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Deliverable 3.6.1

Comparing and integrating genomics, fishery biology data and experience -based knowledge to assess fishery resources status and support their management

ConFish

– Connectivity among Mediterranean fishery stakeholders and scientists resolves connectivity of fishery populations –

WP3 – STUDYING

ACTIVITY 3.6

PARTNER IN CHARGE: ISTITUTO SUPERIORE PER LA PROTEZIONE E LA RICERCA AMBIENTALE

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Contents

1. Introduction

The Mediterranean Sea fisheries are characterized by a high multispecificity, the use of several types of fishing gears, the large incidence of small-scale fishing, the presence of shared stocks and the very high cultural and economic differences across countries. More than 85% of Mediterranean stocks that have a formal analytical assessment of their status are overexploited, and very little improvements have been achieved so far to reverse this condition.

Within this context, current fisheries management in the Mediterranean Sea is recently facing major changes, with the emergence of result-based management approach. In particular, although with some slowness, the usage of stock assessment to evaluate the status of exploited resources and formulate quantitative management targets is now spreading. Such processes have been supported and stimulated by both the General Fisheries Commission for the Mediterranean and Black Sea (GFCM), and the European Commission. In addition, the GFCM is also further qualifying its activities as Regional Fisheries Management Organization, and has recently established a Data Collection Reference Framework that, in parallel with EU Data Collection Framework, should ensure the availability of statistical and scientific data to describe fisheries, their resources, and their exploitation status.

Basically, fishing management is carried out establishing input control (e.g. number of licenses) and technical measures (e.g. fishing gear limitations, spatial restrictions, etc.) whose definition is primarily based on fishery dependent and fisheries independent data, socio-economic considerations, and only partially on evidences from stock assessment. In addition, output control (i.e. the application of Total Allowable Catches) is not spread, having been applied (and with success) with Bluefin tuna.

Main data sources are national landings statistics, national data on fishing capacity and effort, and fishery independent data (such as those collected via experimental trawl surveys). Such data are collected at national level and at Geographical subareas level (GSA). The spatial extension of the latter was defined by GFCM taking into account knowledge on stocks spatial distribution and the spatial domain of countries.

On the opposite, other data sources like genomic and genetic data are little used for several reasons, including a gap in the background and skills of fisheries biologists. This holds true also for other sources of data, like Local Ecological Knowledge, that despite being considered good source of semi-quantitative data (especially for reconstructing trends over the past 3-4 decades) are little used for management purposes.

Scientists have already questioned the spatial domain of GSAs and their effective overlap with stock boundaries. Indeed, the stock is the unit of fisheries management and using the wrong spatial scale (stock boundaries) may determine the stock definition and lead to application of ineffective management measures.

In this deliverable, we jointly assess the complementarity, redundancy and consistency of different sources of data and approaches, integrating typical sources like fishing statistics data and stock assessment with local ecological knowledge, and genomic data, that were acquired with different approaches within the CONFISH project to assess the status and guide fisheries management approaches.

1.1 Case-species and objectives of the report

The two target species selected for this study are the common octopus (*Octopus vulgaris*) and the blue and red shrimp (*Aristeus antennatus*). These species have a relevant economic value and their exploitation is carried out in almost all the Mediterranean Sea.

The common octopus, *Octopus vulgaris*, is a benthic coleoid cephalopod inhabiting a variety of substrates from rocky, sandy to muddy bottoms on the continental shelf (Mangold, 1983; Belcari and Sartor, 1999; Belcari et al, 2002; Jereb et al, 2014, 2015), with a life span of about 12-18 months (Iglesias et al, 2004; Katsanevakis and Verriopoulos, 2006). Octopus populations, because of their short life cycle resulting in a general lack of overlap between generations, are subject to sharp fluctuations in spatial and temporal abundance (Boyle and Boletzky, 1996). In the Mediterranean Sea, *O. vulgaris* is an important resource for commercial fisheries and is subject to intense fishing activity. This cephalopod is targeted throughout the year using several fishing gears such as bottom trawls, pots, hand-jigs, traps and trammel nets (Sánchez and Obarti, 1993; Quetglas et al, 1998; Belcari et al, 2002; Tsangridis et al, 2002; Jereb et al, 2015). Static gears are usually deployed in traditional small-scale costal fisheries, which have a high social and economic importance in the Mediterranean countries (Pereira, 1999; ICES, 2015). Still, an unknown share of catches of *O. vulgaris* is taken to recreational fishing, in particular underwater spearfishing (Chavoin and Boudouresque, 2004; Morales et al, 2005; Lloret et al, 2008).

The blue and red shrimp, *Aristeus antennatus* (Risso, 1816) is a deep water large sized crustacean usually ranging between 10 and 18 cm of total length. It is distributed across the Mediterranean Sea, with the exception of the northern Adriatic Sea (Colloca et al, 1998; Papacostantinou and Kapiris, 2001), and it shows a relatively long lifespan of 10 years (Orsi Relini et al, 2013). *A. antennatus* is a demersal species inhabiting sandy and muddy bottoms near submarine trenches and canyons between 80 m and 3300 m depth (Fisher, 1987; Cartes and Sardà, 1989; Demestre and Fortuño, 1992; Ragonese and Bianchini, 1996; Garcìa-Rodriguez and Esteban, 1999; Sardà et al, 2004; Muffouk et al, 2008).

In the Mediterranean Sea it reaches higher densities in the westernmost part of the basin (Cau et al, 2002), while a lower abundance has been recorded in the eastern basin, with the exception of the Ionian Sea (Tursi et al, 1993; D'onghia et al, 1998; Cau et al, 2002). *A. antennatus* is one of the most valuable invertebrate caught in the Mediterranean Sea (Maynou et al, 2006), and represents a significant resource for the Mediterranean trawl fishery (Ragonese and Bianchini, 1996). This kind of deep-water trawl fishing is more spread in the western basin (Ragonese and Bianchini, 1996), in particular along the Spanish coast and in Italy, in the Ligurian Sea, Tyrrhenian Sea, around Sardinia (Colloca et al, 1998; Fiorentino et al, 1998; Garcìa-Rodriguez and Esteban, 1999), and in the Strait of Sicily (Ragonese and Bianchini, 1996).

The main aims of this deliverable are:

i) to synthetize the results obtained within the CONFISH project in relation to the analyses of the status of these two species (and their populations) taking into account the different approaches we applied (i.e., genomics, fishery biology, Local Ecological Knowledge and fishing communities' perspectives);

ii) to contribute, through the integration of these results, to the management of fisheries exploiting such species, identifying consistencies and inconsistencies among results and with current management assumptions/practices, as well as information gaps to be addressed;

iii) to contribute progressing towards the development of an interdisciplinary framework for establishing an integrative tool for both stock assessment and development of management strategies within a SES context.

