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Marine protected areas: network(s) for enhancement of sustainable fisheries in EU Mediterranean waters

SafeNet: Sustainable Fisheries in EU Mediterranean waters through network of MPAs

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Contents

Preamble

This synthetic report is intended to summarize and give an overall view of SafeNet's results. Contents have been structured in order to provide brief, clear and actionable findings.

For in-depth description of the methodologies adopted (e.g. data collection, development of models) and for further details about the results the reader is referred to the specific deliverables of the project.

1. Ten talking-points from SafeNet:

Following the structure of the report, talking points have been grouped based on the scenario(s) tested and the question specifically investigated.

"Synergistic effect of MPAs"

1. Compared to very large Fully Protected Areas (FPAs), FPA networks can deliver comparable conservation benefits but much larger fisheries benefits. Fisheries benefits are partly driven by larval connectivity and arise after an average time of 10 years. Systems of MPAs not connected through larval dispersal do not show significant fisheries benefits at the scale of the entire system. Displacement of fishing effort following the creation of a network can mask the detection of fisheries benefits. Fishing effort (in-between FPAs and outside networks) should be monitored and regulated for network effect assessment.

"Increasing the extent of fully protected areas through different strategies"

2. Existing MPAs and spatial protection measures have only modest effects on species biomass and ecosystem indicators at the scale of the entire North- western Mediterranean. Extending full protection to the whole Natura 2000 network as well as increasing the size of no-take zones within MPAs would allow increases in biomass of the 3 coastal species investigated (*Diplodus sargus*, *D. vulgaris*, *Epinephelus marginatus*), with the dusky grouper *E. marginatus* benefiting the most (between 80 and 150% increase in biomass after ca 20 years compared to present values). Catches of the three species would always decrease if Natura 2000 sites are fully protected (i.e. no-take zones), while they would slightly increase if the surface of no-take zones is increased up to a coverage of 10% of the MPA s' surface.
3. At the regional scale, fully protecting EBSAs (Ecologically and Biologically Significant Areas), Consensus areas and PACs (Priority areas for conservation of the Mediterranean Sea) would deliver large protection benefits to several species and show clear benefits in terms of ecological indicators. The full closure of PACs was identified as the most beneficial. This scenario also yields the most positive impacts to several GSAs and had positive impacts on southern and northern areas of the Western Mediterranean Sea. Fisheries-related indicators however would decrease under these scenarios.

"Spatial fisheries closures and effort regulation for European hake spawning and nursery grounds in GSA9 and GSA10"

4. Local closures (at a scale of ca. 200 km^2) in GSA9 while keeping overall effort unchanged may contribute to the achievement of GES by improving the status of

the hake stock, without significantly affecting the productivity of its fishery compared to present landings. The closure of areas comprised between the Tuscan Archipelago and the southernmost portion of the Ligurian Sea would guarantee the largest benefits, namely an increase up to 5-10% in fisheries productivity after approximately 15 years compared to what will happen in the future if fisheries effort and protection remain the same as they are today (status-quo scenario).

5. Hake landings would be maximized by banning otter bottom trawls while doubling (with respect to present) the effort of gillnetters; this measure would decrease the overall fishing effort by ca. 57% with respect to present and would determine an increase in both landings and spawning stock biomass with respect to the status-quo scenario. Projections until 2030 showed that in a multi fleet fishery such as otter bottom trawl and gillnet fisheries for hake in GSA9 and 10, strategies following improvement of exploitation patterns through the protection of the sensitive stages of the population, reducing the fishing effort in specific months and in specific areas for different fleets (January-April and September-October depending on the fleet segment), after a first 2-3 years reduction in landings, would have a positive impact on the stock status and on the reduction of the discard, with a less severe impact on the revenues, across fleets. Stock status, landings and revenues would always deteriorate in the future if present fisheries management is maintained.

Scenario: "Trawling ban for European hake"

6. In GSA 9 a closure of the fishery to trawlers in the bathymetric range 0-100 m would improve the status of the hake stock, while at the same time benefitting also the productivity of the fishery with respect to the status-quo scenario (+72% spawning stock biomass, +32% landings), but only if the fishing effort is not reallocated. At the Western Mediterranean level, a 3-month trawling ban would not have a remarkable positive impact on hake stock nor have a noticeable positive impact on ecological indicators. Year-round trawling bans to 100 m and to 150 m would deliver larger, but moderate overall, benefits in terms of both hake stock status and ecological indicators (commercial biomass and predatory biomass).

"Fishing at MSY and spatial fisheries closures in the Western Mediterranean"

7. The stocks of three key coastal species (*Diplodus sargus*, *D. vulgaris*, *Epinephelus marginatus*) in the north-western Mediterranean are presently overfished. Model predictions suggest that stock and catches can be rebuilt if fishing mortality is reduced to FMSY levels. Stock biomass would start increasing immediately and reach BMSY after a transient of ca. 20 years. Catches would first decrease, especially in the first year, and then attain levels at least equal to current ones within 10 to 15 years. From an ecosystem perspective, fishing at FMSY levels in the north-western Mediterranean would deliver substantial benefits for ecological indicators and indicators related to the quality of the catch (average size, weight and trophic level

of the catch), despite the predicted decreases in catch quantity, in comparison with maintaining fishing pressure at current levels.

8. The protection of hake nurseries and protection of nurseries and spawning areas deliver measurable benefits in terms of ecological indicators (commercial and predatory biomass, biodiversity index, mean length of the fish community), while catch-related indicators are predicted to decrease (mean length and trophic level of the catch decline). Protecting only hake spawning areas delivers less benefits in terms of ecological indicators than protecting hake nurseries areas or hake nurseries and spawning areas, likely due to the fact that spawning areas were detectable and localized only in some GSAs.

Recreational and small-scale fisheries impact on vulnerable species

9. Despite recreational and small-scale fisheries in the western Mediterranean are often considered “low impact fisheries” compared to larger-scale fishing methods (e.g. trawling and purse seining), they may still pose a threat to vulnerable species (such as large pelagics, groupers and eels, sharks, cetaceans and sea turtles etc.), whether they are targeted or unintentionally taken as bycatch, and both in coastal and offshore waters. There is a need to develop management measures reducing the fishing pressure on certain vulnerable species (e.g. by regulating fishing gears and baits) or, in some cases, prohibiting their capture (at least in specific areas, and/or in particular seasons of the year). Minimum landing sizes should be implemented for all vulnerable species, whereas maximum landing sizes should be also implemented for sex-changing species in order to preserve their reproductive potential. Effective enforcement and greater public awareness should be promoted, which can lead to support for legislation and action at the consumer end of the supply chain by empowering customers to make better seafood choices (e.g. avoiding the consumption or the catch of vulnerable species).

Stakeholder perceptions

10. The majority of the interviewed stakeholders (professional and recreational fishers, authorities, NGOs and MPA managers) considers that the current state of fisheries in the study region is bad and has worsened in the last 10 years. Responses about the main threats to fisheries showed a clash of views between professional fishers and the other stakeholders: while the first group claims that pollution and illegal fishing are the main threats to fisheries, the remaining stakeholders identify it with excessive fishing effort. Most stakeholders, including professional fishers, agree on the fact that MPAs provide clear ecological benefits; however, they do not believe MPAs reduce illegal fishing nor conflicts among marine users. The majority of stakeholders calls for a higher inclusion in participatory decision-making processes related to fisheries management (i.e. co-management).

2. ABSTRACT

The general objective of the project was to identify coherent network(s) of Marine Protected Areas (MPAs, with this term intended *sensu lato*) and other area-based fisheries management tools (e.g. temporary closures) whose emergent properties (namely the interactive effect of scaling-up MPAs) can help achieve fisheries maximum sustainable yield (MSY) and maximize over the long-term the socio-economic benefits for the stakeholders (e.g. fishers) in the north-western Mediterranean Sea.

To do so we combined existing information with new field data collected in a relevant number of selected case study areas (e.g. MPAs, Nat2000 zones) in order to perform both ecosystem-based and bio-economic modelling of a representative number of fisheries in the Mediterranean sector we have investigated.

1 INTRODUCTION

Worldwide, coastal marine ecosystems are subjected to a multitude of threats, with intense fishing considered as a major one, potentially causing both ecological and socio-economic consequences (SOFIA, 2018). Fishing pressure in many oceans and seas exceeds sustainable levels and coastal marine fisheries are under ever-increasing risk of collapse (SOFIA, 2018). The Mediterranean Sea makes no exception to this global trend, with about 78% of fish stocks currently fished at unsustainable levels (SMBSF, 2018) and facing a wide spectrum of additional threats (e.g. pollution, intense marine traffic, invasive species and climate-change related impacts). There is therefore an urgent need for conservation strategies and management measures to minimize human impacts and restore marine ecosystems and the good and services they provide.

Marine protected areas (MPAs) emerged as an effective tool for the protection and restoration of marine ecosystem health from multiple stressors (Claudet, 2011). MPAs are places in the sea designed to protect marine species and ecosystems, while sometimes allowing for sustainable uses of marine resources within their boundaries.

Extensive literature produced in the last decades highlighted the ability of MPAs to produce a wide array of benefits both within and outside their borders (Gaines et al. 2010, Edgar et al. 2014, Di Lorenzo et al. 2016).

Also in the light of these evidences, a global call for increasing the extent of marine and coastal areas under protection was launched in 2011 (Aichi Biodiversity Target 11 in the Convention on Biological Diversity, CBD) aiming, by 2020, to "at least *10 percent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape*".

Mediterranean countries have legal obligations to protect the marine environment and to designate MPAs through or supported by various agreements, policies, directives and laws. Key international instruments include the above mentioned CBD Aichi target, and the United Nations Sustainable Development Goals (with SDG 14 calling for conservation and sustainable use of the Oceans by 2030). The Barcelona Convention, with the Specially Protected Area and Biological Diversity Protocol, applies to the Mediterranean region. Across the EU, MPAs are also called for in directives such as the Marine Strategy Framework Directive and the Habitats and Birds Directives for implementation of the Natura 2000 network of sites deserving protection at sea.

This integrated strategy places itself in the context of EU Common Fishery Policy (CFP), a set of rules for managing European fishing fleets and conserving fish stocks within an ecosystem-based perspective, aiming at ensuring that Mediterranean fisheries are environmentally sustainable in the long term and are managed in a way that is consistent with the objectives of achieving economic, social and employment benefits. Specifically, CFP aims at achieving maximum sustainable yield (MSY) through multiannual ecosystem-based management plans (regulating spatial fisheries management, effort reduction etc.).

In this framework, in the Mediterranean Sea a relative large portion of sea was put under protection with the extent that almost doubled since 2012. Currently, 186 nationally designated MPAs cover approximately 1.60% (40,327 km²) of the Mediterranean Sea (MedPAN 2017). Considering all forms of spatially explicit management measures (MPAs *sensu lato*, including also internationally designated MPAs belonging to the Natura 2000 network) there are 1,231 MPAs in the Mediterranean Sea, covering about 180,000 km², i.e. about 7.14% of the Mediterranean (MedPAN 2016). These are almost exclusively coastal area with an average size of 278.06 km² and median size of 8.55 km² (MedPAN 2017), with a very large proportion of small MPAs and just few large ones.

However, only the 0.04% of the entire Mediterranean surface is protected from all forms of fishing (i.e. in 'no-take marine reserves'; PISCO & UNS 2016). In addition to this, a considerable proportion of MPAs are failing to fully deliver ecological and social benefits. Such negative/neutral results are mostly due to inappropriate design (e.g. in terms of size, zonation), ineffective enforcement and/or suboptimal management/organisation (e.g., in terms of absence of management plan, capacity shortfalls) (Guidetti et al. 2008, Claudet et al. 2008, Sala et al 2012, Di Franco et al. 2016, Gill et al. 2017; Scianna et al., 2018). Despite an increasing number of MPAs established, there are many issues still unresolved, particularly regarding their optimal size, location, number and relative placement. These issues are particularly important in the perspective of scaling-up conservation effects, through the constitution of interconnected systems of MPAs, i.e. the so-called MPA networks.

Box – MPA networks

MPA networks consist of multiple MPAs connected by dispersal of sexual and asexual propagules and/or the movement of juveniles, sub-adults or adults. Individually, each MPA can provide some conservation, economic, and social benefits. Collectively, the network can create significantly greater benefits, if it is well-designed. Strategically placed MPAs within a network, in fact, are thought to potentially deliver conservation and fishery benefits both inside the borders of the protected areas and outside, benefiting the fished areas between them but also benefiting other MPAs within the network.

In the light of these considerations, it is crucial to assess whether specific systems of MPAs can effectively deliver protection benefits beyond those provided by the single MPAs constituting them, and evaluate which are the specific conditions and the spatial scale(s) over which networks can sustain outer fished locations. In this context, the overall objective of SafeNet was to identify coherent network(s) of MPAs in the north-western Mediterranean Sea whose emergent properties (namely the interactive effect of scaling-up MPAs) can help achieve fisheries MSY and maximize over the long-term socio-economic benefits for the stakeholders.

The term 'MPA' in the SafeNet project was broadly applied to consider all types of MPAs and other spatial protection management tools.

Specifically, to achieve this objective, in SafeNet we coupled extensive data collection (combining review and compilation of existing data with field sampling) with multiple modelling approaches to:

- Quantify the added value of MPA networks compared to a system of single unconnected MPAs;
- Assess how Mediterranean ecosystems associated with networks of MPAs are structured, how they function, how they contribute to present conditions, and how they could be used as fisheries management tools to ensure sustainable long-term use of the marine ecosystem;
- Assess the effects of different spatial fisheries management scenarios on ecological and fisheries indicators (e.g. GES, MSY, catches).

In addition, we evaluated stakeholder perceptions on current and suggested (through our analyses) spatial management measures, as well as the impact of recreational and small-scale fisheries on vulnerable species.

Glossary Box:

GES - In the context of the Marine Strategy Framework Directive (MSFD), the Good Environmental Status (GES) represents a quality status of seawaters that European Union's member states have to achieve by 2020. It is defined as "The environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive".

MSY – In the context of population ecology and economics, the Maximum Sustainable Yield (or MSY) represents the maximum yield or catch that can be extracted from a population, or a stock, in the long term, without depleting it.

2 SYNERGISTIC EFFECT OF FPAS

Glossary Box:

FPA: Fully Protected Area (i.e. no-take where no extractive use is allowed)

nFPA (Networked FPAs): FPAs composing a network

nUPA (Networked UnProtected Areas): unprotected areas between nFPAs

UPA (UnProtected Areas): unprotected areas outside of the network

Connected network: Network where nFPAs and nUPAs are connected through larval dispersal

Unconnected network: Network where nFPAs and nUPAs are not connected through larval dispersal

2.1 Key facts/Recommendations

1) Compared to very large FPAs, FPA networks can deliver comparable conservation benefits but much larger fisheries benefits;
2) Fisheries benefits are partly driven by larval connectivity and arise after an average time of 10 years. Networks that are not connected through larval dispersal do not show any fisheries benefits;
3) Displacement of fishing effort following the creation of a network reduce fisheries benefits. Fishing effort (in-between FPAs and outside networks) should be monitored for network effect assessment.

2.2 Objectives

1) Assess how FPA networks can benefit fisheries;
2) Assess how fishing effort displacement due to area closures can impact the detection of the effectiveness of FPA networks;
3) Assess the potential synergistic effects of FPAs in three actual groups of FPAs (potential networks) located in the Western Mediterranean Sea: BCM (Banyuls-Cap de Creus – Medes), BP5 (Bergeggi, Portofino, Cinque Terre), and TAB (Tavolara, Asinara, Bonifacio).

