Participatory management in a high value small-scale fishery in the Mediterranean Sea

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In the Mediterranean Sea, the dominant type of fisheries is small-scale. Coastal communities remain dependent on fisheries for their income, some of them with limited potential for economic diversification. The top-down micro-management regime has proven ineffective to secure ecological and social sustainability as it lacks flexibility and adaptation to local and regional conditions. This paper explores the advantages of using a participatory approach and a bio-economic model to develop management scenarios in a high value small-scale shrimp trap fishery in Greece. Seeking active stakeholder involvement throughout the management process advanced the identification of management measures aiming at MSY, with high levels of acceptance from stakeholders. It also increased transparency and legitimacy of the proposed management measures and could be considered as a first step towards co-management and regionalization. The participatory approach undertaken could promote compliance and facilitate the transition to sustainable fishing, ensuring the viability of coastal communities and, thus, social sustainability.

Keywords: bioeconomic, modelling, fisheries management, Mediterranean, Plesionika narval, regionalization, small-scale fisheries, trap

Introduction

The reformed Common Fisheries Policy (CFP) of the European Union (EU) highlights the socio-economic importance of European small-scale fisheries (SSFs) and encourages preferential access of SSFs to coastal fisheries resources (European Union, 2013). SSFs represent the largest part of the fishing fleet in the EU Mediterranean waters (Papaconstantinou and Farrugio, 2000). Greece exhibits the highest number of SSF vessels in the EU, comprising 16% of the total EU fishing fleet (STECF, 2017). The small-scale sector provides more than half of the country's total fisheries production and value (STECF, 2017).

With such high number of SSF vessels, fishing operations concentrating mainly in isolated areas/islands, and a plethora of landing sites, monitoring, control, and enforcement in SSFs is both problematic and challenging. To alleviate this, a participatory approach to fisheries management may prove useful. Participatory modelling is an emerging tool of stakeholder involvement into scientific modelling for a more transparent and effective management of natural resources (Röckmann et al., 2012; Shirk et al., 2012). This type of modelling facilitates a common understanding of complex problems among scientists, policy-makers, and fishers, it can help maintain a structured dialogue between different stakeholders, and it also enhances community empowerment (Wiber et al., 2004, 2009; Antunes et al., 2006; Röckmann et al., 2012). Such a participatory process also serves the aim of the new CFP for more self-management and co-management in European fisheries by increasing fishers' involvement in the planning and execution of fisheries policies (Pita et al., 2012; European Union,

2013). The potential of participatory modelling to promote the sustainability of small-scale, artisanal marine fisheries has only been investigated in a handful of case studies (Arculeo and Lo Brutto, 2011; Trimble and Bekers, 2013, 2015; Glaser *et al.*, 2015; Pita *et al.*, 2016), while no such studies have been carried out for the SSFs of the eastern Mediterranean Sea.

Bio-economic models are attracting growing interest as powerful tools to evaluate and improve the sustainability of fishing activities (Prellezo *et al.*, 2012). In this case study, the MEditerranean FIsheries Simulation TOol (MEFISTO) was used to simulate the bio-economic effects of alternative management scenarios. MEFISTO is a multispecies, multigear, and multifleet model, working under steady-state assumptions, that accommodates the dynamic nature of fisheries resources and the economic relationships within Mediterranean fisheries (Lleonart *et al.*, 2003; Maynou *et al.*, 2006; Merino *et al.*, 2007, 2015; Maravelias *et al.*, 2014). In the Mediterranean, input controls are the primary means of controlling fishing activity, and MEFISTO incorporates effort as an input control. Besides changes in effort, MEFISTO can also estimate the impact of other technical and/or economic management measures.

The trap fishery for the narwal shrimp *Plesionika narval* (Crustacea, Pandalidae) in the Dodecanese is one of the most profitable fisheries in Greece, and constitutes a traditional fishing activity with high socio-economic importance, especially for the smaller islands of the archipelago (Kalogirou *et al.*, 2017). Typically, monitoring and control of the Dodecanese SSF is problematic and obstructs the top-down implementation of prescriptive regulations. To overcome this and ensure future buy-in by fishers into proposed management measures we actively involved local fishers, fisheries managers, administrators, and policy makers in the design and implementation of the project.