2. Insights on the status of exploited species

2.1 *Octopus vulgaris:* population connectivity and stock boundaries, status and trends

2.1.1 Genomics

Octopus vulgaris evolutionary analyses studies shows that there is a clear genomic differentiation between populations from the Adriatic Sea and the population from Atlantic Ocean, with the Western Mediterranean populations exhibiting a mix of genomic signatures from those two groups. This highlights a reduced connectivity and population structuring between octopus populations from Western Mediterranean basin and Adriatic Sea. Moreover, octopus populations along Spanish coast are genetically distinct from one another, despite their apparent geographic proximity.

While the large-scale population structure for octopus seems to be in part influenced by geographical distance, the observed patterns of genomic differences indicate that the large part of differentiation is also stemming from environmental differences. Indeed, *Octopus vulgaris* populations show correlations between patterns of genomic differentiation, and differences in environmental factors such as temperature, salinity and dissolved oxygen among sites. [Considering the particular case of the Adriatic Sea, the populations appear to be locally adapted to those specific environments.]

It is known that populations that are genetically isolated and well adapted to their specific environment tend to be less diverse. Indeed several octopus populations from Adriatic showed lower levels of genetic diversity.

These populations should be taken special care of as they exhibit limited connectivity, high local adaptation and, under fast shifting environmental scenarios, lower evolutionary potential. In theory, those populations would not easily recover and are particularly endangered from changes in external stressors. This also means that in the case of population collapse it would be harder for migrants from other populations to replace them, as they are not specifically adapted to those environments.

2.1.2 Fishery statistics

O. vulgaris, in the Mediterranean Sea, is a very important resource for professional fishing. According to official statistics landings of this species declined since 1992 (Figure 1). However, the assessment of catches is difficult due to fact that i) this species very rarely is the single target species of a fishery and that ii) a large variety of fishing gear may be used to exploit this species, according to area and traditions.

Moreover, catches from recreational and IUU fishing (Illegal, Unreported and Unregulated fishing) may be locally relevant, and being not declared they are not included in the official statistics, pointing to an underestimation of total catches and landings for this species.

The most relevant octopus fishing grounds are concentrated in the Western Mediterranean Sea (i.e. Spanish waters and the Tyrrhenian Sea, as also reported by Söller et al, 2000; Jereb et al, 2014, 2015), and around the southern regions of Italy (i.e. the Ionian Sea) and in the Aegean Sea (Figure 2).

Small scale fishery is important especially in Italy and Croatia, while in Spain the majority of catches are taken with demersal trawlers.

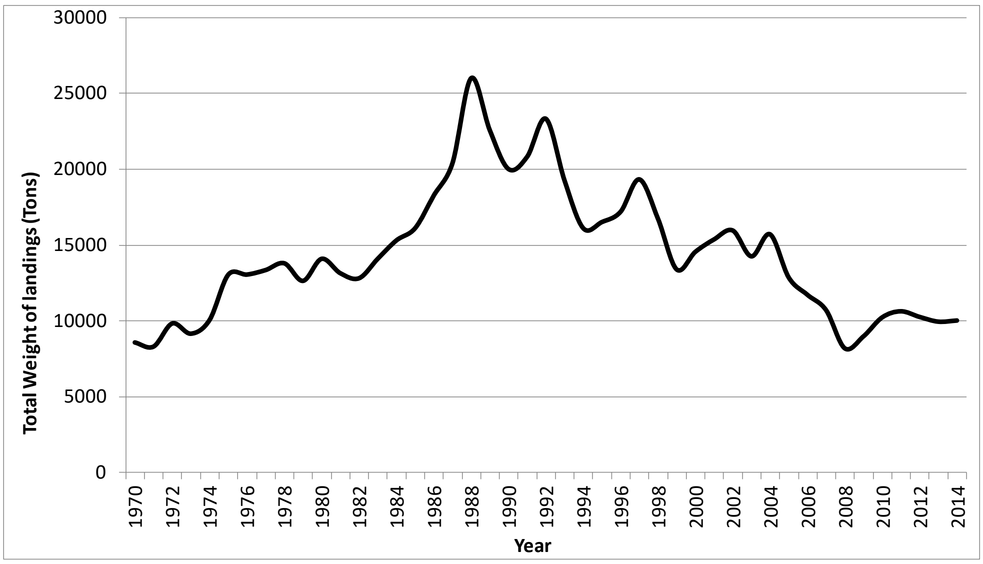

Figure 1. Total weight of landings, expressed in tons, for the species *Octopus vulgaris* in Italy from 1970 to 2014.

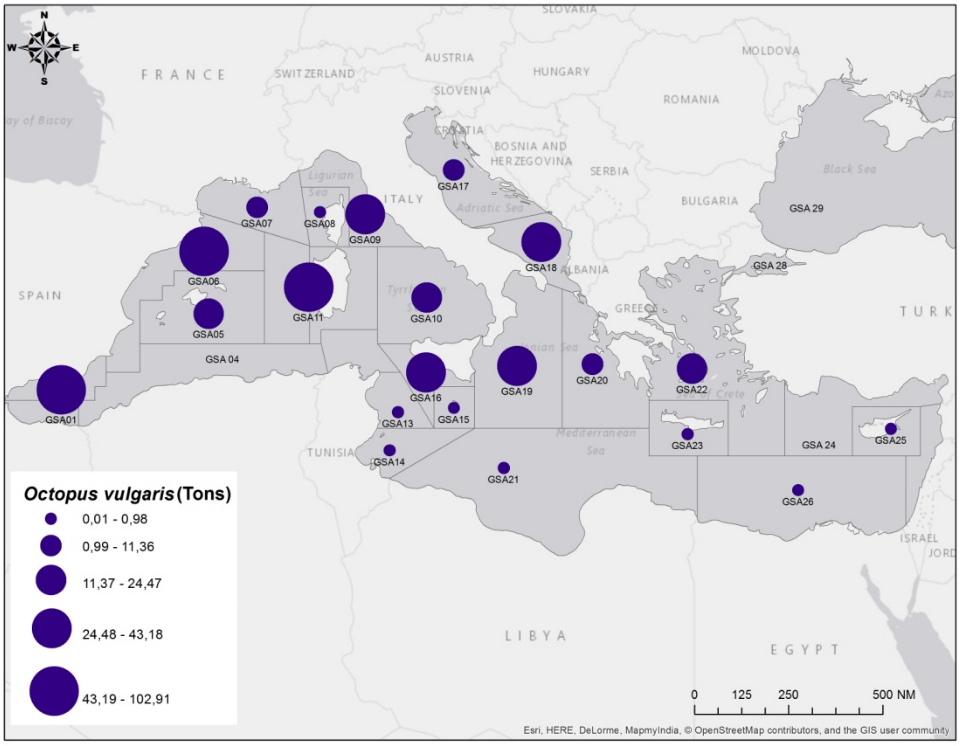

Figure 2. Mean landings (2008-2014) of *Octopus vulgaris* in the Mediterranean Sea according to Geographical SubAreas (GSA).