2.3 What we did?

- We used a coupled physical-biological model parameterized for an ecologically and commercially important species, *Diplodus sargus*;

- We modelled the effects of a large FPA, a connected network and an unconnected network compared to no protection at all (Figure 2.1);
- We modelled increased levels of fishing effort displacement and attraction from outside networks to nUPAs;
- We assessed how these results can help inform the experimental assessment of networks;
- Data about density, size and biomass of marine organisms were collected in three potential MPA networks (BCM, BP5, TAB).
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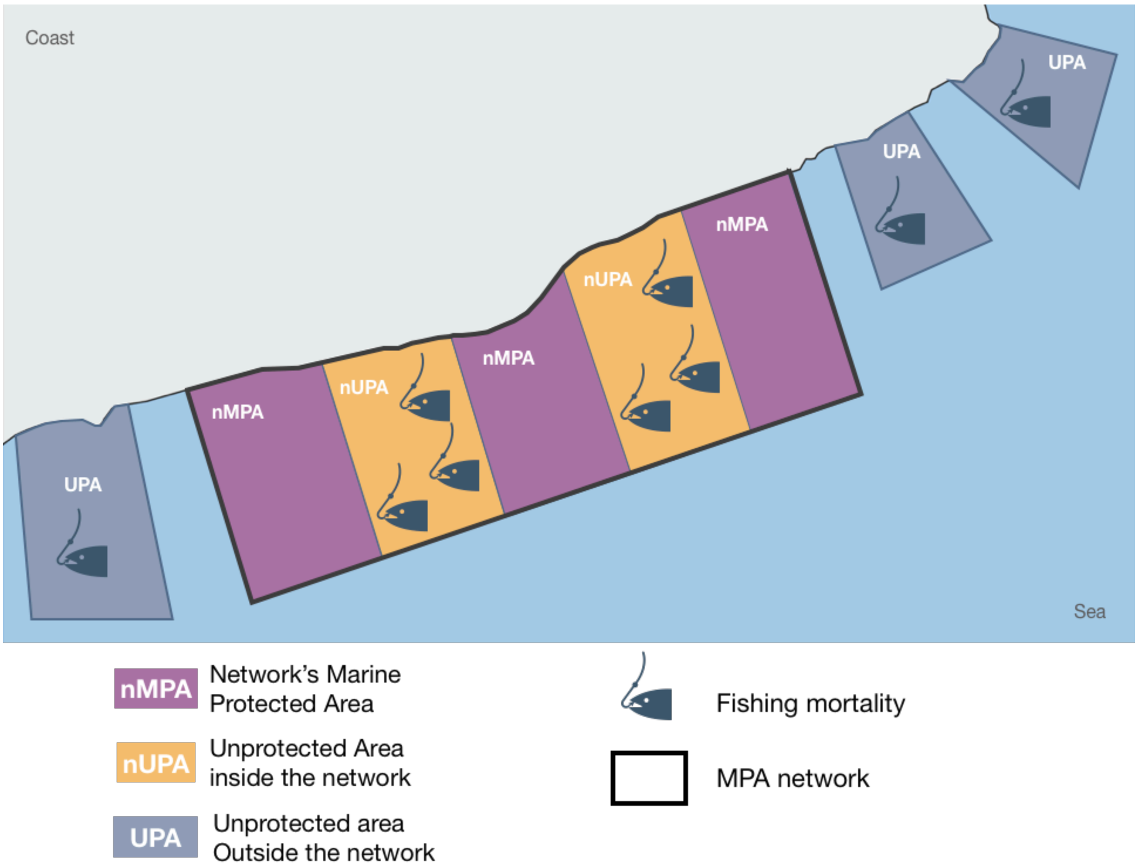

Figure 2.1: Example of MPA network showing the protected areas of the network (nMPAs), unprotected areas between nMPAs (nUPAs) and unprotected areas outside of the network (UPAs).

2.4 **Results**

Model simulations show that FPA networks can provide ecological benefits comparable to large FPAs, where fish biomass of *Diplodus sargus* can increase 4.5 fold after 11 years of protection.

In a connected network, potential fisheries benefits appear after 10 years of protection (with potential losses in fisheries catches during the first two years) whereas in an unconnected one, the biomass inside nUPAs is significantly lower compared to the same zone without protection, resulting in potential losses in fisheries catches during 15 years (Figure 2.2).

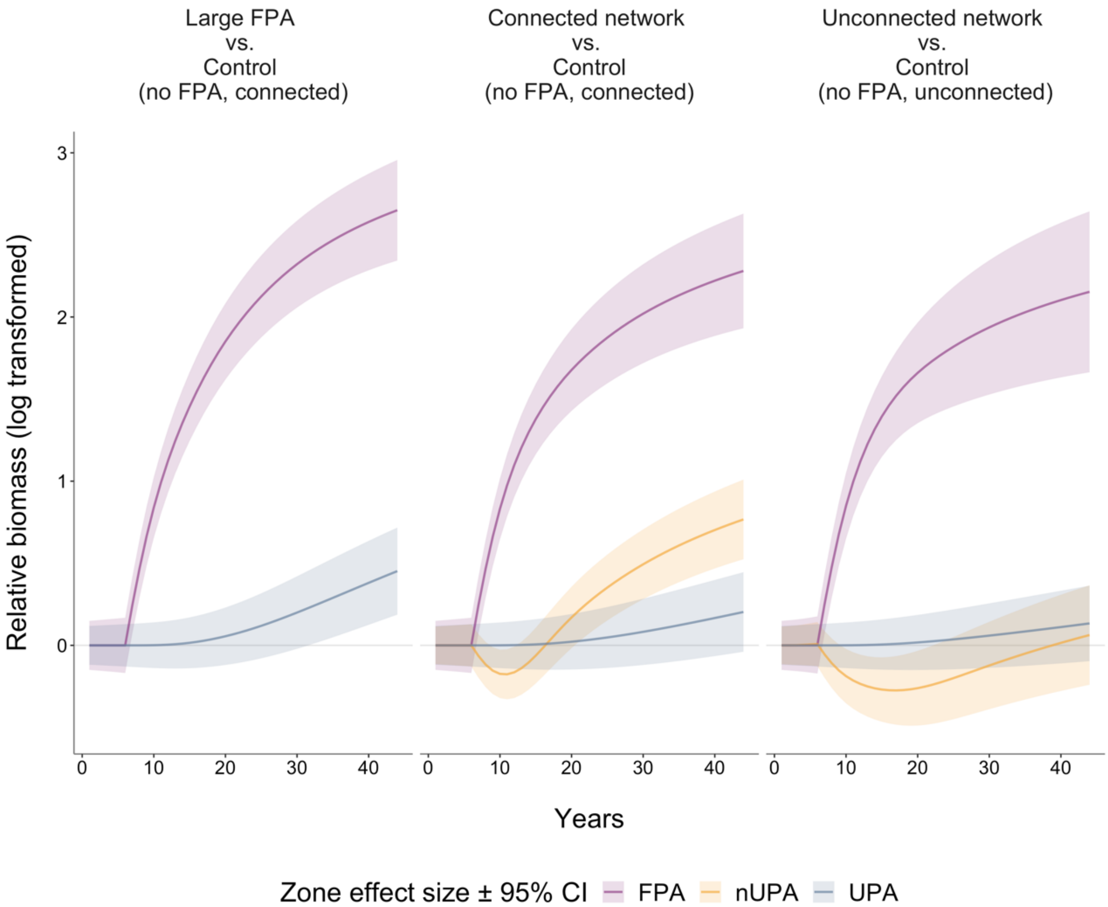

Figure 2.2: Modelled changes in the effect size (log-ratio of the biomass of two simulations) in each zone (FPA – regrouping the large FPA and nFPAs, nUPA, UPA), for each set of simulation (Large FPA vs. Control, Connected network vs. Control and Unconnected network vs. Control). The area of the large FPA is equivalent to the sum of the areas of all the nFPAs and nUPAs.

Fishing effort displacement simulations show that a too large increase in fishing pressure in the nUPAs can negatively impact the ability of the network to deliver fisheries benefits on the long term.

Network ecological effectiveness (using a meta-analytical approach as in Figure 2.3) was tested for three Mediterranean potential networks. Species of high commercial value show a six-fold increase in biomass inside nFPAs compared to UPAs for the 3 potential networks. Biomass inside nUPAs was 1.4 times that in UPAs, for the TAB network only. Biomasses of species of low commercial value did not differ between nFPAs and UPAs.

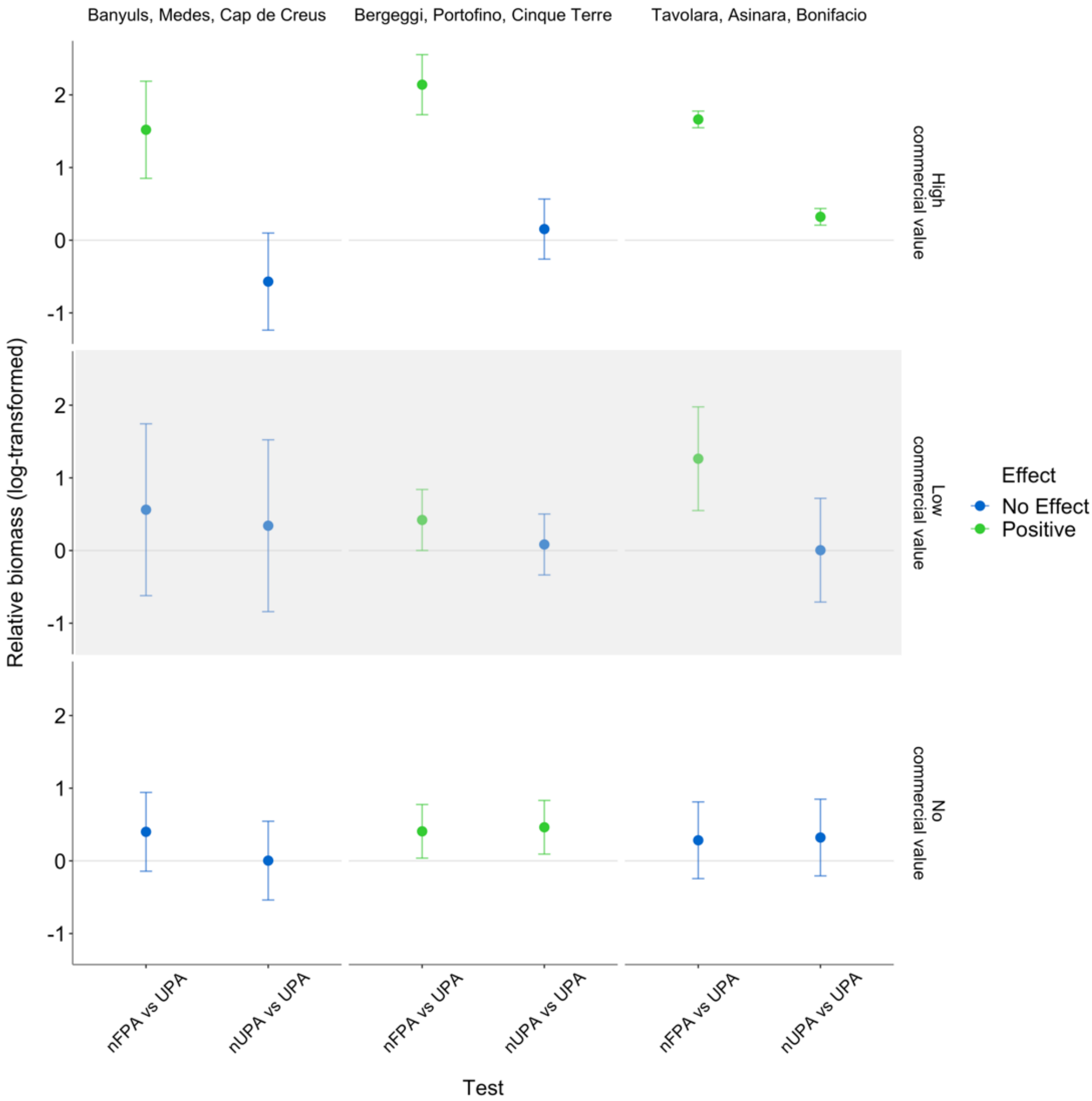

Figure 2.3: Assessments of MPA networks ecological effectiveness. Effect size (log ratio of the biomass) and confidence interval comparing two zones of each network (i.e. nFPA and nUPA) to UPAs for each class of species (High, Low or No commercial value). These calculations were done separately for each potential network.

These results confirm that it is difficult to draw conclusion about conservation and fisheries effectives of networks without data on fishing effort. The fact that biomasses do not differ between the fished areas within the network (nUPAs) and the outside of the network (UPAs) can either reflect the absence of a fisheries benefit of the network or the fact that nUPAs can sustain a larger fishing effort than UPAs, if there has been a concentration of fishing effort in those areas.

An extended description of methods and results can be found in ***D.2.9. "Report identifying and showing how different network types and configurations can help fisheries help MSY through quantification of emergence".***

3 Increasing the extent of fully protected areas through different strategies

Glossary Box:

Natura 2000 – It is a EU coordinated network of protected terrestrial and marine sites for the protection of rare and threatened species, and some rare natural habitat types. Marine Natura 2000 site – Each single EU established marine protected site forming the Natura 2000 network.

Nationally designated Marine Protected Areas (MPAs) - All types of marine protected areas (including among others: fully protected no-take marine reserves, multiple use protected areas, fishery reserves, etc.) established through national laws.

EBSAS – Under the Convention on Biological Diversity (CBD), Ecologically and Biologically Significant Marine Areas (EBSAS) are special areas of the ocean that serve to support the healthy functioning of oceans and seas and the services that they provide. They are identified and established by States and intergovernmental organizations in accordance with international laws.

Consensus areas – Areas resulting by the overlap of different conservation initiatives, as defined in Micheli et al (2013), and considered conservation priority areas as resistant to variation in the objectives and criteria guiding the different proposals.

PAC areas – Priority areas for conservation of species at risk of the Mediterranean Sea, as identified by Coll et al (2015), and representing areas of low threats and high diversity for vertebrate species at risk in the Mediterranean Sea.

Effect of current system of MPAs in the Western Mediterranean:

The effects of the currently implemented MPAs in the Western Mediterranean have been assessed for a set of species by using ecosystem models (see Deliverable 4.4 for further details). When the current protection status of the Mediterranean Sea (with all the typology of spatial protection measures implemented) was compared with a no-protection scenario (i.e. with all MPAs *sensu latu* turned off) only a modest effect on the biomasses of all selected species and ecosystem indicators was recorded: this effect was larger in white seabream, than in common two-banded seabream and groupers. The effect was smallest for European hake. This suggests that current MPAs are poorly effective for the investigated species.

3.1 Key facts/Recommendations

- Extending full protection to the whole Natura 2000 network as well as increasing the size of no-take zones within MPAs would allow increases in biomass of the 3 coastal species investigated (*E. marginatus, D.vulgaris and D. sargus*), with the dusky grouper *E. marginatus* benefiting the most.
- Catches of the three species would always decline if Natura 2000 sites are fully protected (i.e. FPAs), while they would slightly increase if the area of no-take zones is increased up to a coverage of 10% of the MPA surface.
- Catches of two-banded seabream *D. vulgaris* would be maximized (with a +4% increase compared to present) when no-take zones are set to cover around 40% of existing MPAs.
- At the local scale, to overcome the negative effect of fishing effort redistribution and concentration if MPAs were to be increased in the area, a strategy to modulate fishing effort around protected areas should be established to allow rebuilding of biomass of marine resources and the recovery of ecosystem structure and functioning beyond the MPAs.
- At the local scale, our results suggest that to rebuild marine resources in the North-western Mediterranean Sea area, more drastic measures of protection are needed in addition to turning current PPA and UPA into FPA, likely involving reducing fishing effort for the larger fisheries activities in the area (such as bottom trawling and purse seiners).
- At the regional scale, Scenario 14 (protecting EBSAs), Scenario 15 (protecting Consensus areas) and Scenario 16 (protecting PACs) delivered larger protection benefits to several species and showed clear benefits in terms of ecological indicators. Overall, these alternative protection schemes had different outcomes in terms of the spatial distribution of biomasses, diverging in those areas where protection is larger (such as in the Alboran Sea for EBSAs or the Northern African coasts for PACs).
- The most bold protection schemes (Scenario 14 to 16) yield the most beneficial results for the four selected species, and within those, the full closure of PACs was identified as the most beneficial. Full closure of PACs also yields the most positive impacts to several GSAs and had positive impacts on southern and northern areas of the Western Mediterranean Sea.
- Overall, our results show that accounting for local food-web dynamics within MPAs is especially important to predict protection outcomes at the ecosystem level, too.