Similar small-scale trap fisheries for congeneric shrimps exist in other areas of the Mediterranean Sea and the eastern Atlantic (González *et al.*, 2001; Castriota *et al.*, 2004; Arculeo and Lo Brutto, 2011; Arrasate-Lopez *et al.*, 2012; Sousa *et al.*, 2014), but in all cases there have been no studies investigating ways to improve their management. In 2014–2015, a 2-year EU-funded pilot project (Plesionika Manage) (http://plesionika-manage.eu/en/) was carried out in the Dodecanese archipelago of the south eastern Aegean Sea (Figure 1), aiming to produce a participatory management plan for the local SSF targeting the narwal shrimp. Here, we present the participatory approach undertaken for the identification of management measures. Results from the participatory bio-economic modelling are also shown and discussed in the light of promoting SSF sustainability in the area.

Material and methods
The fishery
According to national legislation, the trap fishery in Greece is closed for 3 months (May–July). This is also the period of the highest narwal shrimp abundance (Kalogirou *et al.*, 2017) and the peak of the touristic period that increases demand for high quality fish food supply. Provided that a complete reporting of activities and catches would be submitted, a number of experimental fishing licenses was issued (2005–2011) to accommodate fishers' demand for fishing during the ban period. Since 2012 these exemptions ceased. A number of fishers continued to fish illegally during the ban period causing conflicts with those following the rules. As a result, the Plesionika Manage project (http://plesionika-manage.eu/en/) was timely in the sense that provided fishers with the incentive to alleviate disputes and co-manage a high value fishery resource.

Monthly experimental surveys were carried out from November 2014 to October 2015 throughout the area where the fleet normally operates. During the course of the project (2014–2016), gear selectivity trials were carried out, while logbook and socio-economic data were also collected. The logbook dataset included vessel and owner name, length overall and horse power of the fishing vessel, name of the fishing area, time of day when the traps were set and retrieved, wet headed weight of shrimps and number of traps that had been deployed. Economic data were also collected using suitable questionnaires where trap fishers provided information on both the total fixed and total variable costs of their fishing operations and indicated their total fishing days.

The SSF fleet consists of 42 vessels with a length from 4.5 to 14 m, usually operated by 1–2 fishers. The fishery operates mainly from April to October, peaking in the summer months. Trap fishing for narwal shrimp takes place over rocky substrates from dusk till dawn by means of baited bottom shrimp traps at depths ranging from 5 to 200 m, but usually at depths between 70 and 90 m. Night fishing is preferred due to the higher species activity and the reduced risk of predation on catches. The mesh size of traps ranges from 8 to 12 mm and the size of the narwal shrimps caught ranges from 7 to 20 mm (carapace length—CL), with the females dominating the catch. Size at maturity (CL_{50}) for *P. narval* in the studied area is 11.7 mm (Anastasopoulou *et al.*, 2017). Based on that threshold, 16% of the catch by numbers in 2015 can be classified as juveniles. The narwal shrimp accounts for ca. 70% of the total catch of that SSF, with other commercial species including *Plesionika edwardsii* and *Octopus vulgaris*. Headed shrimps are sold directly to fishmongers and restaurants in the Dodecanese islands with an average price of 25€ per kilo and an overall estimated value of around 875 000€ for 2014 (Kalogirou *et al.*, 2016).

Participatory approach
Stakeholders were categorized into stakeholder groups: decision makers, scientists, and other actors following Röckmann *et al.* (2015). Stakeholders included members of the National Greek Parliament at the prefecture of Dodecanese ($n = 5$), representatives from the Greek Ministry of Agriculture ($n = 10$), representatives from Dodecanese municipalities ($n = 11$), the deputy mayors of Rhodes ($n = 3$), the vice governor of Dodecanese responsible for rural economy, veterinary, and fisheries ($n = 1$), representatives from the District of south Aegean ($n = 8$), representatives from the General Directorate of Dodecanese for rural economy, veterinary, and fisheries ($n = 5$), regional policy officers at the Department for Fisheries at the District of south-eastern Aegean ($n = 8$), representatives from the Decentralized Administration of the Aegean ($n = 3$), representatives from local port authorities responsible for fisheries control at sea ($n = 5$), fishers' associations (both district-level and island-level) ($n = 8$), individual fishers targeting the narwal shrimp ($n \approx 40$), other fishers ($n = 40$), and environmental NGOs ($n = 6$) (Supplementary Table S1). Some of the meetings were also open to members of the public.