2.1.3 Stock Assessment

Studies on stock assessment of octopus and cephalopods, in general, are very limited (Pierce and Guerra, 1994), mainly due to the peculiar biology of the species. A short life-span (Iglesias et al, 2004; Katsanevakis and Verriopoulos, 2006) and a rapid non-asymptotic growth with high variability in weight and mantle length (Alford and Jackson, 1993) make this species vulnerable to overfishing (Pierce and Guerra, 1994). Only one stock assessment study was made for Spanish octopus population in the Balearic Islands (GSA5). The study showed a pattern of overexploitation from 1977 to 2014 with an average F of about 1.5 times the reference limit (Figure 3).

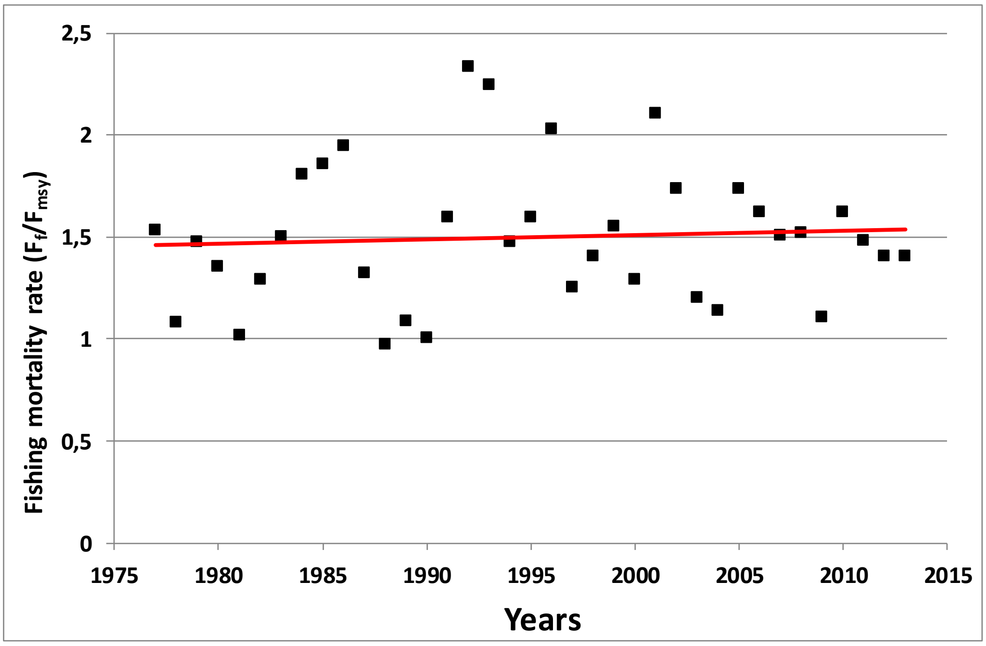

Figure 3. Overexploitation index (Ration between fishing mortality rates and fishing mortality at MSY(Ff/Fmsy), from 1976 to 2014 in GSA 5 (Balearic Islands). Values above 1.0 shows unsustainable exploitation; the red line represent linear trend in data.

2.1.4 Local Ecological Knowledge

Local Ecological Knowledge associate to the common octopus fishery was analyzed in three different sites, i.e. Komiža in Split-Dalmatia (Croatia), Patti in Sicily (Italy) and Palamós in Cataluña (Spain), along with a gradient of increasing economic value of this species for local communities and fishermen. Interviews revealed that *O. vulgaris* isn't the target species (in terms of its share in the catches) for any of the Croatian fishermen and for the majority of Italian and Spanish respondents; however this resource becomes more important from an economic point of view due to its high commercial value and its ubiquitous exploitation (Belcari et al, 2002; Tsangridis et al, 2002; Guerra et al, 2014). In the three areas, fishermen confirmed the depletion trend of the resource, both in terms of reduction in the maximum daily catch and maximum individual size. In particular, such effect seemed to be more pronounced in Patti and Palemos as compared to Komiža (Figure 4 and Figure 5).

From the point of the resource management view, the general perception is that there is good cooperation between fishermen and the various policy makers; in any case, there is a request for an increase in controls against illegal recreational and sport fishing, opinion of it as a real threat to the fishing activity is put forward. Greater collaboration with the research community was also requested, in order to create a fishermen's education path which, thanks to a better knowledge of the species, will be able to implement sustainable fishing plans.