3.2 Objective

Test the effect, both at species and at ecosystem level, of different scenarios implying the partial or total turning of different types of partially protected areas (nationally and/or internationally designated) into fully protected areas.

3.3 Turning Natura 2000 areas into no-take zones

3.3.1 What we did – species level

- We reconstructed the current state of the stocks across the whole north-western Mediterranean;
- We assessed the potential effects on coastal species (*D. sargus, D. vulgaris, E. marginatus*) biomass and landings of turning all Natura 2000 sites of the north-western Mediterranean Sea into fully protected areas (setting fishing effort to 0)
- We simulated changes in biomass and catches for the three species over the next 50 years and compared changes in species biomass and landings with the current levels.

3.3.2 Effects at the species level

For all three species, the effect of extending full protection to the whole Natura 2000 network would be very positive in terms of stock biomass, with percent changes comprised between approximately 80 and 150% of present values. The dusky grouper *E. marginatus* would benefit from the largest increase. On the other hand, effects on catches would be negative, with a decrease between 20% and more than 40% depending on the species, and with *E. marginatus* experiencing the largest decrease (Table 3.1).

Table 3.1. Expected variation (compared to the present conditions) of biomass and catch of the three coastal species when all Natura 2000 sites are converted into fully protected areas.

Species	Biomass variation	Catch variation
Diplodus sargus	+79%	–39%
Diplodus vulgaris	+96%	–22%
Epinephelus marginatus	+151%	–44%

3.3.3 What we did – ecosystem level

- We developed a spatial-temporal food-web model of Western Mediterranean Sea calibrated from 1995 to 2016;
- We tested different scenarios compared to scenario 1 (status quo);
- We tested the scenario of prohibiting all forms of fishing in Natura 2000 sites;
- We compared changes in ecological indicators and fisheries indicators after the closures to the status-quo scenario.

3.3.4 Effects at ecosystem level

The ecological indicators selected from the scenario of a full closure of Natura 2000 sites showed notable increases in Commercial biomass, Predatory biomass, Shannon Biodiversity index and Mean Length of the fish in the community. On the contrary, the TL catch and the Mean Length of the fish in the catch decreased (Fig. 3.1). This is likely due to the reduction of larger organisms from the catch in comparison with the status quo (Scenario 1).

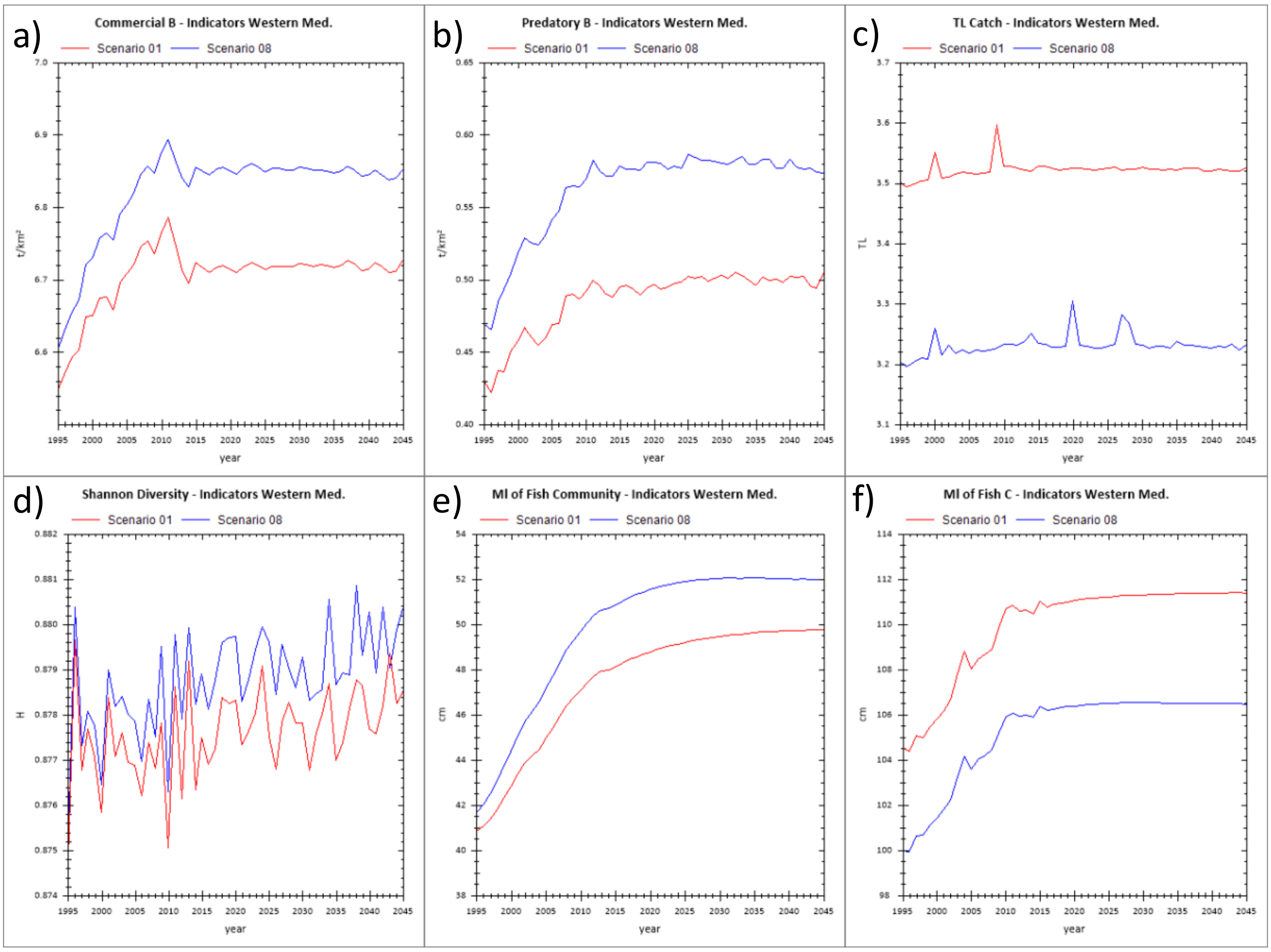

Figure 3.1. Selected ecological indicators of the Western Mediterranean Sea Ecospace model for the status-quo (Scenario 1) compared to the full closure of Natura 2000 sites (Scenario 08).

3.4 **Turning nationally designated MPAs into Fully Protected Areas**

3.4.1 What we did – species level

- We reconstructed the current state of the stocks across the whole north-western Mediterranean;
- We tested the effect of changing the extent of fully protected areas within existing MPAs by keeping fishing effort in unprotected and partially protected areas at its present levels and simulated variations of biomass and catches for the three coastal species (*D. sargus, D. vulgaris, E. marginatus*); over the next 50 years;

- We compared changes in species biomass and landings to the current levels.

3.4.2 *Effects at the species level*

For all three species, the effect of increasing the size of fully protected areas on stock biomass is positive and approximately proportional to their extension. When the proportion of full protection is set to 100% of the existing MPAs' area, the predicted increase in stock biomass relative to present is 33% for *D. sargus*, 40% for *D. vulgaris*, and 61% for *E. marginatus* (Fig. 3.2). On the other hand, effects on catches are strongly species-dependent. For *D. sargus* and *E. marginatus*, catches show a very moderate increase (less than 1% higher than present levels) up to a coverage of 10%, and then decline for increasing levels of protection. In contrast, for *D. vulgaris*, protection has a positive effect on catches, except when the fully protected fraction is greater than 90%. In particular, catches of *D. vulgaris* are expected to be maximized (with a +4% increase compared to present) when fully protected areas are set to cover around 40% of existing MPAs.

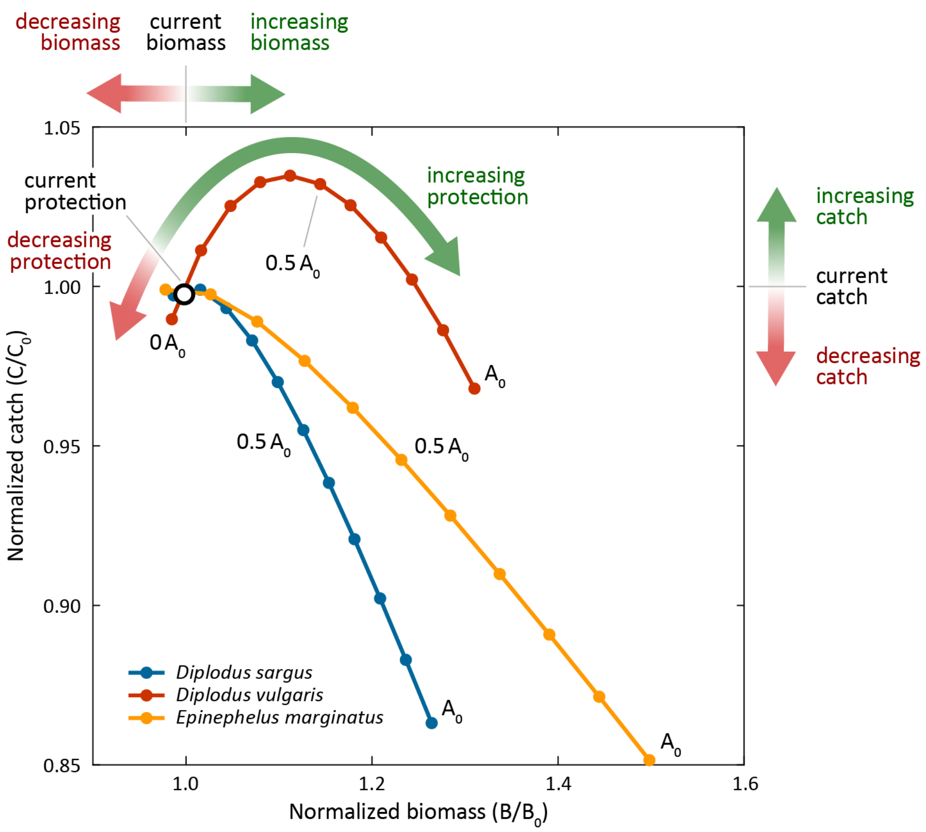

Figure 3.2. Estimated stock biomass and catches for the three model species as a function of the fraction of existing MPAs converted into fully protected area. Biomass and catches are averaged over the last 10 years of a 50-year simulation and are normalized with respect to their baseline values, corresponding to the current extent of full protection (A_0). The 11 values of the fraction of

full protection used in these simulations, indicated by circles along the 3 curves (from left to right) are: 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and 1.

An extended description of methods and results can be found in:

D.4.4 "Report on the optimal configuration of the networks of management units in the study area to optimize fishing benefits and sustainability, and comparison with current network"

D.5.2. "Report on the bio-economic benefits of recruitment protection for small scale fisheries

3.5 Increasing fully protected areas using proposed protection schemes

3.5.1 What we did – ecosystem level

- We developed a spatial-temporal food-web model representing the Western Mediterranean Sea and calibrated it with time series of data from 1995 to 2016;
- We tested the scenario 13 (*Achieve 20% of no-take* to explore the impact of closing all existing protected areas and Natura2000 sites to all fishing), 14 (*Closure of EBSA* prohibiting all fishing in Ecologically or Biologically Significant Areas as defined by the CBD 2019), 15 (*Closure of consensus areas* prohibiting all fishing in Consensus Areas selected in at least 5 proposed schemes (as defined by Micheli et al. 2013)) and 16 (*Closure of PACs* prohibiting all fishing in priority areas for conservation of species at risk, including endemic species and data deficient species (as defined by Coll et al. 2015));
- We compared changes in ecological indicators compared to scenario 1 (status quo).

3.5.2 Scenario 13 - Achieve 20% of no-take

The ecological indicators selected from the scenario of 20% of no-take sites showed visible increases in Commercial biomass, Predatory biomass, Shannon Biodiversity index and Mean Length of the fish in the community. The TL catch and the Mean Length of the fish in the catch decreased (Figure 3.3).

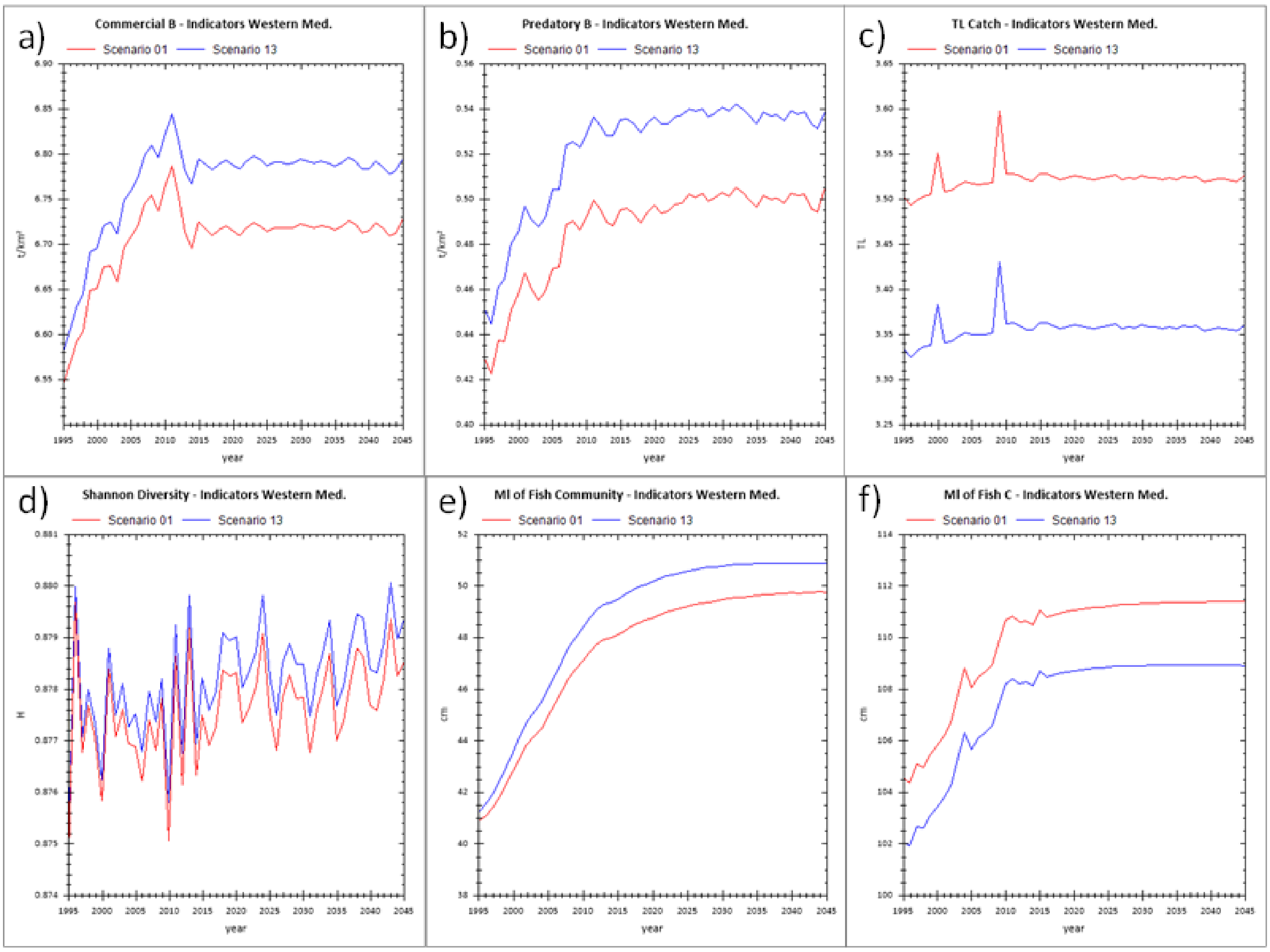

Figure 3.3. Selected ecological indicators of the Western Mediterranean Sea Ecospace model for the status-quo (Scenario 1) compared to a 20% of no-take (Scenario 13).