The participatory process of stakeholder involvement initially started in 2013, prior to the submission of the research project
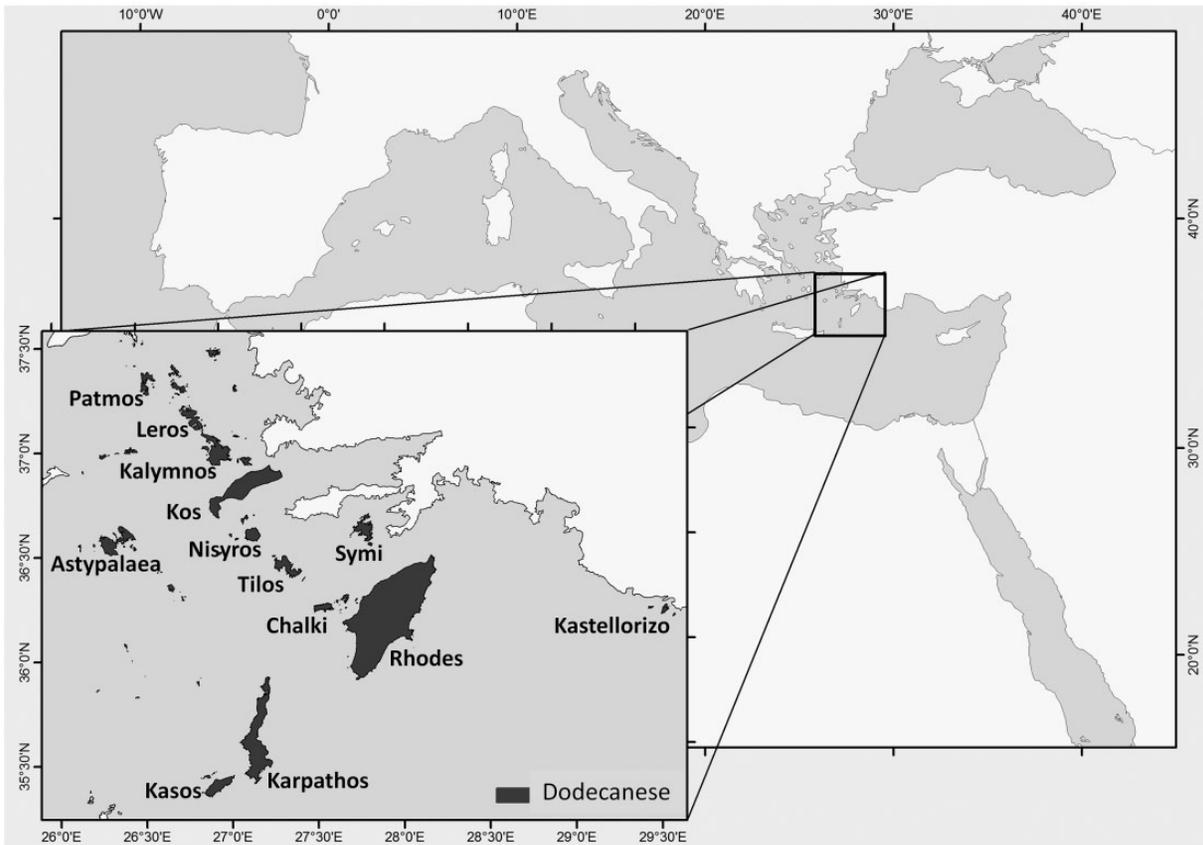
Figure 1. The Dodecanese archipelago in the eastern Mediterranean where the small scale trap fishery for *P. narval* operates.

proposal to the European Marine Fisheries Fund 2007–2013. At that stage, local knowledge of fishing activity from fishers' associations and individual fishers targeting the narwal shrimp, as well as from fisheries policy officers, illustrated the need for developing a management plan for this fishery. After project approval and during the course of the project (2014–2016) four formal open meetings were arranged: one prior to inception of samplings and project approval, two during samplings, and one final meeting where the project results and management scenarios were presented (Supplementary Table S1). In all meetings stakeholders were invited to give feedback and insights to the project both orally and through written text. During the project development, all relevant fishers were involved. For the fishers who could not be contacted in person for any reasons (e.g. bad weather conditions) telephone calls were carried out, either during samplings or during meetings, and the fishers were asked to provide their insights to all issues relevant to the management of the narwal shrimp fishery (e.g. trap selectivity, banned periods). Posters of the project with contact details of project members were set up at all fishers' associations in all relevant islands of the studied area. At all stages personal data has been rendered anonymous. All other potentially interested parties and the wider public were informed through flyers, articles in local and national newspaper and fishers' journals, personal communication, and through the project website. During the monthly samplings in all islands and personal visits to local harbours, presentations of the project development were given to those fishers, local port authorities,

municipalities, and members of the public that were not able to attend the formal meetings arranged (Supplementary Table S1). All management scenarios were presented at the final meeting (held in February 2016) and a consensus was achieved on specific management measures.