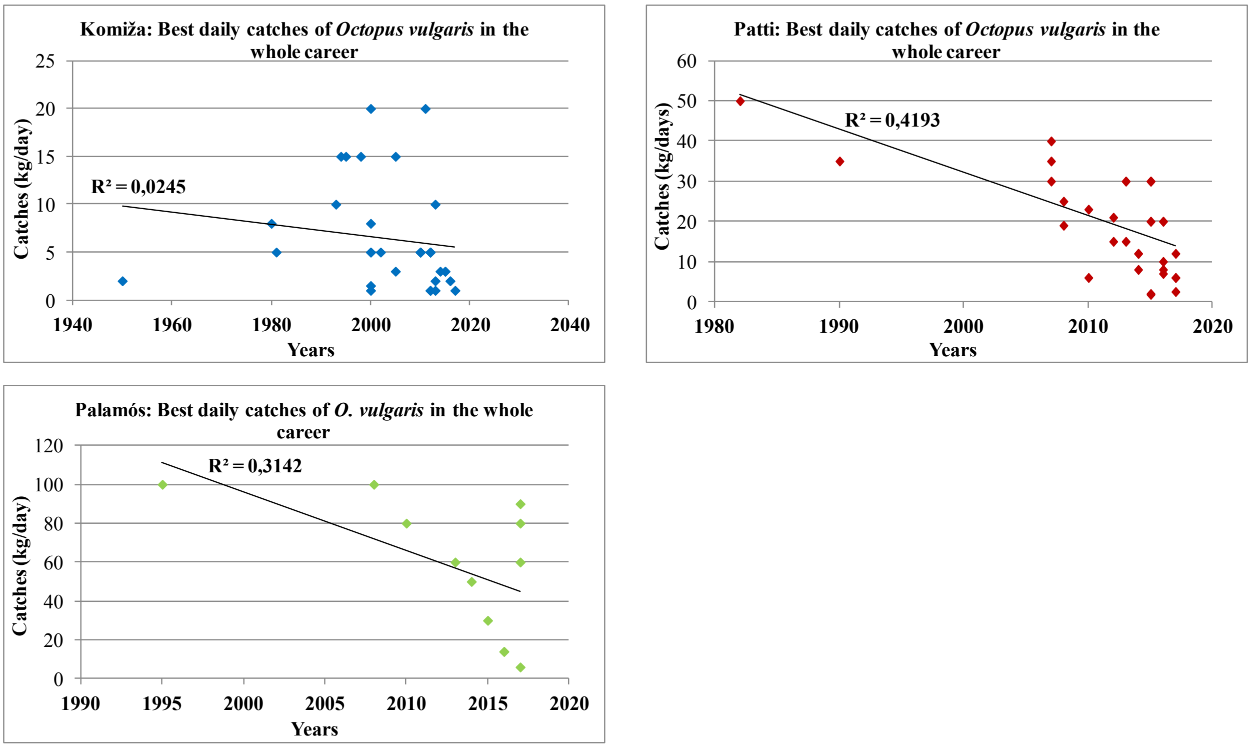

Figure 4. Best daily catch of *Octopus vulgaris* (kg/day) as reported by interviewed fishermen in the three study sites: Croatia, Italy and Spain. Linear trend per study site and R^2 values are superimposed.

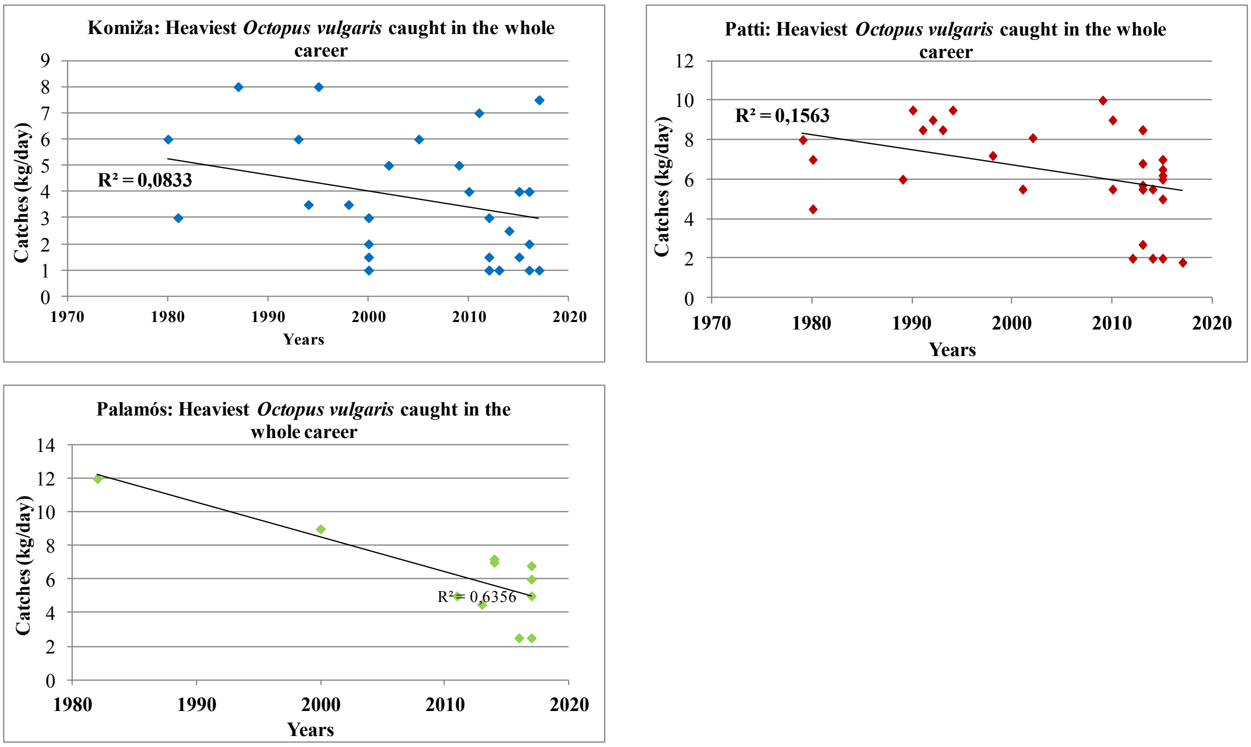

Figure 5. Heaviest *Octopus vulgaris* (kg/day) as reported by interviewed fishermen in the three study sites: Croatia, Italy and Spain. Linear trend per study site and R2 values are superimposed.

2.1.5 Consistency in the evaluation of stock status

Overall, a general consistency between local perception of fishermen in the three different sites where LEK was acquired, GSA stock assessments and general trends (i.e. Mediterranean) in landings was recorded. Indeed, at all spatial scales (and within the respective temporal domains), it emerges that octopus is showing a decreasing trend both based on fishermen perceptions and official data. Unfortunately, the lack of availability of data from standardized trawl surveys (e.g. MEDITs) does not allow to check at local and GSA spatial scales the consistency between the data we recorded and fishery independent data. At the same type, the biological features of *Octopus vulgaris* (in particular the short life-cycles) impedes or restrict the application of stock assessment.

2.1.6 Management implications.

Taking into account genomics, LEK and fisheries data three major messages emerges for *Octopus vulgaris* management:

-*spatial scale:* populations more isolates (as in the case of Adriatic Sea) would deserve special attention for the management. The spatial approach adopted in the Mediterranean Sea (with the GSA) is consistent with this scale (especially when analysis at Adriatic sub basin –joint GSA17 and GSA18 – are given). Additionally, differentiation among stocks within the Western Mediterranean Sea (WMS) seems less strong, so that larger spatial scale consistent with the WMS could be applied;

-*temporal scale:* multi-decadal time series and LEK agree in showing a declining trend for the species at different spatial scale. Fisheries independent data (e.g. those from trawl survey) should be used to assess local to regional pattern to identify hotspot of criticalities and their temporal trends, including potential recovery patterns;

-*management framework:* given the relatively high connectivity within WMS and the low connectivity/higher specificity of the Adriatic Sea populations, management approach could be relatively different in the two areas, being the first somehow less strict and the latter more strict and adaptive. In particular signs of severe decline at local scale (e.g. due to failure in recruitment) should be immediately detected and trigger adaptive fishing, i.e. reducing fishing pressure (and, for instance, releasing species) to sustain reproduction. At the same time the presence of IUUF and other sources of competition (even recreational) at the very local level is a management issue that should be solved, possibly with local co-management tools (see report 3.1.1).