3.5.3 Protecting EBSAs, Consensus areas, and PACs

The ecological indicators selected from the scenarios of protecting EBSAs, Consensus areas and PACs showed visible increases in Commercial biomass, Predatory biomass, Shannon Biodiversity index and Mean Length of the fish in the community. On the contrary, the TL catch and the Mean Length of the fish in the catch decreased (Fig. 3.4). The protection of EBSAs (Scenario 14) projected the highest increases of Commercial biomass, Predatory biomass, Shannon Biodiversity index and Mean length of the community.

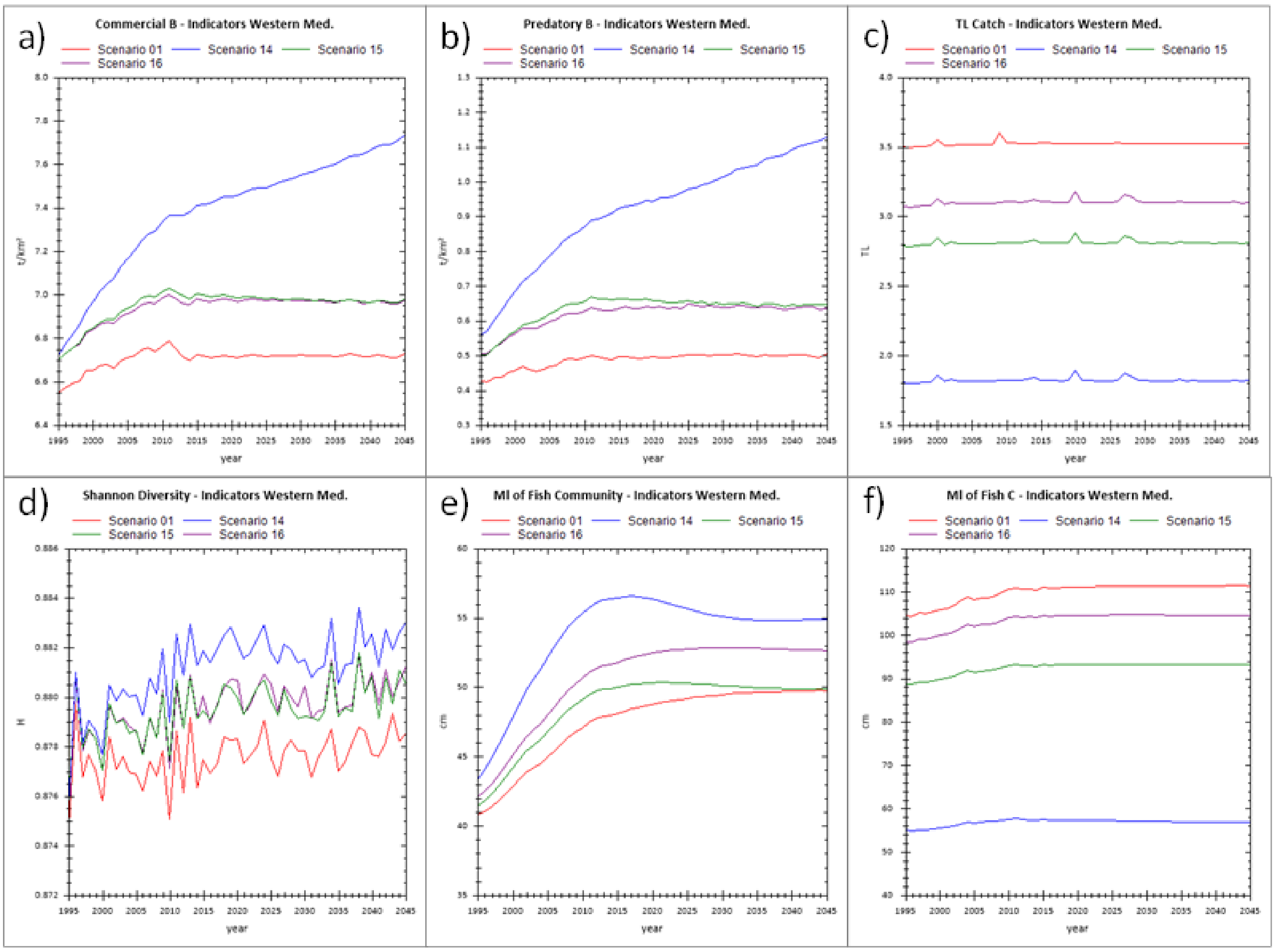

Figure 3.4. Selected ecological indicators of the Western Mediterranean Sea Ecospace model for the status-quo (Scenario 1) compared to the protection of EBSAs, Consensus areas and PACs (Scenario 14-16).

4 Spatial fisheries closures and effort regulation for European hake in GSA9

Glossary Box

Status-quo scenario: the status quo scenario is the forecast of what will happen in the future in terms of fish biomass and fish catches if fishing effort and protection remain the same as they are now.

Spawning stock biomass (SSB): SSB is the total weight of the fish in a stock that are old enough to spawn and is used as an indicator of conservation benefits in the following scenarios.

4.1 Key facts/Recommendations

- Local closures (at a scale of ca. 200 km^2) in GSA9 may contribute to the achievement of GES by improving the status of the hake stock, without significantly affecting the productivity of its fishery in GSA 9 compared to present landings.
- The closure of cells comprised between the Tuscan Archipelago and the southernmost portion of the Ligurian Sea would guarantee the largest benefits (increase up to 5-10% in fisheries productivity) compared with the status-quo scenario.
- Although the long-term closure of a single and large area may be difficult to implement, there is room for win-win alternatives to current fisheries management in the region, that would allow a more equitable spatial distribution of costs and benefits at the regional scale.
- Hake landings would be maximized by banning otter bottom trawls while doubling (with respect to present) the effort of gillnetters; this measure would decrease the overall fishing effort by ca. 57% with respect to present and would determine an increase in both landings and spawning stock biomass with respect to the status-quo scenario.
- In the multi fleet fishery of GSA9, strategies following improvement of exploitation patterns through the protection of the sensitive stages of the population (i.e. spawners and juveniles), reducing the fishing effort in specific months and in specific areas for different fleets, demonstrated to have a positive impact on the stock status and on the reduction of the discard and, with a less severe impact on the revenues, across fleets. Stock status, landings and revenues would always deteriorate in the future if present fisheries management is maintained.

4.2 Objective

This scenarios test the effects of spatial fisheries closures and of fishing effort reduction in spawning and nursery grounds on hake populations and catches in GSA9 (Thyrrenian and

Ligurian Sea). A bioeconomic model was also applied to test the effects of additional spatial and temporal management measures in a mixed fishery context.

4.3 What we did

- We developed a model describing the spatiotemporal dynamics of hake stock in GSA9;
- We set fishing effort to zero in areas of 210-220 km^2 and simulated subsequent changes in hake spawning biomass and landings over the next 50 years starting from 2015;
- We compared changes in hake spawning stock biomass and landings under a status-quo scenario with their response to 1) spatial closures and 2) changes in fishing effort (gillnetters and otter bottom trawls).
- We developed a bio-economic model with BEMTOOL for the hake multi-fleet fishery in GSA9 and explored the impact of additional management measures compared to current levels based on different combinations of temporal and spatial closures (Table 4.1);
- Each scenario was assessed by simulation over the time horizon 2018–2030 and its performances were assessed in terms of spawning stock biomass and overall utility by means of a Multi Criteria Decision Analysis approach implemented in BEMTOOL, accounting for the biological, economic and social components of the fishery sustainability.

SC1 -SQ	Status quo (SQ);
SC2-SFBf	Seasonal fishing ban (matching recruitment peaks) for one or more fleet segments associated to a nursery ground. Closures synchronised by fleet segment and fishing ground (SFBf);
SC3-SFBd	Seasonal fishing ban (following recruitment peaks) for one or more fleet segments associated to a nursery ground. Closures are asynchronous and differentiated by fleet segment and fishing ground according to the relative impact (SFBd);
SC4-SC	Year-round closure of nursery grounds, increasing the length at first capture (L50%) to 20 cm.

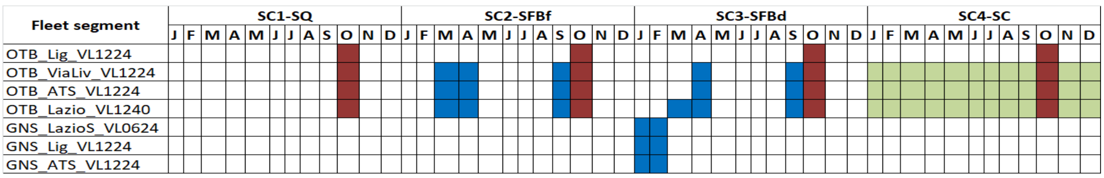

Table 4.1 - The four management scenarios designed in BEMTOOL. The table shows the closures by fleet and ground in different months depending on recruitment peaks. OTB = otter bottom trawls;

GNS = gillnets; Lig=Liguria; ViaLiv=Viareggio-Livorno (Tuscany); ATS = Arcipelago Toscano (Tuscany). Red represents measures already in place (trawling ban during the autumn recruitment peak), blue additional seasonal closures, and green year-round closures).

4.4 Effects of spatial closures

About half (49%) of the local spatial closures tested in GSA 9 would determine an increase in both landings and spawning stock biomass (evaluated at the scale of the whole GSA 9) with respect to the status-quo scenario.

The impacts of local spatial closures on the status of the stock and the performances of the fishery are shown in Fig. 4.1. In general, the cells guaranteeing the largest benefits are those comprised between the Tuscan Archipelago and the southernmost portion of the Ligurian Sea, followed by a range of cells approximately located in the Gulf of Gaeta.

The cell whose closure would maximize spawning stock biomass (+40% compared to the status-quo scenario) is located in front of La Spezia, while the highest benefits on landings (+8%) would derive from closing the fishery in a cell of the Tuscan Archipelago located around the group of small islands called Formiche di Grosseto. Although no management scenario would be able to guarantee current landings, closing the latter cell would keep them substantially unchanged (–1%), while they would fall by 8% compared to the present if fishing effort is kept as it is today (status-quo scenario).

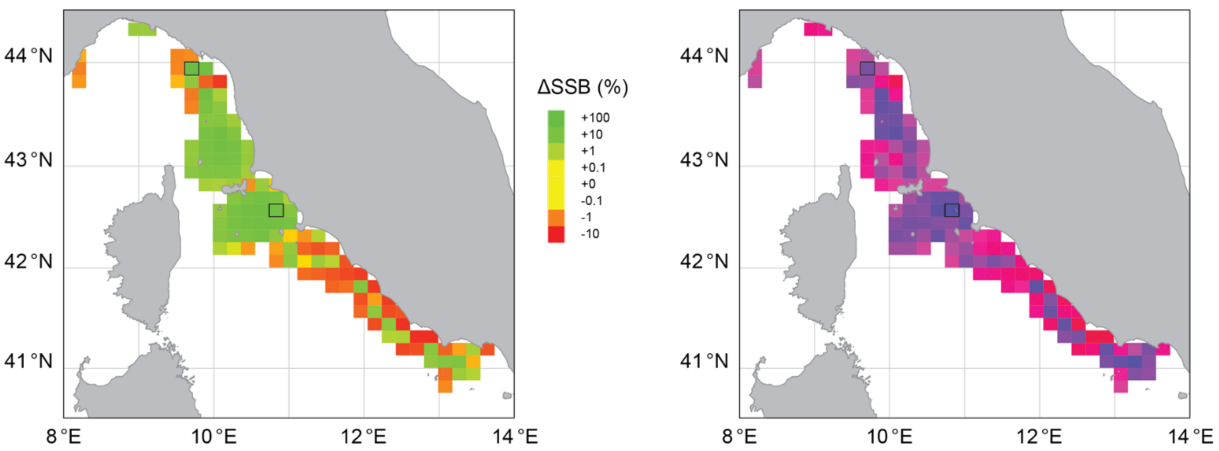

Figure 4.1: Overall impact of closing European hake fisheries in a 0.125° × 0.1875° cell in GSA 9. Fishing effort was relocated homogeneously across the whole study area. Colour shades indicate the percent variation of (a) spawning stock biomass (SSB) and (b) landings (Y) across the whole GSA with respect to the status-quo scenario where fishing effort is kept unchanged.

4.5 Effects of changing fishing effort

Spawning stock biomass in GSA9 is maximized when the efforts of gillnetters (GNS) and otter bottom trawls (OTB) are both set to zero. In contrast, landings are maximized when the effort of otter bottom trawls is set to zero but gillnet effort is doubled compared to present (GNS effort multiplier = 2.2). This setting would determine a +225% increase in landings with respect to the status-quo scenario, while ensuring a +240% increase of spawning stock biomass. This measure would also decrease the overall fishing effort (which was, on average, 11,334 KW x day for the OTB segment and 2,766 KW x day for the GNS segment between 2006-2014) by ca. 57% with respect to present (Fig. 4.2).

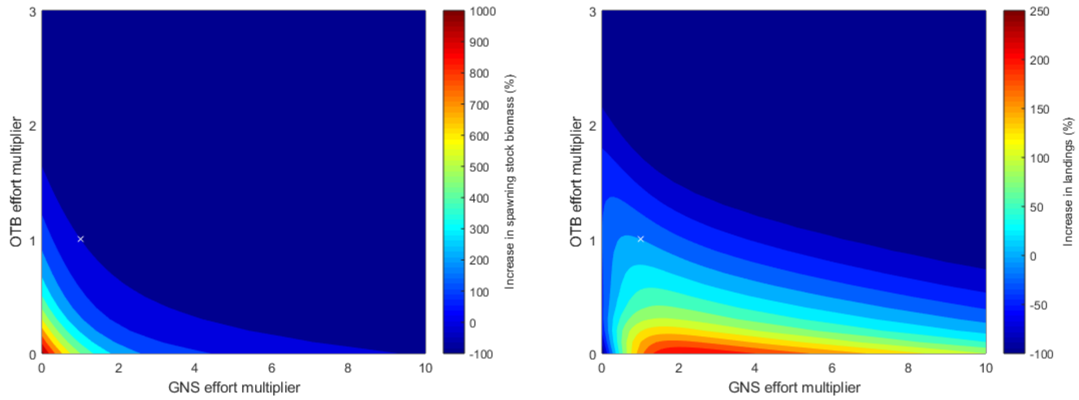

Figure 4.2. Overall impact of changing the fishing effort of the two main fleet segments targeting the European hake stock in GSA 9 (GNS, on the x-axis, and OTB, on the y-axis), expressed as a percent variation with respect to the status-quo scenario (indicated with a white cross). Efforts are expressed as multiples of current ones.

4.6 Effects of other temporal and spatial restrictions

The reduction of fishing effort in the considered scenarios was between 20 and 30%. The forecast in the medium-long term highlighted that a status quo scenario would determine a decrease of the SSB of about 25% and of the landing of about 10% in a time frame of about 13 years (Fig. 4.3). All scenarios perform better than the status quo on SSB, with the scenario envisaging an asynchronous fishing ban differentiated by fleet segment and fishing ground (SC3) delivering the higher benefits. Scenario 4 would impact positively on the landing of the target species in the medium-long term, although a decrease of the landings in the short terms (2-3 years) is expected before the rebuilding of the stock takes place. Unwanted catches and discard would also be reduced under this scenario.