Bio-economic modelling

MEFISTO consists of three modules or "boxes": a "stock box", a "market box", and a "fisherman box" (for a detailed description see Lleonart *et al.*, 2003). These three modules incorporate stock dynamics, market development, and fisher behaviour, and they are linked through various functions such as harvest, fishing mortality, price formation, costs, investment, fishing effort, and catchability. The stock box simulates multispecies, age-structured stock dynamics, considering two types of species: the main species, whose dynamics are known and modelled by an age-structured population model, and the secondary species (not included in this case study), whose catches are proportional to one of the main target species. During model iteration, the stock box receives data on effort and catchability from the fisherman box, whose product is fishing mortality, and generates catches, which are then forwarded to the market box (Lleonart *et al.*, 2003). The market box converts the catch of each species generated by the stock model into revenues, via constant price functions, and then revenues are imported into the fisherman box. Although market price varies with landing amount, price dynamic was not taken

Table 1. Summary of the economic, technical, and market parameters of the fishing fleet, which were used in the MEFISTO fisherman and market boxes (status quo).

Parameters	Mean	s.e.
Capital (€/vessel)	24 643	4 272
Annual costs in (€/vessel)	2 692	302
Daily fuel consumption (L/vessel)	38.52	2.34
GT/vessel	4.51	0.76
Crew/vessel	1.45	0.11
Annual fishing days	146	4.22
Shrimp price (€ /kg)	25	–
Opportunity cost (%)	2.5	–
Financial cost (%)	4.0	–
Fuel price in (€/L)	0.7	–

Table 2. Biological parameters used in the MEFISTO stock box (status quo).

Parameters	*P. narval* males	*P. narval* females
L_∞ (mm)	17.00	21.04
K (year^{-1})	0.87	0.89
t_0 (year)	−0.30	−0.31
a	0.0014	0.0012
b	2.74	2.81
Age classes (year)	0–2	0–2
Natural mortality (all ages)	0.99	1.01
Fishing mortality (*F*bar)	0.94	2.14
Maturity (% by age)	Age0: 54%; Age1: 94%; Age2+: 100%	

into account since market price has not shown any significant variation in the last 10 years. The technical, economic, and market parameters of the fishery were imported to MEFISTO's market and fisherman boxes (Table 1). Detailed data on catch and effort (days at sea, number of traps) for 2015 were obtained from logbooks.

Information on the population dynamics and fishing pressure of the narwal shrimp stock was obtained by means a Length Cohort Analysis (LCA) applied on age-sliced catch data, which was performed separately for males and females using the VIT software (Lleonart and Salat, 1997) (Supplementary Table S2). The reasons for choosing this method was because there was only one year of fisheries data available, which prohibited the use of methods requiring multiple successive cohorts (e.g. XSA), and that an age-structured model was needed to model changes in selectivity, which prohibited the use of surplus production models. Also, VIT was preferred because it is routinely used for the stock assessment of crustacean species with distinct sexual dimorphism (STECF, 2013, 2014). A key assumption of VIT is that the stock is in equilibrium, which could potentially be problematic for stocks where there are large interannual variations in stock size and fishing mortality.

In the case of the narwal shrimp stock, separate assessments were carried out for males and females also because the larger females were expected to be under higher fishing pressure than the smaller males (Sousa *et al.*, 2014). Natural mortality, growth parameters and allometric equation parameters were estimated from the catch samples taken throughout the year (Table 2). The growth parameters were calculated using the ELEFAN model (Gayanilo *et al.*, 1989, 2005), while natural mortality was calculated using the ELEFAN-derived K values (Gunderson and Dygert, 1988). The stock assessment suggested that exploitation starts already at age 0, at a size (CL) of 7 mm, and that the F averaged over age-classes 0–2 (*F*bar) in 2015 for males and females combined was *F*bar = 1.29, while $F_{0.1} = 0.94$ (Kalogirou *et al.*, 2016).