2.2 *Aristeus antennatus:* population connectivity and stock boundaries, status and trends

2.2.1 Genomics

Studies on genomics of the species *Aristeus antennatus* have proved that high levels of genomic differentiation were found for the populations from Eastern Balearic Islands and South of Spain. Interestingly, those populations are genetically similar to those of the Italian coast, while the shrimp populations along Spanish coast are genetically distinct from one another, despite their apparent geographic proximity.

There are indeed correlations between patterns of genomic differentiation and differences in environmental factors such as temperature, salinity and dissolved oxygen among sites. The blue and red shrimp population of the Balearic Islands appear to be locally adapted to those specific environments.

Yet, populations that are genetically isolated and well adapted to their specific environment tend to be less diverse as, for example, the shrimp populations from Eastern Balearic and South of Spain, that also exhibit higher population differentiation.

These populations should be taken special care of as they exhibit limited connectivity, high local adaptation, and, under fast shifting environmental scenarios, lower evolutionary potential. In theory, those populations would not easily recover and are particularly endangered from changes in external stressors. This also means that in the case of population collapse it would be harder for migrants from other populations to replace them, as they are not specifically adapted to those environments.

2.2.2 Fishery biology

Aristeus antennatus is a commercial species with a high economic value, so it is studied in great detail (Maynou et al, 2006), as it represents one of the most valuable invertebrate species of the Mediterranean trawl fisheries (Ragonese and Bianchini, 1996). The fishery of *A. antennatus* is highly specific and carried out only by demersal trawlers.FAO data, recorded from 1970 to present days, show an increasing with a peak in 1987, followed by a collapse and a recovery till 2008, and a following decreasing trend (Figure 6).

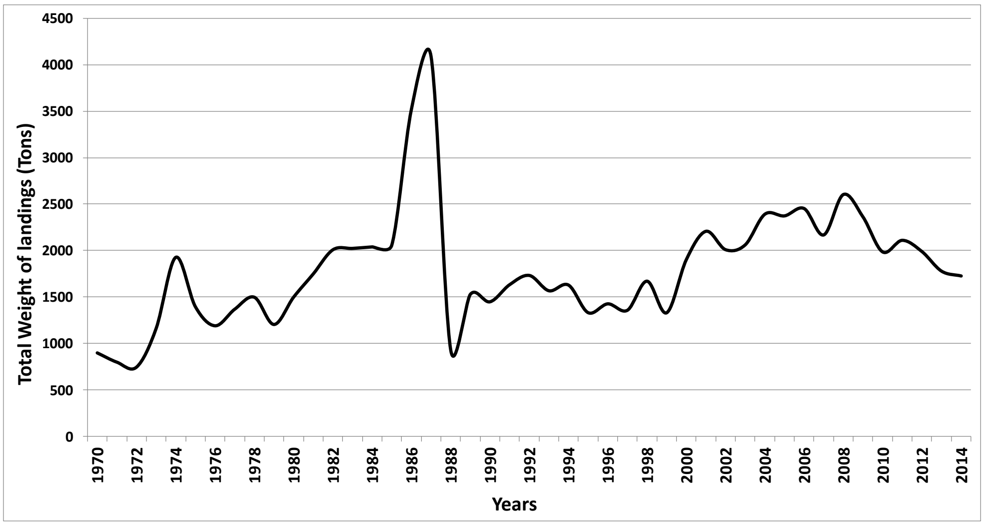

Figure 6. Total weight of landings, expressed in tons, for the species *Aristeus antennatus* in the whole Mediterranean Sea from 1970 to 2014.

The blue and red shrimp fishing areas are found mainly in the western part of the Mediterranean Sea, with the exception of the northern Adriatic Sea (Cau et al, 2002; Colloca et al, 1998; Fiorentino et al, 1998; Garcìa-Rodriguez and Esteban, 1999; Papacostantinou and Kapiris, 2001; Ragonese and Bianchini, 1996) (Fig. 6). Low landings are recorded in the Eastern Mediterranean (Cau et al, 2002; Tursi et al, 1993; D'onghia et al, 1998) while in the Ionian Sea, i.e. GSA19, the highest landings of the whole Mediterranean are recorded (Cau et al, 2002; Carlucci et al, 2003) (Figure 7).

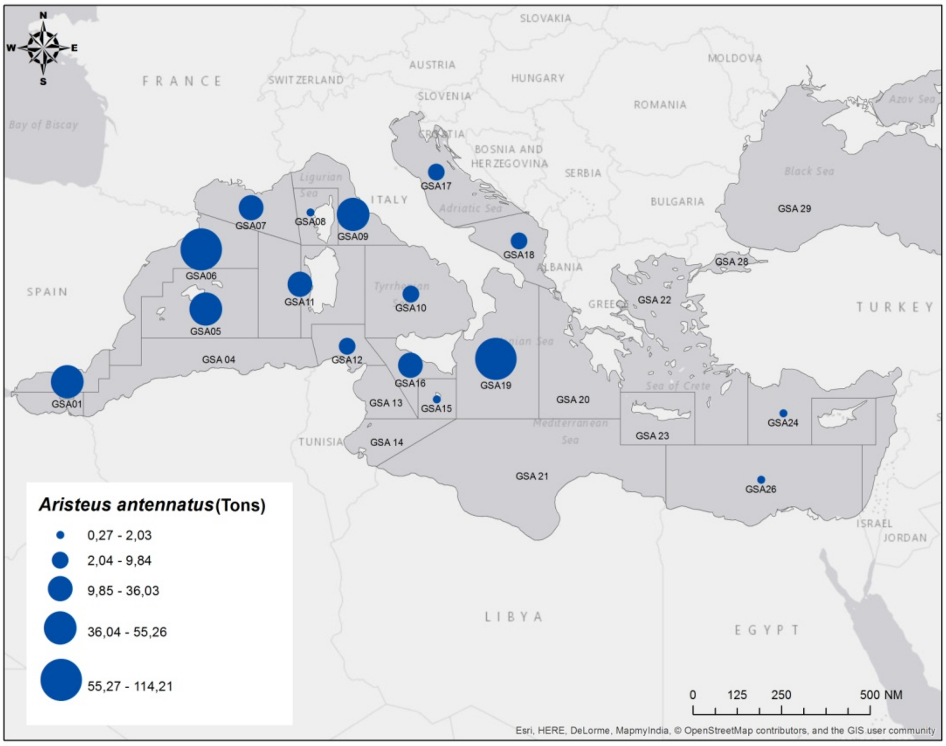

Figure 7. Mean landings of *Aristeus antennatus* divided by Geographical SubAreas (GSA) on the Mediterranean Sea.

Since shrimp fishing is so important from an economic point of view for fishing communities, a first management plan in association with local the fishermen have been promoted and established in Spain (Gorelli, 2014).