The forecast in the medium-long term highlights that a status quo situation would also return a deteriorated economic indicator of the fleet viability (e.g. revenues) if compared to the current levels and to the expected levels following the application of the management measures.

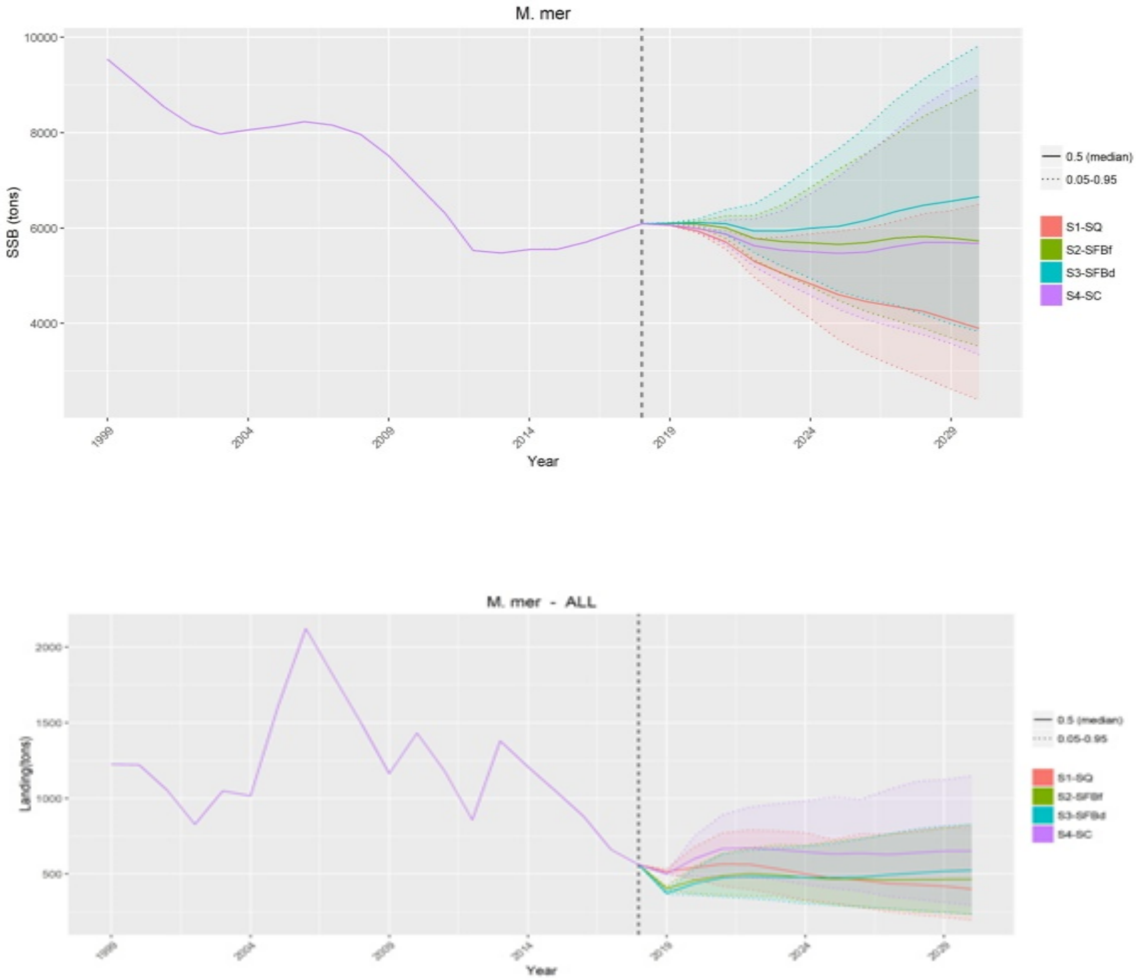

Figure 4.3. Comparison of the effects of the different scenarios on European hake SSB and landings.

The Multi Criteria Decision Analysis shows that the overall utility improves when a stock rebuilding strategy is followed, based on a combination of spatial and effort measures. The strategies following improvement of exploitation patterns, through the protection of the sensitive stages of the population, reducing the fishing effort in specific months and in specific areas (Scenarios 2-4), would have a positive impact on the reduction of the discard and on the stock status, with a less severe impact on the revenues, across species and fleets (Fig. 4.4)

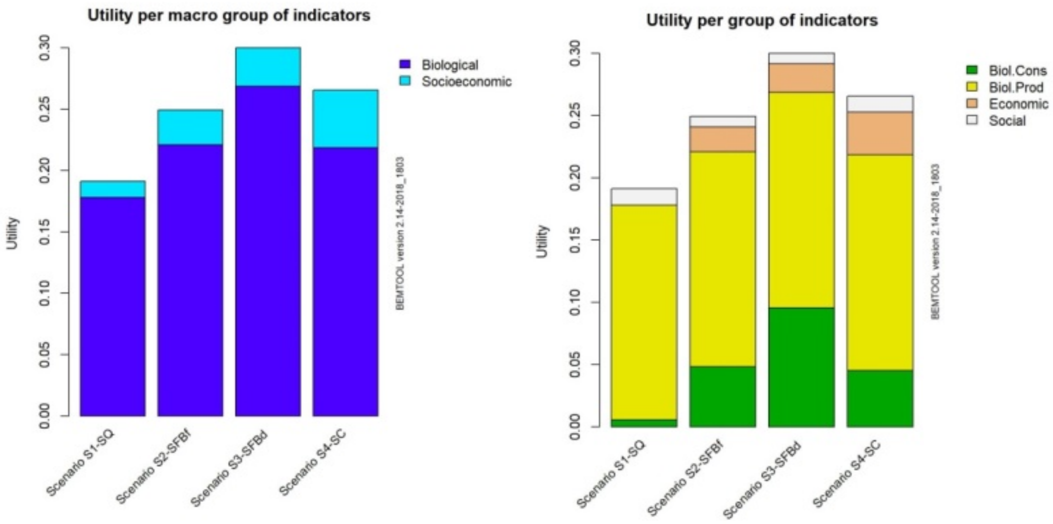

Figure 4.4. Impact of the 4 scenarios measures as Utility per group of indicators. Biological indicators include Biological conservation indicators (SSB and fishing mortality) and Biological production indicators (catches and discards). Socio-economic indicators include Economic indicators (revenues) and Social indicators (wage and employment). Utility indicates the maximum value reached by the 7 indicators listed above in relation to best management objectives (e.g the maximum utility of Fishing mortality is at FMSY, the minimum at $2*F_{MSY}$).

An extended description of methods and results can be found in: ***D.5.1. "Report on the bio-economic benefits of recruitment protection in a mixed fisheries context"***

5. TRAWLING BAN FOR EUROPEAN HAKE

5.1 Key facts/recommendations

- In GSA 9 a closure of the fishery to trawlers in the bathymetric range 0-100 m would improve the status of the hake stock, while at the same time benefitting also the productivity of the fishery, with respect to the status-quo scenario, but only if the fishing effort is not reallocated.
- At the Western Mediterranean level, a 3-month trawling ban up to 100m depth would not have a remarkable positive impact on hake nor have a noticeable positive impact on ecological indicators. Year-round trawling bans to 100 m and to 150 m would deliver larger benefits in terms of both stock status and ecological indicators.

5.2 Objective

This scenario tests the effects of:

- a bottom trawling ban up to 100 m depth on hake stock and catches in GSA9 (northern Tyrrhenian and Ligurian Seas);
- a 3-month (May to July) trawling ban up to 100m depth on hake stock and ecological indicators in the Western Mediterranean;
- a permanent, year-round trawling ban up to 100 meter depth and up to 150 m depth on hake stock and ecological indicators in the Western Mediterranean.

5.3 What we did – species level

- We reconstructed the current state of the stock in GSA 9.
- We set trawlers’ fishing effort to zero between 0 and 100 m depth and simulated changes in hake spawning biomass and landings over the next 50 years (Fig. 5.1);
- We compared changes of hake spawning stock biomass and landings after the ban to the status-quo scenario (fisheries unchanged).

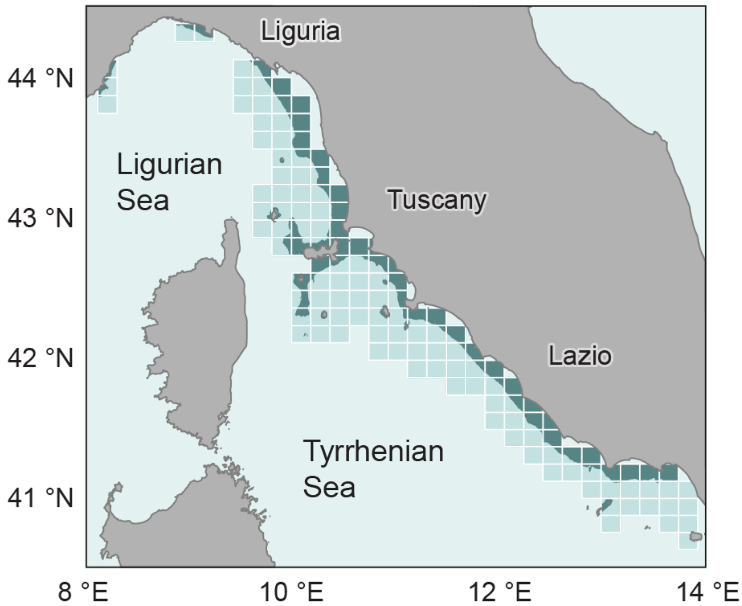

Figure 5.1. Coloured cells indicate the domain of the metapopulation model used for the simulations. The portion of each cell included within the bathymetric range 0-100 m depth is highlighted in dark green.

5.4 Effects of the trawling ban in GSA 9 at species level

The response of spawning stock biomass and landings to a trawling ban between 0-100 m very much depends on whether or not a spatial reallocation of the fishing effort if considered (Table 5.1). If the fishing effort of trawlers is reallocated to the areas outside the bathymetric range 0-100 m so as to keep the total effort unchanged, both spawning stock biomass (–24%) and landings (–20%) undergo a remarkable decrease with respect to the status-quo scenario, where fishing effort is kept unchanged. Conversely, if the fishing effort is not reallocated, spawning stock biomass increases by 72%, while landings increase by 39% with respect to the status-quo scenario.

Table 5.1. Expected variation (with respect to the status-quo scenario) of spawning stock biomass and landings of hake in GSA 9 after the implementation of a trawling ban, with and without spatial reallocation of the fishing effort.

Scenario	SSB variation	Landings variation
effort reallocation	–24%	–20%
no effort reallocation	+72%	+39%

5.5 What we did – Western Mediterranean ecosystem level

- We developed a spatial-temporal food-web model of the Western Mediterranean calibrated from 1995 to 2016;

- We tested three scenarios of bottom trawl bans and compared them to status quo (current trawling bans) and to a scenario of no protection: a 3-month (May to July) trawling ban up to 100 m depth, a permanent, year-round bottom trawling ban up to 100 meter depth, and a permanent, year-round bottom trawling ban to 150 m;
- We compared changes in hake biomass, landings and ecological indicators after the closures in comparison to the status-quo scenario.

5.6 Effects of the trawling ban in the Western Mediterranean

There was a gradient of positive impacts: the partial 100 m trawling ban (3-months, Scenario 10) showed a moderate positive impact on European hake, while both the permanent 100 m (Scenario 9) and the permanent 150 m trawling bans (Scenario 11) showed a larger positive impact on this species (Fig. 5.2).

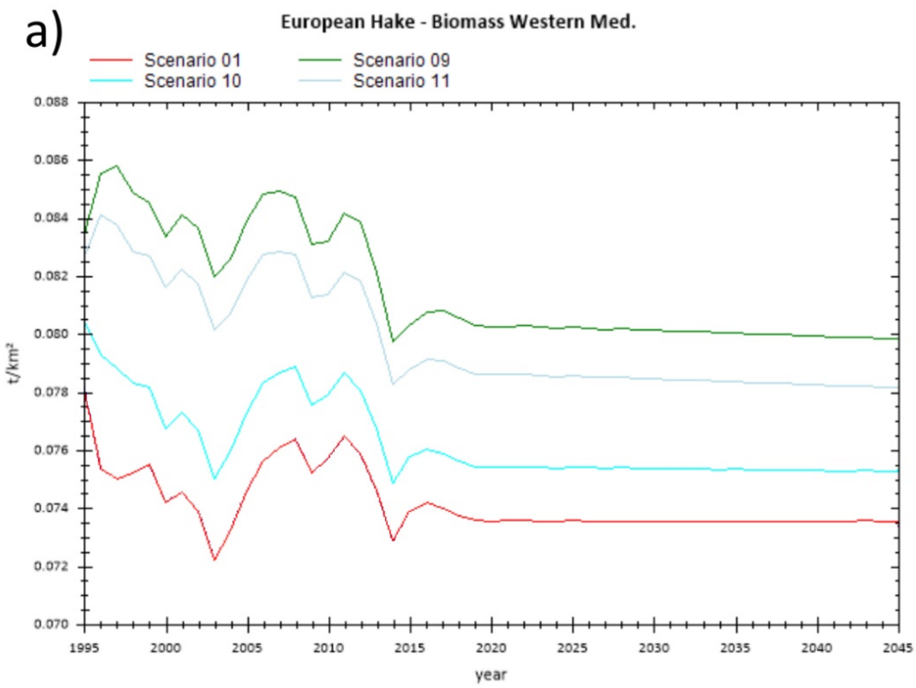

Figure 5.2. Time series of biomass density of European Hake of the Western Mediterranean Sea Ecospace model for the Status-quo scenario (Scenario 1) compared to year-round 100 m trawl ban (Scenario 9), 3-months 100 m trawl ban (Scenario 10), and a year-round 150 m trawl ban (Scenario 11).

The ecological indicators selected from the three scenarios of bottom trawl bans showed small changes. The scenario of permanent, year-round 150 m trawling ban showed the largest increases in Commercial biomass and Predatory biomass, and lower values in the TL catch and the Mean length of the fish in the catch. The Shannon Biodiversity index and the Mean length of fish in the community did not show significant changes between the protection schemes and the status-quo (Fig. 5.3).

