-off meeting of the Evaluation of the population status and specific management alternatives for the small pelagic fish stocks in the North-Western Mediterranean Sea

Contract – EASME/EMFF/2016/1.3.2.5/02/SI2.770218

Wednesday 07th February 2018, 11:00-12:30

COVENT GARDEN BUILDING 2 (Place Rogier, 16; B-1210 Brussels, Belgium)

ROOM COV2 11/190

Participants:

- Rocio SUAREZ JIMENEZ (EASME A.3), RSJ
- Adolfo MERINO BUISAC (EASME A.3), AMB
- Laurent MARKOVIC (MARE D.1) , LM
- Antonios STAMOULIS (EASME A.3), AS
- Rita CANNAS (Conisma, Italy), RC
- Marta COLL MONTON (CSIC, Spain), MCM

11:00 – 11:15

1. Welcome and Tour de table.
   a. Presentation of the contracting involved actors: roles of EASME and DG MARE.
   b. Presentation of the consultants' team.
   c. Review of the draft agenda.

11:15 – 11:30

2. Background and purpose of the project (briefing by DG MARE).

AMB explains the roles of EASME and DG MARE: EASME is assisting in the administrative part and is the legal responsible of the contract. EASME will act in coordination with DG MARE. AMB asks the SPELMED coordinators to always email in copy EASME and DG MARE representatives in every correspondence during the contract to keep everybody informed. AMB explains that the specific contract SC02 was motivated by requests from member states, specifically by a request by Spain.

11:30 – 13:00

3. Tasks, methodology and quality assessment (Project Coordinator/ALL).
   a. Presentation of the Inception report.
   b. Discussion of the tasks to be performed.
   c. Quality management, data collection and contingency plan.
   d. Preparation of genetic analysis (sampling) and next steps.
   e. Required input from Contracting Authority.

f. Additional comments on the Inception report.
g. Questions & Answers.

The genetic analyses sampling strategy is discussed. RC and MCM explain the last discussions about the sampling sites during the kick-off meeting of the project in Barcelona. The possibility of including GSA09 and excluding the North Spanish Atlantic point or GSA10 is discussed. LM will check with Chato Osio and will come back to RC and MCM as soon as possible about this possibility.

The possibility to combine results from parallel projects on sardine happening in the Mediterranean and the Atlantic and being coordinated by IEO (TRANSALBORAN and SARGEN) is illustrated. All the participants agree on try minimizing duplication of work and hence in the need of evaluating the possibility to reduce/eliminate the Atlantic sampling locations in SPELMED genetic analyses, being already included/analysed in the other projects.

It is agreed that RC and MCM will send to EASME and DG MARE the final version of the sampling and shipping protocol (a drafted version is available in the Inception Report as Deliverable 1.2.1) to facilitate further comments. DG MARE will provide feedback.

RC explains the specificities of the genomic analyses to be developed under SPELMED and the fact that a 'SNPs discovery' and 'SNP genotyping' will be performed for both species.

The critical situation of sardine in the study area is discussed. LM suggests looking at literature for Cod in Atlantic waters to have insights on the possible role of climate change for shifts in distribution and abundance of stocks.

LM provides comments about the stock assessment work and points out that from DG MARE perspective the stock synthesis is not a priority, being preferable to concentrate on the classic stock assessment methods. Therefore, if there is the need to prioritize tasks, the stock synthesis task can be omitted.

RSJ asks clarifications on the possible application of EAF within SPELMED, and on tasks related to food web modelling. MCM explains the methodology and stresses that the project aims at obtaining data from three typologies of models for advice management: stock assessment models, species distribution models, and preliminary food-web models.

LM asks for the role of IFREMER in the project. MCM explains the steps followed to officially involve IFREMER and the actions done to involve researchers unofficially. The discussion evolves to the request for the Data Call that the consortium has prepared. It is agreed that MCM will send the request to DG MARE in the next days to check.

MCM invites EASME and DG MARE to the next project meetings (in May and October) and to the stock assessment workshop in September.