2.2.3 Stock Assessment.

Stock assessment studies show that there has been a condition of severe over exploitation of the blue and red shrimp stocks, especially (but not exclusively) in the Spanish GSAs, as it was already proposed in previous studies (Cau et al, 2002; D'Onghia et al, 2005; Fiorentino et al, 1998; Ragonese and Bianchini, 1996). Indeed, the ratio between fishing mortality a(F_f) and the fishing mortality calculated for the maximum sustainable yield (F_{msy}) were always greater than 1 both in Spain and in Italy, although in the very last years in GSA 5 and 9 values close to 1 were observed (Figure 8).

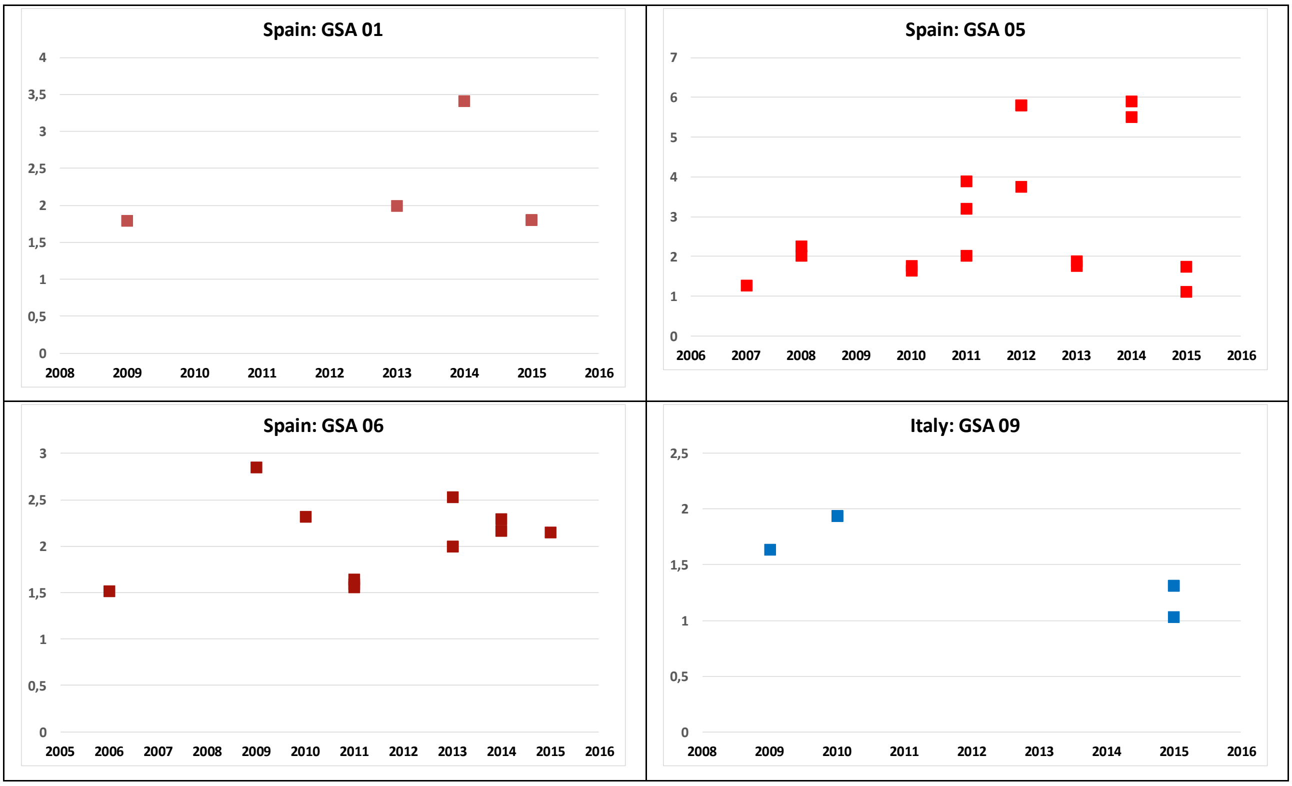

Figure 8. Ratio between fishing mortality rates of *Aristeus antennatus* (F_f) and the fishing mortality at the maximum sustainable yield (F_{msy}) for Spain (GSA 01, GSA 05 and GSA 06) and Italy (GSA 09).

2.2.4 Local Ecological Knowledge

Most of the interviews documenting LEK on *Aristaeus antennatus* were carried out in Spain, in the fishing communities of Palamós (Spain) where the species is very relevant (n=20), while only 2 were carried out in Patti (Italy), where two-three fishing vessels exploiting this species are currently active. In addition, in the northern and central Adriatic Sea the species is not present (Colloca et al, 1998; Papacostantinou and Kapiris, 2001). The fishing activity is very specific considering that it is always carried out by deep water demersal otter-trawlers. Moreover, *A. antennatus* was the only target species for the majority of respondents interviewed within CONFISH.

In Spain fishermen showed the perception that the stock is slowly recovering, with an improvement in catches rates in the last few years. Indeed, since 2013, in the Palamós area a management plan on blue and red shrimp fishery has been put into force, promoting responsible and sustainable fishing (Gorelli et al, 2014). On the opposite, the perception of the Italian respondents was that the resource has decreased over time.

When considering best daily catches in the whole career as reported by fishermen, a long term declining trend can be observed (Figure 9). When the last 5 years of activities are concerned, this pattern seems to be slightly better: in particular, most of fishermen reported that they best catches in this period were taken in the very last years, thus implying an improvement in the trajectory of landings as perceived by fishermen over time. (Figure 10).

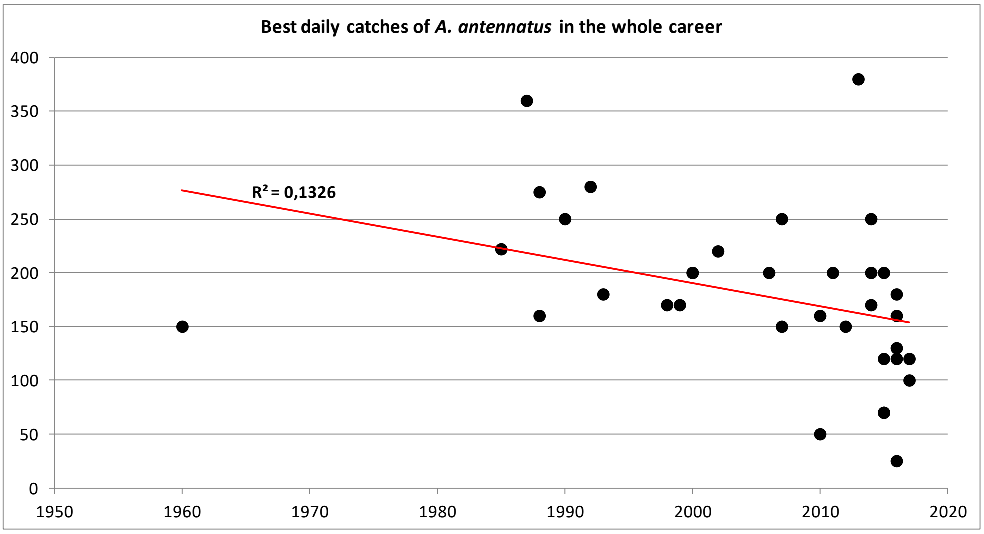

Figure 9. Best daily catch of *Aristeus antennatus* (kg/day) as reported by interviewed fishermen in Palamós. Linear trend per study site and R^2 values are superimposed.