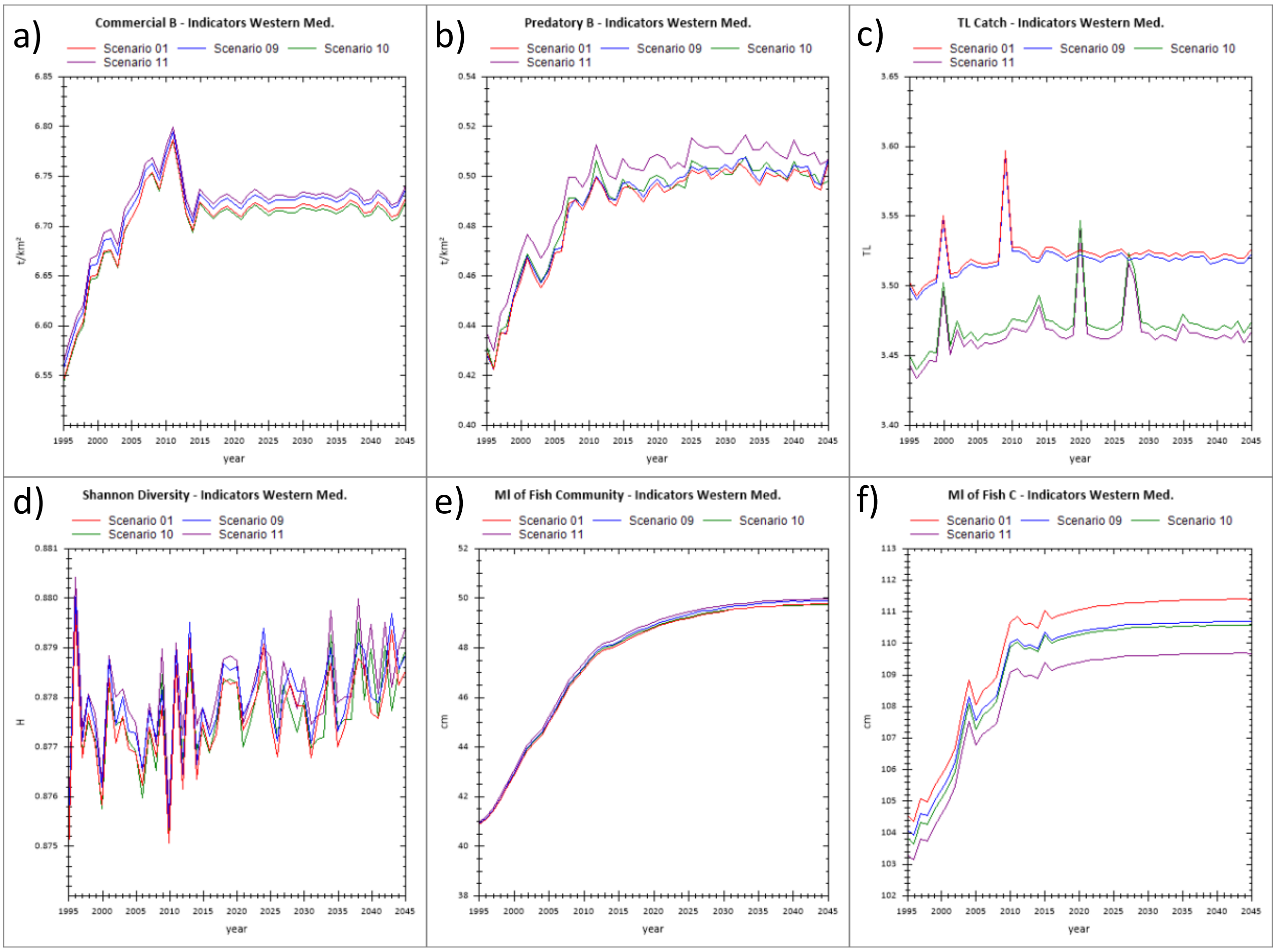

Figure 5.3. Selected ecological indicators of the Western Mediterranean Sea Ecospace model for the status-quo (Scenario 1) compared to year-round 100m trawl ban (Scenario 9), 3-months 100m trawl ban (Scenario 10), and a year-round 150m trawl ban (Scenario 11).

An extended description of methods and results can be found in:

D.2.9. "Report identifying and showing how different network types and configurations can help fisheries help MSY through quantification of emergence".

D. 4.3. "Report on the quantitative food web models calibrated with time series of data"

D.4.4 "Report on the optimal configuration of the networks of management units in the study area to optimize fishing benefits and sustainability, and comparison with current network"

D.5.1. "Report on the bio-economic benefits of recruitment protection in a mixed fisheries context"

6 Fishing at MSY and spatial fisheries closures in the Western Mediterranean

Glossary Box:

Several ecological indicators were computed to assess the impact of the tested management scenarios on ecosystem structure and health as well as on fisheries.

Biomass-based indicators: These indicators are calculated from the biomass of components included in the food-web model. Indicators included were total biomass (TB, t km^{-2}), biomass of commercial species (CB, t km^{-2}), biomass of fish species (FB, t km^{-2}), and predatory biomass (t km^{-2})

Trophic-based indicators: These indicators reflect the trophic level (TL) for different groups of the food web. TLs are calculated by assigning primary producers and detritus to trophic level 1, and consumers to a trophic level of 1 plus the average trophic level of their prey, weighted by their proportion in weight in the predator's diet (Christensen 1996, 2000). Trophic level may indicate ecosystem “health” because it reflects fishing pressure due to removal of predators (Christensen & Walters 2004). The considered indicator was the TL of the community (TLc), which includes all components of the food-web.

Catch-based indicators: These indicators are based on catch and discard species data in the food web. Indicators included were: total catch (TC t km^{-2} $year^{-1}$), total discarded catch (TD, t km^{-2} $year^{-1}$), trophic level of the catch (TLC), mean length of fish in the catch (MLC, cm).

Marine Trophic Index (MTI): it measures the mean trophic level of fisheries landings. Preferred fish catches consist of large, high value predatory fishes. The intensification of fishing has led to the decline of these large fishes, which are high up in the food chain. As predators are removed, the relative number of small fish and invertebrates lower in the food web increases, and the mean trophic level (i.e. the mean position of the catch in the food chain) of fisheries landings, goes down.

Shannon-Wiener diversity index: it is a measure of diversity that combines species richness (the number of species in a given area) and their relative abundances.

6.1 Key facts/Recommendations

- Food-web interactions play an important role in future outcomes of protection scenarios or reduction of fishing mortality in the Western Mediterranean, as predators and competitors of commercial species would also recover and thus would pressure commercially targeted species through increasing predation or resource competition.

- The stocks of key coastal species (*D. sargus*, *D. vulgaris*, *E. marginatus*) in the north-western Mediterranean are presently overfished. Model predictions suggest that stock and catches can be rebuilt if fishing mortality is reduced to F_{MSY} levels. Stock biomass would start increasing immediately and reach B_{MSY} after a transient of ca. 20 years. Catches would decrease (between –20% and –45%, depending on the species, in the first year) and then attain levels at least equal to current ones within 10 to 15 years .
- Scenarios of fishing at F_{MSY} levels in the north-western Mediterranean suggested substantial benefits for ecological indicators and indicators related to the quality of the catch (average size, weight and trophic level of the catch), despite the predicted decreases in catch quantity, in comparison with maintaining fishing pressure at current levels.
- The protection of hake nurseries and protection of nurseries and spawning areas deliver measurable benefits in terms of ecological indicators (commercial and predatory biomass, biodiversity index, mean length of the fish community), while catch-related indicators are predicted to decrease (mean length and trophic level of the catch decline).
- Protecting only hake spawning areas delivers less benefits in terms of ecological indicators than protecting hake nurseries areas or hake nurseries and spawning areas, likely due to the smaller sizes of identified spawning areas.

6.2 **Objective**

At the scale of the Western Mediterranean, these scenarios test the effects of fishing at F_{MSY} and of closing hake nursery and/or spawning grounds on coastal species and on ecological indicators.

6.3 **What we did – species level**

- We reconstructed the current state of coastal species stocks (*Diplodus sargus*, *Diplodus vulgaris*, *Epinephelus marginatus*) across the whole north-western Mediterranean.
- We tested the effects of changes in fishing mortality and compared changes in species biomass and landings to the current levels.

6.4 **Effects of Fishing at MSY level – species level**

2.1.1.1. Coastal species (*Diplodus sargus, Diplodus vulgaris, Epinephelus marginatus)*

The responses of stock biomass and catch to changes of fishing pressure at the scale of the whole north-western Mediterranean for the three coastal species are shown in Fig. 6.1. For each species, maximum sustainable yield (MSY) is identified as the maximum value of catch with respect to fishing mortality. For all three species, the normalized MSY and the corresponding stock biomass (B_{MSY}) are greater than 1: indeed, fishing mortality rates associated with MSY (F_{MSY}) are lower than current fishing mortality rates (F_0) for all three species (F_{MSY} = 0.75F_0 for *D. sargus*, 0.5F_0 for *D. vulgaris* and *E. marginatus*). These results suggest that all three fish stocks are presently overfished, and that current catches are, in fact, not sustainable.

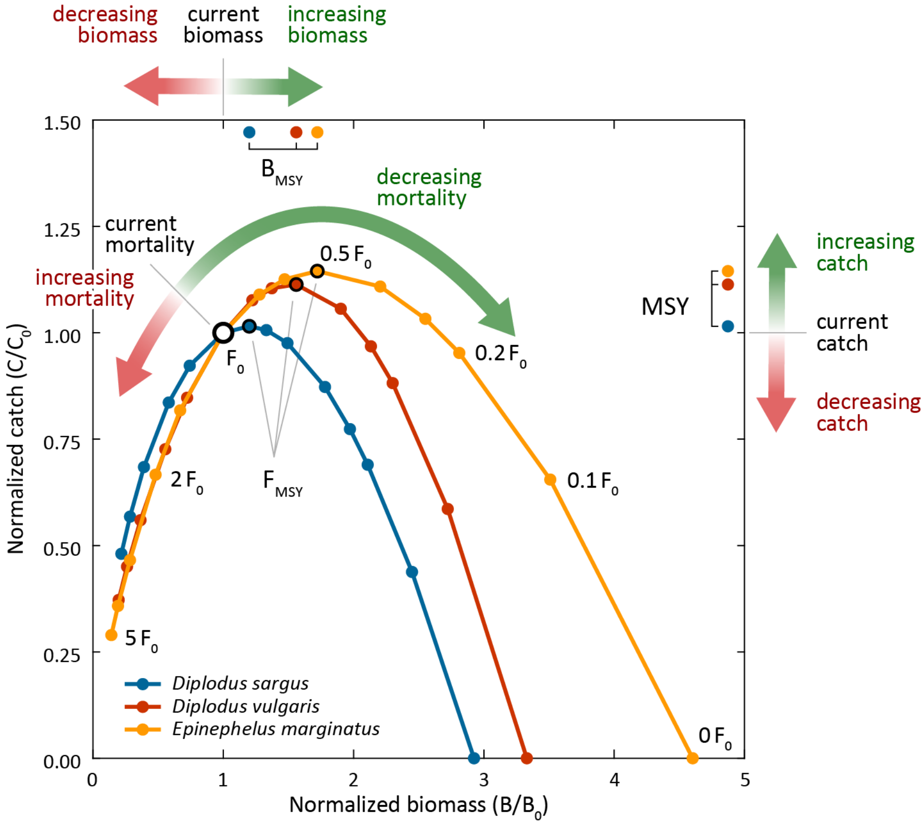

Figure 6.1 Estimated stock biomass and catches as a function of fishing mortality rate for the three model species. Biomass and catches are averaged over the last 10 years of a 50-year simulation and are normalized with respect to their baseline values, corresponding to the present levels of fishing mortality rate. The 14 multipliers of fishing mortality rate used in these simulations, corresponding to the circles along the 3 curves (from right to left) are: 0, 0.1, 0.2, 0.25, 0.33, 0.5, 0.625, 0.75, 1, 1.5, 2, 3, 4, and 5. F_0, B_0 and Y_0 indicate present values of fishing mortality rate, stock biomass and catch, respectively. F_{MSY}, B_{MSY} and MSY indicate the values of the same variables corresponding with the maximum sustainable yield.

At present fishing levels, biomass and catch of *D. sargus* are estimated to be around 83% and 98%, respectively, of what would be achieved with a fishing mortality rate equal to F_{MSY} (the level of fishing mortality that maximizes catches). Present biomass and catch of *D. vulgaris* are around 64% and 90%, respectively, of those associated with F_{MSY}, while for *E. marginatus* they are about 58% and 87%, respectively. Relative values of B_{MSY} compared to unfished biomass (estimated biomass of the stock in the absence of any fishing effort across the whole study area) are 41% for *D. sargus*, 47% for *D. vulgaris* and 37% for *E. marginatus*. The ratio of baseline biomass to unfished biomass is 34% for *D. sargus*, 30% for *D. vulgaris* and 22% for *E. marginatus*.

Fig. 6.2 shows the expected temporal dynamics of stock biomass and catch (obtained from simulations performed using F_{MSY}) with respect to B_{MSY} and baseline catch (C_0), respectively, for the three studied species. In the first year of simulation, stock biomass is 85% of its final value for *D. sargus*, 61% for *D. vulgaris* and 60% for *E. marginatus*. Stock biomass recovery after the reduction of fishing effort (from F_0 to F_{MSY}) occurs progressively until reaching the maximum corresponding to B_{MSY}. The recovery time for the three studied species is around 20 years. Model predictions suggest that the process of rebuilding catch to levels at least equal to current ones would take about 16 years for *D. sargus*, 11 years for *D. vulgaris* and 10 years for *E. marginatus*. During this period, catches may be remarkably reduced, especially in the first year (about –20% for *D. sargus* and –45% for *D. vulgaris* and *E. marginatus*).

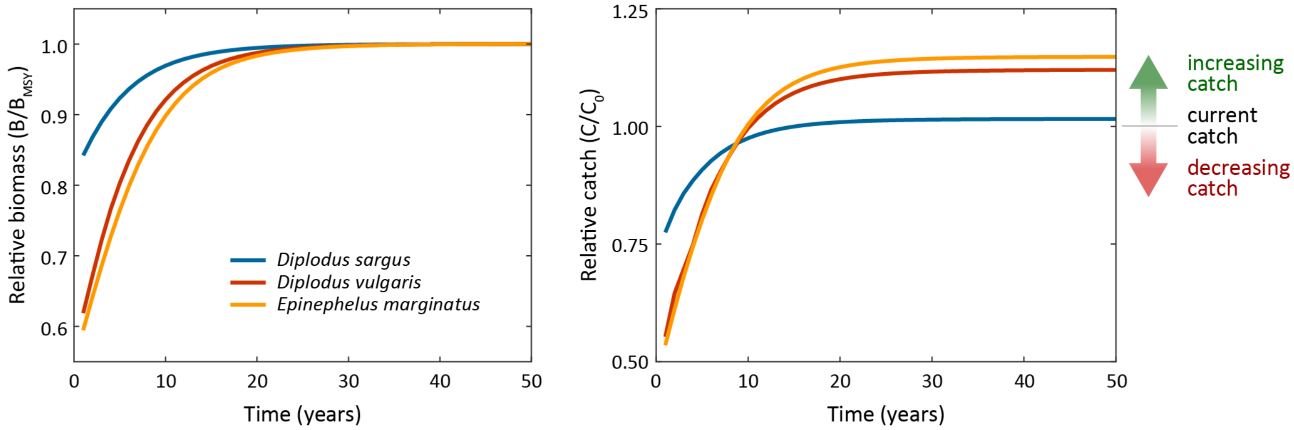

Figure 6.2 Temporal dynamics (over a 50-year simulation period) of stock biomass and catch for the three focus species under a MSY scenario. For each species, biomass is normalized with respect to its value at the end of the simulation (B_{MSY}), while catch is normalized with respect to the baseline value (C_0), corresponding the current value of fishing mortality (F_0).

6.5 What we did – ecosystem level

- We developed a spatial-temporal food-web model representing the Western Mediterranean Sea calibrated from 1995 to 2016;
- We tested the effect of alternative fisheries management scenarios, such as the effect of fishing at Maximum Sustainable Yield (F_{MSY}) in comparison to fishing at current F (using fishing mortality levels of 2016-2018 retrieved for valued species from STECF2018 and SPELMED2018);
- We tested the effect of closing hake spawning areas, nursery areas or both compared to scenario 1 (status quo) and scenario 0 (no protection);

- We compared variations of ecological indicators of all the scenarios to the status-quo scenario.

6.6 Effects of fishing at FMSY – ecosystem level

Temporal simulations of fishing at FMSY levels suggested substantial benefits in the region for ecological indicators (Fig. 6.3), especially for commercial biomass, fish biomass or predatory species biomass. Although catch-based indicators declined, the average size, weight and trophic level of the catch improved in comparison with the status-quo run (Fig. 6.4).