The projection period for the simulations was set to 15 years with an annual step. Year 2015 was the reference year assuming recruitment uncertainty (lognormal distribution function with mean $= R_{2015}$ and standard deviation $= 0.01$). Each scenario was applied in year 5. This time-frame was the one actually presented in all stakeholder meetings, based on a dual rationale: to give a realistic time-frame for the actual implementation of the new management measures, which would not take place sooner than 5 years later, given the slow pace of the consultation and legislative

processes, and to provide a clear visual contrast between the pre- and post-implementation period. 100 stochastic iterations were carried out for each simulation run. The results were SSB, catch and profits, in a relative scale, presented as mean values of the 100 simulation runs with 95% confidence intervals. The wide participatory approach described earlier enabled the identification of the following management scenarios:

(1) Selectivity. The current mesh size used ranges from 8 to 12 mm, with the majority of fishers using 12 mm. The 8 mm are considered less selective. Fishers asked us to investigate the effects of the 8 mm traps. To accommodate their request, we used the results from the project's selectivity experiments of 8 and 12 mm mesh size traps, resulting to CL50 estimates of 8.25 and 11.28 mm respectively (Kalogirou *et al.*, 2016), and modelled a ∼23-fold and a ∼9-fold increase in F at age 0 of males and females, respectively.

(2) Distribution of fishing effort. It was observed that during summer the large ovigerous *P. narval* occupied shallow areas with water depth less than 30 m, susceptible to low fishing pressure (Anastasopoulou *et al.*, 2017). The stakeholders involved in the project requested to examine the effects from closing shallow areas in the summer. Due to the absence of a spatial component in MEFISTO, this scenario was modelled by reducing the F of the plus age-class of *P. narval* females (age 2+, corresponding to sizes >18 mm) to zero.

(3) Temporal allocation of fishing effort. Fishers suggested examining the effects of an opening of the fishery from May 1st to August 31st and a closure of the fishery for the remaining year (September–April). This requires a reduction of the annual fishing effort by about 26%. This request was due to May–August corresponding to the highest abundance of narwal shrimps in the area, and also coinciding with the touristic season, when demand is high.

(4) Reduction of fishing effort. A scenario was built to reduce exerted F to exploit the stock at MSY levels. According to the outcome of the assessment of narwal shrimp stock undertaken within the Plesionika Manage project, a 30% reduction of effort would be required to reach $F_{0.1}$ sustainability levels (Kalogirou *et al.*, 2016). This was achieved with the withdrawal of 14 out of the 42 vessels corresponding to a 30% reduction of the fleet's GT, assuming linearity between effort and fishing mortality. Alternatively, a reduction in the number of gears (traps) may also be used to reach the same objective.
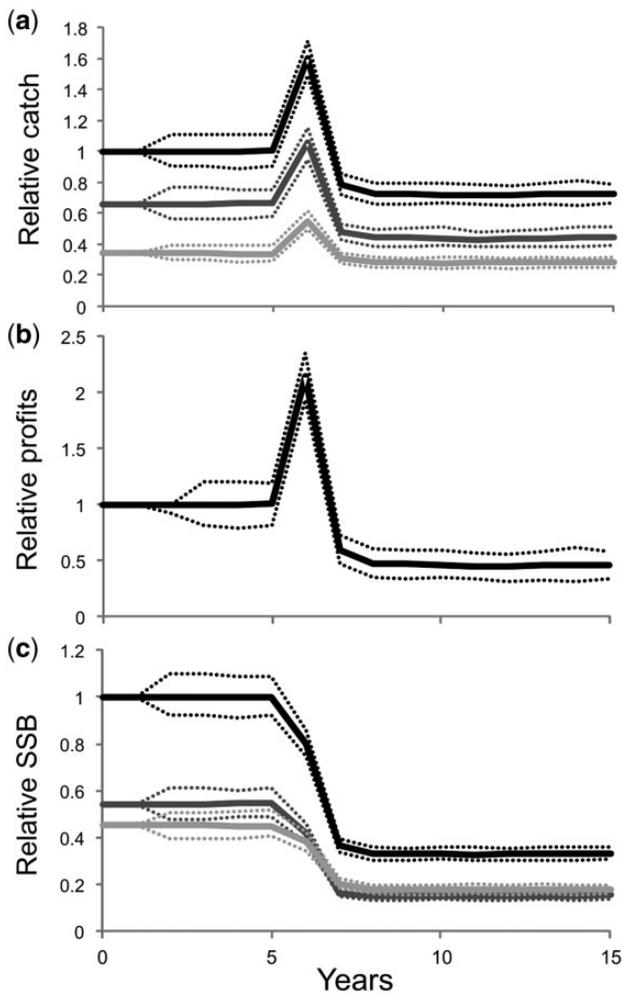
Figure 2. Scenario 1 (8 mm mesh size trap) outputs on relative (a) catch, (b) profits, and (c) SSB. Implementation year: 5. Black line: total values, dark grey: females, light grey: males, dotted: confidence intervals.