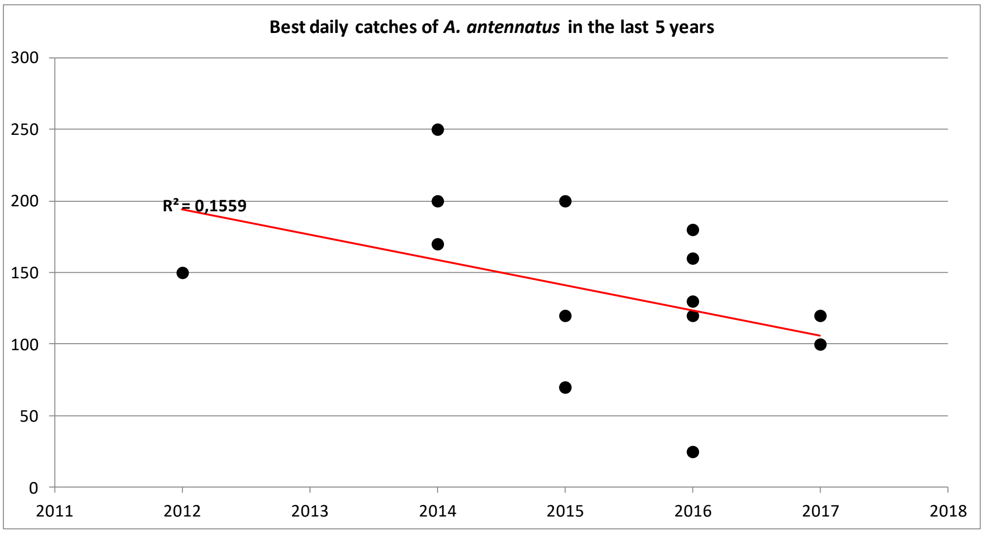

Figure 10. Best daily catch of *Aristeus antennatus* (kg/day) as reported by interviewed fishermen for the last five years in Palamós. Linear trend per study site and R^2 values are superimposed.

The regulation of *A. antennatus* fishing activities is diversified in the two sites. In Palamós, thanks to the fishery management plans that started in 2013, there is the allocation of a limited number of fishing licenses for shrimp industrial fishery (Gorelli et al, 2014). Here, thus, exists a fruitful collaboration between fishermen, policy makers and researchers, and this is also reflected in the opinion of the respondents in Palamós that affirm that the regulation on fishery are well conceived and respected by all fishermen.

In Patti, on the other hand, there is a ban on industrial fishing throughout the area inside the Gulf of Patti, once heavily exploited by trawlers; however, this prohibition has been imposed on fishermen by political decision-makers, or at least this is the idea that emerged from the interviews.

2.2.5 Consistency in the evaluation of stock status

The lack of spatial replication in the collection of LEK prevents an overall comparison of the consistency between fishermen perceptions, fisheries data and genomics data. However, at the vey local scale, i.e. an “internal” consistency in the perception of long term declines and recent recovery were observed from the interviews to Spanish fishermen. However, the general improvement of catches (and more sustainable exploitation) they mention is not consistent with trends in fishing mortality rates (and exploitation index) observed in GSA06 (that comprises Palamós area, but is much larger). At the same time, genomic results showing the low connectivity among Spanish population tell us that the GSA scale could be too wide to manage (but also assess) this resource. Again, the availability of abundance and biomass index from fishery independent data (along with spatial distribution of fishing effort), along with intensification in genetic studies, could allow better defining population geographic limits and stock boundaries.

2.2.6 Management implications.

Taking into account genomics, LEK and fisheries data three major messages emerges for *Aristaeus antennatus* are the following:

-*spatial scale:* spatial proximity is not the best proxy to determine differentiation among populations. Accordingly, the genomic structure of this species must be further investigated to better understand stock limits, at least in the case of Spanish Mediterranean. Current spatial scale (GSAs bases) seems to be inappropriate, encompassing several stocks.

-*temporal scale:* while multi-decadal time series and LEK seems to show a relative stability (or light recovery after degradation, at least in some areas) it would be necessary to expand the analyses (and consider trends within homogeneous areas, i.e. those that encompass the same stock) to confirm the actual trend at population level. This holds true also in relation to stock assessment.

-*management framework:* current approach based on fishing effort (and mortality) limitation at GSA level could be inappropriate if compared to real stock boundaries. Accordingly, it is necessary to revise the current assumption and act at multiple levels. In this light, positive experiences at very small spatial scale (e.g. Palamós fisheries and its canyon) shows that positive outcomes can be achieved in the context of co-management experiences when Territorial User Rights for Fishing (TURFs) are established, through management plans (see report 3.1.1). Since these experiences were really positive the main recommendation would be to ensure such approach to be adopted in other areas, with a sort of nested approach that considers the spatial boundaries of stocks.

3. Discussion and Conclusions

In this study we compared the main findings from the application of genomics and local ecological knowledge to those derived from official fisheries data (e.g. landings) and stock assessments. Our aim was to assess coherence in the species status along multiple spatial and temporal scales, as well as to show how each single approach can provide important elements that are needed to establish a successful management framework. To this purpose, we worked on two demersal species characterized by different biological feature, i.e. *Octoptus vulgaris* and *Aristaeus antennatus*.