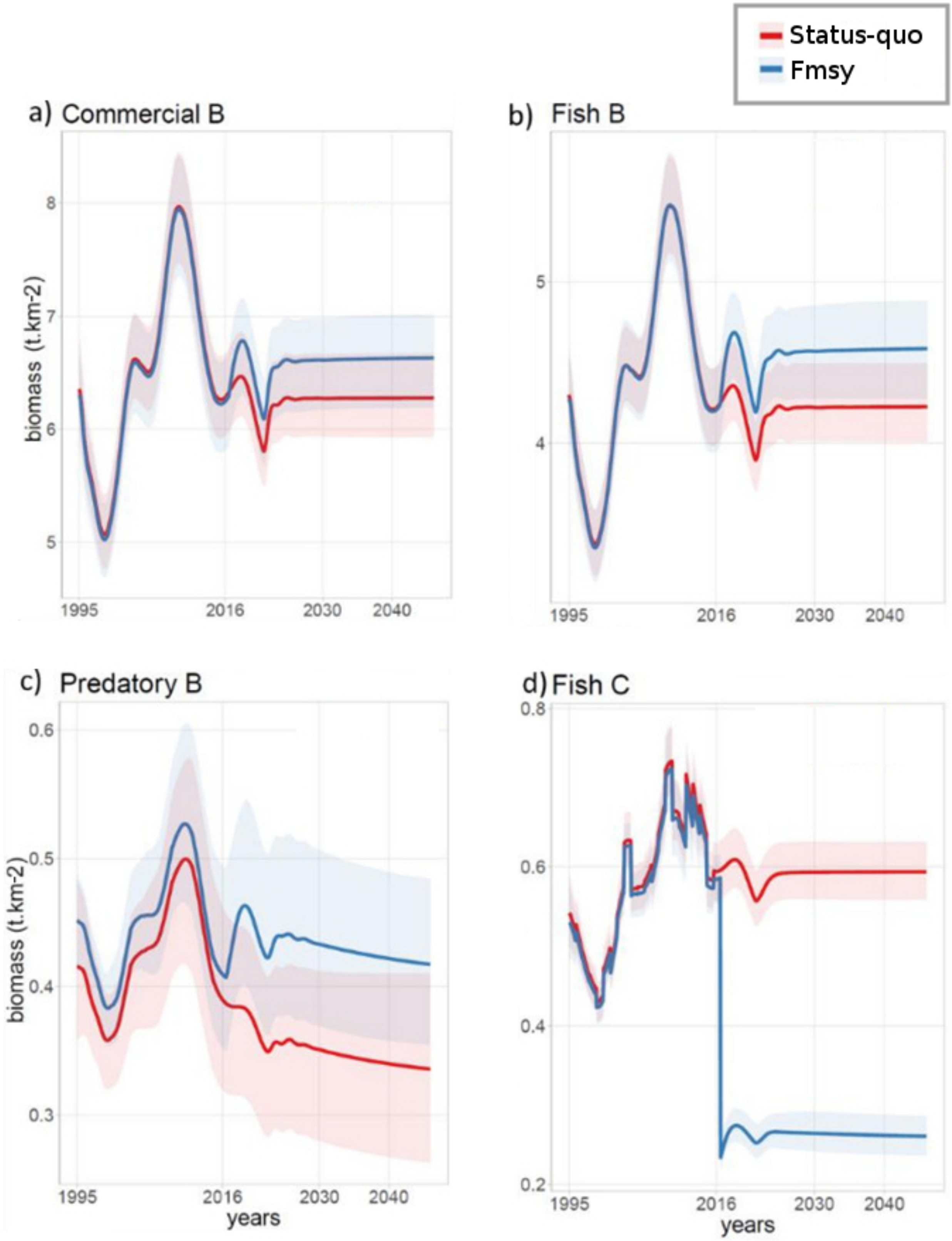

Figure 6.3. Predicted biomass-based indicators (t km^{-2}) under status-quo and F_{MSY} simulations in the Western Mediterranean Sea model for the period 1995-2046. For information about the indicators, see glossary box at the beginning of the chapter.

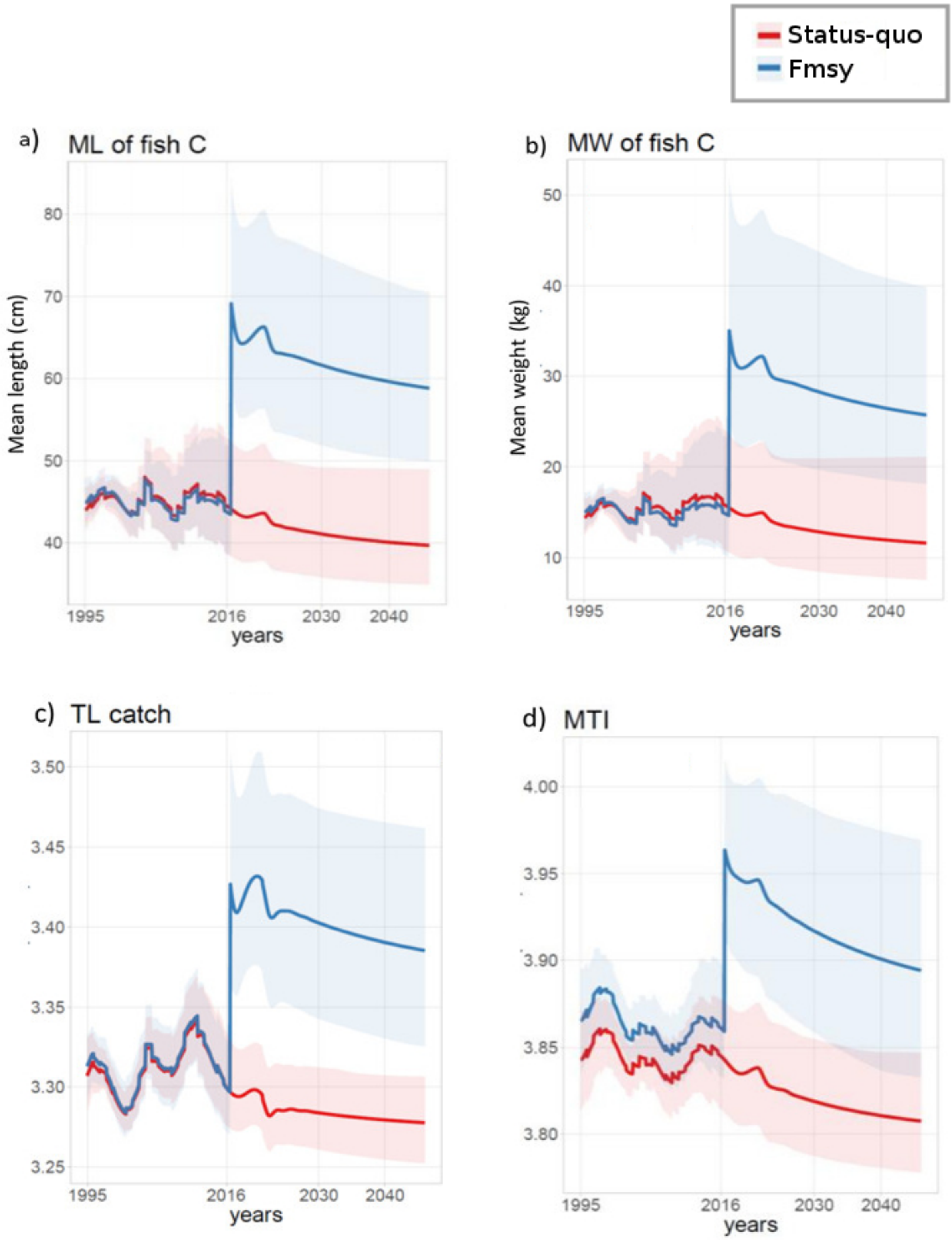

Figure 6.4. Predicted catch-based and trophic level indicators under status quo and F_{MSY} simulations in the Western Mediterranean Sea model for the period 1995-2046. For information about the indicator see glossary box at the beginning of the chapter.

6.7 Effects of the spatial closures – ecosystem level

The ecological indicators selected from the three scenarios of full protection of hake nurseries and spawning areas showed increases in indicators linked to the state of the community at sea (Commercial biomass, Predatory biomass, Shannon Biodiversity index and Mean Length of the fish in the community). On the contrary, indicators linked to catches quality (TL catch and the Mean Length of the fish in the catch) decline (Fig. 6.5). This is likely due to the decline of European hake and “other medium-sized demersal fish” in the catch because of the closures of the nurseries and spawning areas. Protection of nurseries and spawning areas and protection of nursery areas were the scenarios predicting larger benefits in terms of ecological indicators.

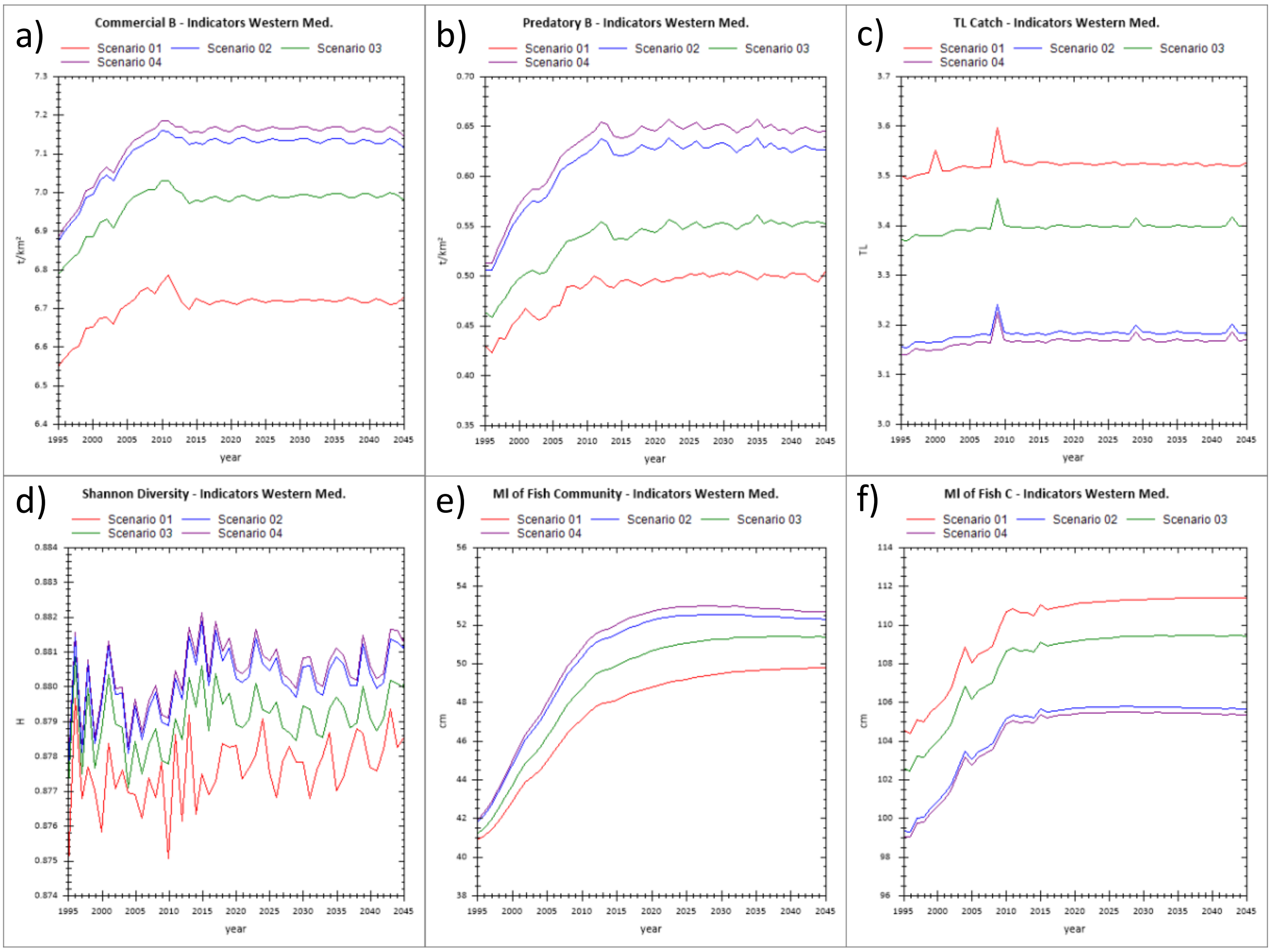

Figure 6.5. Selected ecological indicators of the Western Mediterranean Sea Ecospace model for the Status-quo (Scenario 1) compared to full closure of European hake nurseries (Scenario 2), spawning areas (Scenario 3), and nurseries and spawning areas (Scenario 4).

An extended description of methods and results can be found in:

D.4.3. “Report on the quantitative food web models calibrated with time series of data”

D.4.4 "Report on the optimal configuration of the networks of management units in the study area to optimize fishing benefits and sustainability, and comparison with current network”

D.5.2. “Report on the bio-economic benefits of recruitment protection for small scale fisheries

7 RECREATIONAL AND SMALL SCALE FISHERIES IMPACT ON VULNERABLE SPECIES

7.1 Key facts/ Recommendations

- Despite recreational (RF) and small-scale fisheries (SSF) in the western Mediterranean are often considered "low impact fisheries" compared to larger-scale fishing methods (e.g. trawling and purse seining), they may still pose a threat to vulnerable species, whether they inhabit coastal or offshore waters, and whether they are targeted and commercialized, or unintentionally taken as bycatch.
- There is a need to develop management measures that could include reducing the fishing pressure on certain vulnerable species (e.g. by regulating fishing gears and baits) or, in some cases, prohibiting their capture, at least in specific areas, such as marine protected areas (MPAs), and/or in particular seasons of the year.
- Minimum landing sizes should be implemented for all vulnerable species, whereas maximum landing sizes should be also implemented for sex-changing species in order to preserve their reproductive potential.
- Effective enforcement and greater public awareness should be promoted, which can lead to support for legislation and action at the consumer end of the supply chain by empowering customers to make better seafood choices (e.g. avoiding the consumption or the catch of vulnerable species).

7.2 Objective

Evaluate and compare the fishing pressure exerted by small-scale fisheries (SSF) and recreational fisheries (RF) operating in coastal and offshore waters of the western Mediterranean Sea on the vulnerable species exploited in these waters (target species and bycatch).

7.3 What we did

- We created an extensive dataset on coastal and off-shore catches for 1) RF, by combining information from scientific papers and grey literature from 20 coastal areas and for 2) SSF, by monitoring SSF catches in three MPAs
- We assessed species vulnerability (as fully described in Lloret et al. 2019, https://doi.org/10.1093/icesjms/fsz071) for RF and SSF distinguishing coastal/off-shore catches. Firstly, we select, among the species present in the RF and SSF dataset created, those listed in the IUCN Red List as threatened or near threatened, those classified as Least Concern but with a high index of vulnerability (IV , i.e. an expert based index that considers the life history traits and the ecological characteristics of species). Then we computed mean IV for RF and SSF and, when possible, by gear.

- We evaluated species vulnerability of species present in bycatch from RF and SSF reviewing the scientific and grey literature available.

7.4 **Results**

7.4.1 Coastal waters

Taking into consideration all types of SSF and RF, and all coastal water areas reviewed, a total of 152 different species are caught, 36 of which (i.e. 23% of the total) were deemed vulnerable. SSF caught a total of 90 species (73 by trammel net; 61 by gillnet; 36 by longline and 25 by pound net) of which 26 (29%) were deemed vulnerable. RF caught 136 different species (111 by boat fishing; 102 by shore fishing and 48 by spear fishing), 29 of which (21%) were deemed vulnerable (Figure 1). The fishing methods targeting the highest number of vulnerable species are, in order, trammel net (25 vulnerable species), boat fishing (24), gillnet (17), shore fishing (16), spearfishing (12), longlines (10) and pound nets (7) (Fig. 7.1).