MCM informs that there is going to be a meeting with stakeholders the 17th of February 2018 at ICM-CSIC with the principal aim to inform the fishery sector of purse seiners about the project aims and activities. EASME informs that every activity with stakeholders need to be officially communicated to the Contracting Authority. It is agreed that MCM will send official notification of the meeting by email.

AMB recalls the need to inform EASME/ DG MARE for every event it is organized within the SPELMED, and he stress the need of a formal authorization for using data/results derived from this project, including publications.

LM suggests to contact MEDAC to have further reach on stakeholders. AMB informs that, if needed, EASME/DG MARE can provide introduction letters to specific institutions to facilitate contacts.

13:00 – 13:15 4. Deliverables, meetings and timeframe (EASME).

AMB informs that he will send soon comments on the Inception (IR) Report and that these comments should be incorporated in a new version of the IR to be submitted to EASME for the final approval.

EASME explains that they prefer to receive all deliverables in the reports, unless we need their feedback in a specific deliverable. If this is the case deliverables can be sent to EASME and DG MARE to be checked.

EASME informs that reports and deliverables need to be simple and easy to read. They need to contain a short executive-summary for non-specialists (1-3 pages at maximum) where it is explained what was done, what was found and what are the recommendations. All specific information should go to annexes.

AMB will send the visibility guidelines, and eventual template and standard requirements for the final report.

Next meetings with the Contracting Authority are discussed considering the calendar. Because the next meeting following the Interim Report may fall at the end of July and may conflict with vacation periods, the possibility to have a skype meeting in July to receive EASME and DG MARE comments on the Interim Report and have a physical meeting early September is discussed. It seems there would be no problems with this possible arrangement.

AMB informs on the need of having supporting evidences (e.g. attendance list, tickets, boarding passes, etc.) for the reimbursement of travels. MCM proposes to check with CONISMA as soon as possible on this aspect, to coordinate partners and specify roles and responsibilities in order to fulfil this requirement.

13:15 – 13:25 AOB

13:25 – 13:30 5. Conclusions (EASME)

AMB makes emphasis on establishing a two-way communication and invites SPELMED project to contact immediately EASME and DG MARE if problems arise.

ANNEX VI: List of final deliverables of SPELMED

D.0.1. Inception Report
D.02. Interim Report
D.03. Draft Final Report
D.04. Final Report + Executive Summary
D.1.1.1. Report on available genetic information
D.1.1.2. Report on available information about distribution
D.1.2.1. Sampling and shipping protocol
D.1.2.2. Report on bioinformatic analyses of the GBS data and report of the population genetic analyses
D.1.2.3. Report of all biological and genetic data related to connectivity and stock identification
D.1.3.1.1. Report on age, growth and age-composition
D1.3.1.2. Protocol for age determination
D.1.3.2.1. Report on gonadosomatic index, size at firs maturity and reproductive parameters
D.1.3.2.2. Report on historical reproductive pattern
D.1.3.3.1. Report on abundance and biomass
D.1.4.1. Report on mortality parameters
D.1.5.1. Report on available body condition and energy content
D.2.1.1. Report of the dietary habits of anchovy and sardine
D.2.2.1. Addition to D2.1.1 information about trophic overlap of SPF and predators information
D.2.3.1. Report on the potential role of environmental fluctuations and changes in status of studied species
D.2.4.1. Report on past and current catch and effort by stock in the study area and economic performance of main fisheries
D.3.1.1. Review on the past and current management measures of anchovy and sardine fisheries
D.3.1.2. Review on fishers and stakeholder perceptions on involvement in technical measures implementation

D.3.2.1. Report on stock status (including uncertainty) and referent points for each stock performed by a4a and two stage biomass model
D.3.3.1. Report on modelling options developing future scenarios of environmental and anthropogenic change for small pelagic fish in the Mediterranean Sea
D.3.3.2. Report on recommendation of management measures for small pelagic fisheries in the study area
D.3.4.1. Report on the feedback process with stakeholders

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