However, when making such comparison, and interpreting results, it is necessary to recall the features of data we were able to gather according to different approaches, in particular in terms of temporal and spatial scales (Figure 11). Indeed, genomic data can allow assessing stocks/populations boundaries and connectivity (and somehow populations' vulnerability to environmental changes and, potentially, anthropogenic pressure) over the last 5-10ys, but they may also allow some qualitative predictions for the future to be made. The spatial scale may range from the very local to the regional scale (i.e. Mediterranean) according to sampling intensity and species' features. On the opposite, Local Ecological Knowledge can provide information dating back to the last 3-4 decades, but at a very low spatial scale, unless an ad hoc (potentially very demanding) approach at high spatial scale is applied. Fishery dependent and fishery independent data can cover both relatively long time series, but recent data are more accurate and are acquired with better statistical approaches. Their spatial resolution can be high (locally very valid data) but this depends on the statistical approach, the raising factors applied, etc. Indeed, in some cases, local statistics are not available, while data at GSA or regional level could be. In addition, experimental data could be available at both local and regional spatial scale (several sampling stations per GSA are sampled, for instance, by the MEDITs trawl survey). Usually, in this context, the main constrain could be the availability of original data whose access could be restricted. Finally, stock assessment represent an integration of several fishery dependent and fishery independent data sources, and allow gathering at GSA (or multiple GSAs) a quantitative assessment of stocks status. They also allow some predictions to be made in relation to the future prospects of stocks according to different simulations (Figure 11).

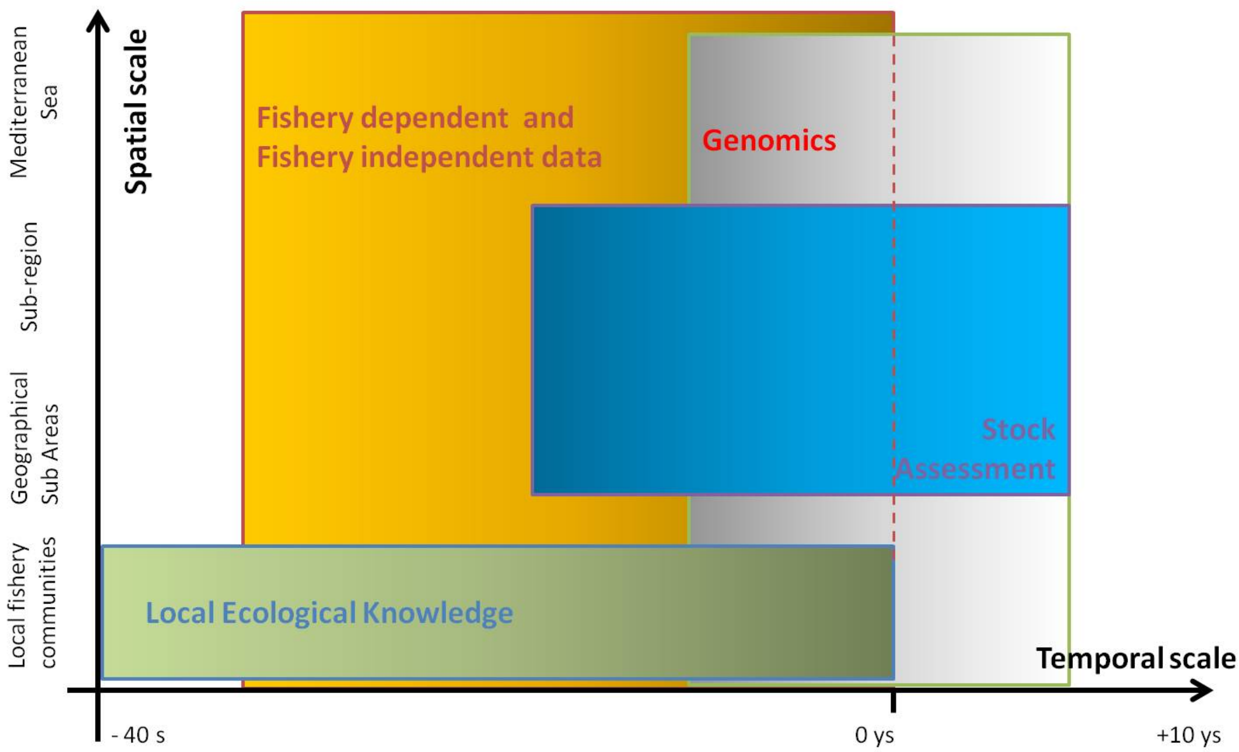

Figure 11. Conceptual scheme representing potential temporal and spatial scales coverage of data gathered from Local Ecological Knowledge, Fishery dependents and fishery independent sources, Stock Assessment and Genomics.

Overall, we found a good consistency among the trend in landings, the exploitation ratio from stock assessments and the local perception from fishermen both in the case of Octopus and red and blue shrimp. However, what emerges is that such alignment is not always present. Indeed, in the case *A. antennatus* the

stock assessment at GSA06 level shows an overexploited status while local fishermen consider the stock under recovery. This is a typical situation where the mismatch in spatial scale (LEK very local as compared to stock assessment) could be a good reason to justify this outcome. In addition, we must remark that, potentially, the two conditions are not mutually exclusive and, also, a recovering stock can still be overexploited (i.e. the biomass/abundance is increasing, but still F is above Fmsy).
Further to this, our analyses show that the availability of fishery independent data (data from trawl survey) would be very important to a deeper interpretation of signals from LEK (and landings).

This condition becomes relevant if we take into account the main insights that we derived from genomic, i.e. the evidences that GSAs are, in some Mediterranean sub-region and for certain species, inappropriate as stock boundaries. Indeed, for *A. antennatus* we learnt that populations are highly differentiated in the south of Spain (i.e. within the same GSAs several populations are present). On the opposite, for Octopus, it seems that in the WMS a lower differentiation is present. Notably some stocks in some areas could be potentially very vulnerable to environmental changes, as in the case of *O. vulgaris* in the Adriatic Sea, thus deserving this stock special attention and adaptive management in case of evidences of collapse.

Accordingly, a major outcome is that it would be necessary to rethink (reanalyze) stocks boundaries and assess the implication of new geographical limits in their assessment, both in terms of the outcomes of stock assessment (is something changing in their status?) but also in term of the definition of management strategies (approaches and goals, including identification of those stocks that deserves special attention due to their vulnerability). What also emerges is the value of considering the fishing community as a starting point to define management practices and goals. In this case it is not only the value of LEK that we wish to highlight, but rather the opportunity that arises from engaging fishing community into management (especially co-management) practices (see the outcomes, reflections and highlights of Wp2 communication). However, and again, the spatial and temporal scale (in this case of the human dimension of management) emerges: if the community level is the right spatial scale, how to engage several communities exploiting the same stock? How to ensure management is carried out within a timeframe that allows success to be achieved (and keep momentum)? Part of the answers to these questions lays in the overall assumption of CONFISH, i.e. that the connectivity within species can explain connectivity in fishing communities.
What emerges from our analyses is that such connectivity has not the same meaning as spatial proximity, and that the vehicle for further connecting fishing communities and fisheries resources would be fisheries management. This would entail addressing the issue of spatial scale, temporal scale, integrating different natural science and humanities approaches, building on CONFISH overall outcomes. And building on the complementarity that each approach we considered (genomic, fish biology, stock assessment, LEK) has.

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