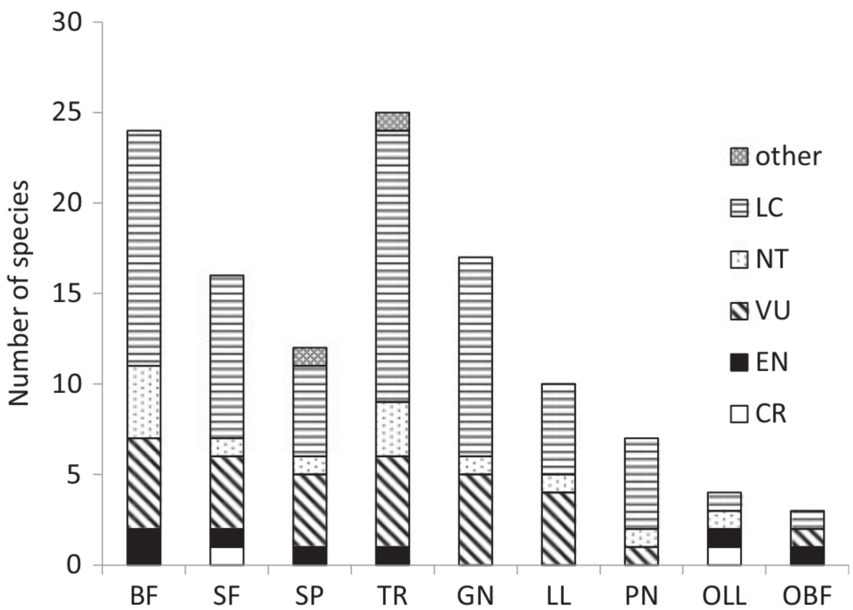

Figure 7.1. Number of vulnerable species caught by each fishing method operating in coastal and offshore waters. The fishing methods are: Recreational fisheries (BF, boat fishing; SF, shore fishing; SP, spearfishing; OBF, offshore boat fishing) and small-scale fisheries (TR, trammel net; GN, gillnet; LL, longline; PN, pound net; OLL, offshore long line). The vulnerability categories are: LC, least concern with IV >60; NT, near threatened; VU, vulnerable; EN, endangered; CR, critically endangered; Other, species not on the IUCN Red List, but which are included in International Conventions (Barcelona, Bern, and CITES conventions) and/or the EU Habitats Directive. Figure from ICES Journal of Marine Science (2019), doi:10.1093/icesjms/fsz071

Some vulnerable necto-benthic species caught by SSF and RF in coastal waters, such as European Eel *(Anguilla anguilla),* dusky grouper *(Epinephelus marginatus),* Brown meagre *(Sciaena umbra),* common dentex *(Dentex dentex)* were among the most vulnerable in terms of the IV index (>60) and are under threat according to the IUCN Red List (*A. anguilla*: CR; *E. marginatus*: EN; *S. umbra* and *D. dentex*: VU). Furthermore, nine of the coastal species targeted by small-scale and recreational fisheries were included in Annex III of the Barcelona and/or Bern conventions; one species is included in CITES-Annex II (*A. anguilla*) and another (Mediterranean slipper lobster *Scyllarides latus*) is included in the Habitats Directive-Annex V.

Of all the fishing methods in use in coastal waters, the mean intrinsic vulnerabilities (IV) were highest in the longline and spearfishing catch, with 72.6 and 64.7 (out of 100) respectively; such levels are considered as 'high to very high'. The lowest mean IV index was in the pound net catch (38.3; low to moderate vulnerability) while the mean IV index for the catches by the other coastal fishing methods (boat fishing, shore fishing, trammel net and gillnet) ranged from 43 to 51 (moderate vulnerability).

7.4.2 Offshore waters

In offshore waters, small-scale fishers fishing with pelagic longlines caught four species, Atlantic bluefin tuna *(T. thynnus),* swordfish *(X. gladius),* albacore *(T. alalunga),* blue shark *(P. glauca)*, all of which are vulnerable. At the same time, recreational boat fishers caught three species, *Thunnus thynnus*, *T. alalunga* and *M. merluccius*, all of which are vulnerable.

These five vulnerable species caught in offshore waters were among the most vulnerable both in terms of their IV values (60 or higher in each case) as well as in their classification in the IUCN Red List, because, with the exception of *T. alalunga*, which is classified as LC, all of these pelagic species are threatened (*T. thynnus*: EN; *P. glauca*: CR) or NT (*X. gladius*). Furthermore, *T. thynnus*, *X. gladius*, and *P. glauca* are included in Annex III of the Barcelona and Bern conventions.

2.1.1.2.

7.4.3 Bycatch of vulnerable species

Due to a lack of specific data on the methods used, the bycatch of vulnerable species could not be analysed separately for coastal and offshore waters. The combined bycatch in both areas by SSF and RF included a total of 27 vulnerable vertebrate species, many of which are listed in international legislations for threatened species covering cetaceans, reptiles, bony fishes, elasmobranchs and birds (including iconic species as common bottlenose dolphin *Tursiops truncatus*, loggerhead sea turtle *Caretta caretta*).

An extended description of methods and results can be found in ***Deliverable 2.8 "Report of poorly known aspects: impact on vulnerable fish species (recreational & professional fishing)"*.**

Results have been partially published in ICES Journal of Marine Science: https://doi.org/10.1093/icesjms/fsz071

8. STAKEHOLDER PERCEPTIONS

8.1 Key facts/ Recommendations

- The majority of the interviewed stakeholders considers that the current state of fisheries in the study region is bad and has worsened in the last 10 years.
- Responses about the main threats to fisheries showed a clash of views between professional fishers (both small scale and large scale) and the other stakeholders: while the first group claims that pollution and illegal fishing are the main threats to fisheries, the remaining stakeholders identify it with excessive fishing effort.
- Most stakeholders agree on the fact that MPAs provide clear ecological benefits; however, they do not believe MPAs reduce illegal fishing and conflicts among marine users.
- Professional fishers from France and Italy claim for better enforcement of existing management measures, while Spanish professional fishers suggest seasonal fisheries closures.
- The majority of stakeholders calls for a higher inclusion in participatory decision-making processes related to fisheries management (i.e. co-management).

8.2 Objective

To develop and support a participatory bottom-up approach to fisheries conservation and management (with a view to feed into the regionalized processes on conservation measures under the CFP), placing stakeholders at the core of the activity.

8.3 What we did

We developed a questionnaire to gather stakeholder opinions on the state of fisheries in the north-western Mediterranean, conflicts, role of Marine Protected Areas (MPAs), management objectives and suggested management measures to pursue fisheries sustainability. A total of 189 questionnaires were administered to professional fishers (both small scale and large scale, with the first group representing a higher proportion of the respondents) and recreational fishers' representatives, fisheries' authorities, MPA managers, scientists, and NGOs in France, Italy and Spain.

8.4 Results

8.4.1 State of fisheries

Perceptions about the state of fisheries (Fig. 8.1) were different among countries, with most Spanish respondents claiming that fisheries are currently in an acceptable state and respondents from France and Italy pointing out that they are in a bad state. Regarding trends, Spanish stakeholders mostly answered that the state of the fishery has not changed over the last ten years (although more than half of the total respondents said it has worsened a little or a lot), while more than three quarters of French and Italian stakeholders deem it has worsened.

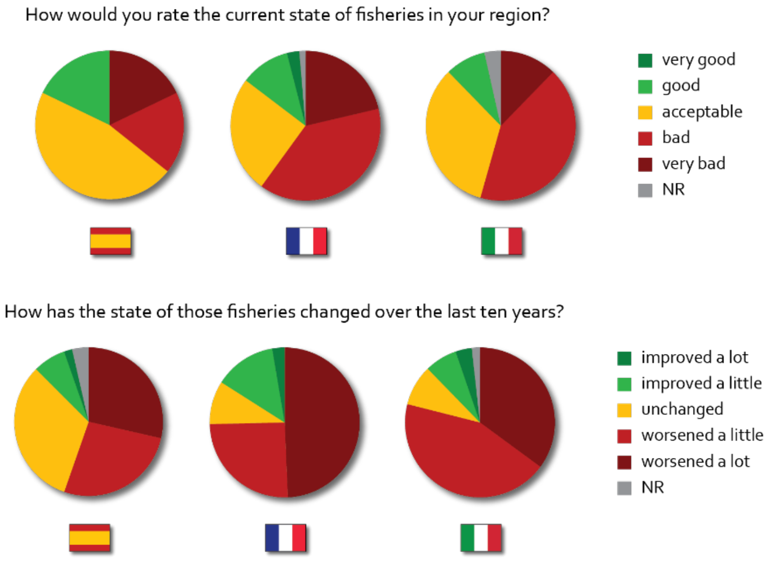

Figure 8.1. Summary of stakeholder responses to questions regarding the state of fisheries.

8.4.2 Fishing activities and other marine uses

Excessive fishing effort is considered the main threat to a good status of fish stocks (Fig. 8.2) by recreational fishers and non-fishers from the three countries. Illegal fishing was perceived as the main threat by most professional fishers in Italy, while pollution was the first most selected response by professional fishers from France and Spain. Large-scale fishing was the most frequent response to the question regarding the most impacting fishing activity by all stakeholders from all three countries. Bottom trawling was by far the most selected response to the question regarding the most impacting fishing technique by non-fishers from all three countries and professional fishers from Italy and Spain.

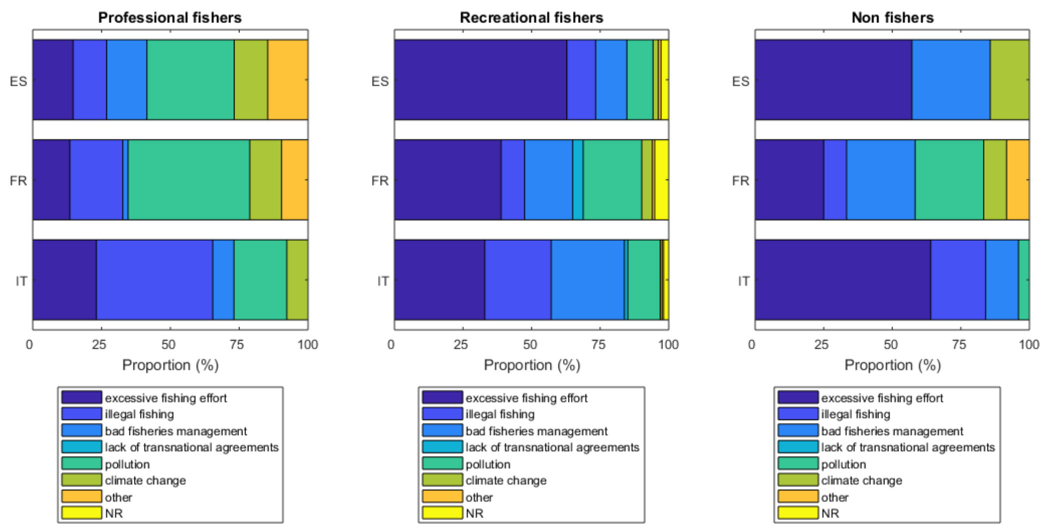

Figure 8.2. Summary of stakeholder responses to questions regarding the main threats to a good status of fish stocks.

8.4.3 Protected areas

Protected areas were generally considered to have a good to very good impact on local fisheries (>50% positive answer from all stakeholders) (Fig. 8.3), protecting biodiversity, helping increase the abundance and/or size of fish within partially protected zones and around the protected area. In Spain and France, there was also a quite wide agreement on the fact that protected areas benefit professional fishers, and professional fishers pointed out that they benefit also recreational fishers (a view not shared by recreational fishers themselves). Despite the recognition of many positive impacts of marine protected areas, the majority of stakeholders said that protected areas fall short of reducing illegal fishing (61% of professional fishers) and reducing conflicts among marine users (approx. 50% of professional fishers).

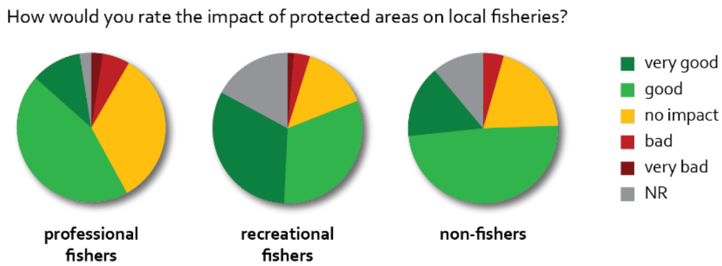

Figure 8.3. Summary of stakeholder responses to some key questions regarding the effectiveness of protected areas.

8.4.4 Fisheries management

Guaranteeing fishers' revenues was the most frequent response from professional fishers of all three countries (>30% of respondents in all countries) to the question regarding the main objective of good fisheries management (Fig. 8.4). In contrast, protecting exploited fish stocks and protecting marine ecosystems were the most frequent responses of recreational fishers and non-fishers. No clear pattern could be pointed out in the answers to the question about the most recommendable measure to achieve the management objectives, but enforcing existing management measures was indicated as a priority measure by all French respondents, Italian professionals and Spanish recreational fishers. Most Spanish professionals suggested to introduce seasonal fisheries closures. Italian recreational fishers and Spanish non –fishers mostly highlighted the need to decrease fishing effort. Italian non-fishers mostly chose to increase spatial fishery closures.

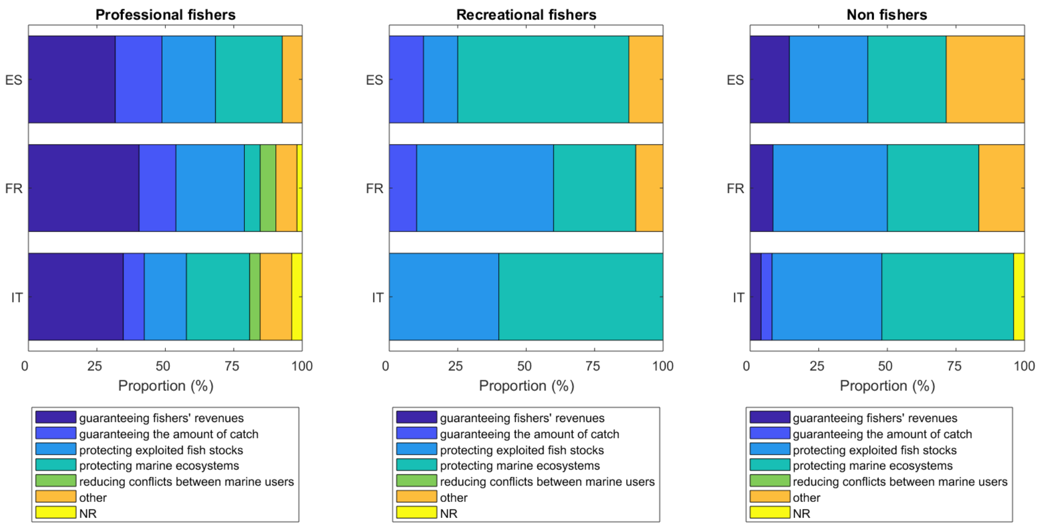

Figure 8.4. Summary of stakeholder responses to questions regarding the main objectives of good fisheries management.

8.4.5 Involvement in decision-making

The vast majority of stakeholders from the three countries considers the involvement of their professional group in the decision-making process very important and would be interested to undertake co-management or self-management initiatives (<60%,80% and 90% respectively for Italy, France and Spain).

Slightly more than half of the respondents from Spain and France indicated that they had been previously involved in experiences of co-management. In contrast, about one third of the Italian stakeholders did not answer this question, while, among those who did, the proportion of positive responses was slightly lower than one half. In general, the stakeholder category that was less often involved in co-management was that of recreational fishers.

An extended description of methods and results can be found in:

Deliverable 5.4 "Questionnaire based survey performed and results obtained from stakeholders"

And

Deliverable 5.8 "Multi Criteria Decision Framework"

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