Figure 3. Scenario 2 (redistribution of effort to >30 m depth) outputs on relative (a) catch, (b) profits, and (c) SSB. Implementation year: 5. Black line: total values, dark grey: females, light grey: males, dotted: confidence intervals.

Results

The scenario outputs were as following:

Selectivity

If the mesh size of the traps is reduced to 8 mm the catch will increase by approximately 60% and profits by almost 50% in the first year, mainly due to an increase in the F of age 0 specimens. Evidently, as females are larger than males, these effects will be more pronounced for females (Figure 2). From the second year onwards, the catch will be reduced by ca. 30% and the profits by ca. 50% in comparison to the status quo, which is a strong indication of growth overfishing. A significant decrease in spawning stock biomass per recruit (SSB) (ca. 60%) will be observed in year three of the implementation with females being more affected than males (Figure 2c). Long-term Fbar will increase by 30%, to become ca. 80% higher than $F_{0.1}$.

Distribution of effort

The spatial redistribution of effort to deeper waters (>30 m) to avoid the high aggregations of large females (age 2+, CL > 18
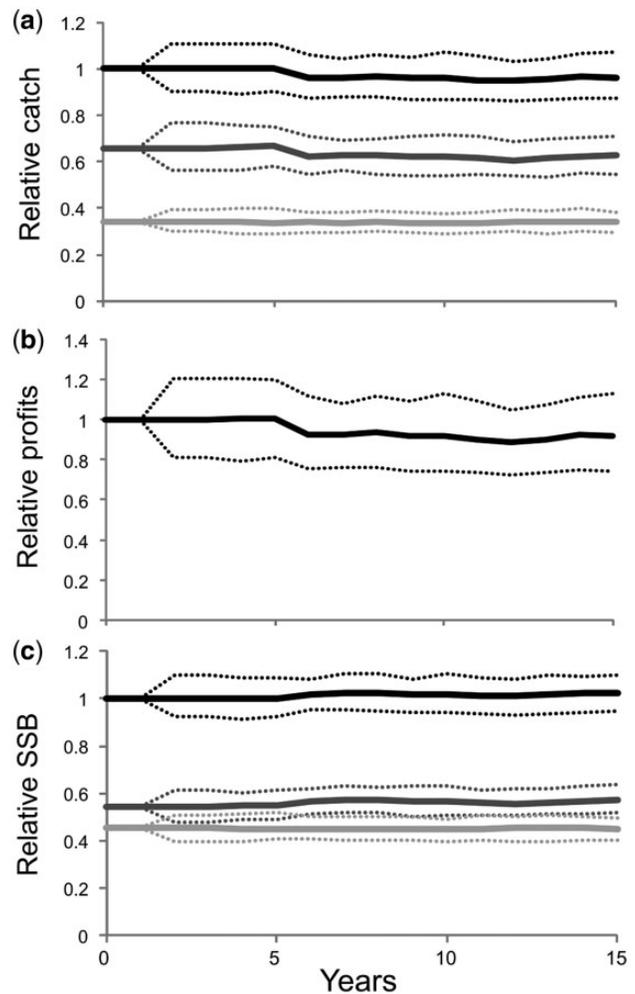
mm) in the shallow areas, did not affect significantly either the fleet or the species (Figure 3). Although there was a slight increase in SSB (Figure 3c), both the fleet's catch and profits decreased by less than 10% compared to the status quo (Figure 3a and b). Fbar would be reduced to levels close to $F_{0.1}$, because current F on females aged 2 used in the calculation of Fbar is very high.

Temporal allocation of effort

Fishers specifically requested for a scenario demonstrating the likely effects from a banned fishing period from September to April alongside an open period between May and August. This scenario resulted in minor reductions in catch/profits in implementation year 1 and in higher profits from year 2 onwards (Figure 4a and b). Albeit with lower catches in year > 2, the higher profits achieved were due to the reduced fishing effort (days at sea) and thus to the reduced fleet costs and expenses. As a result of the female biomass increase, the SSB also increased by almost 10% (Figure 4c). Fbar would be reduced to levels close to $F_{0.1}$.
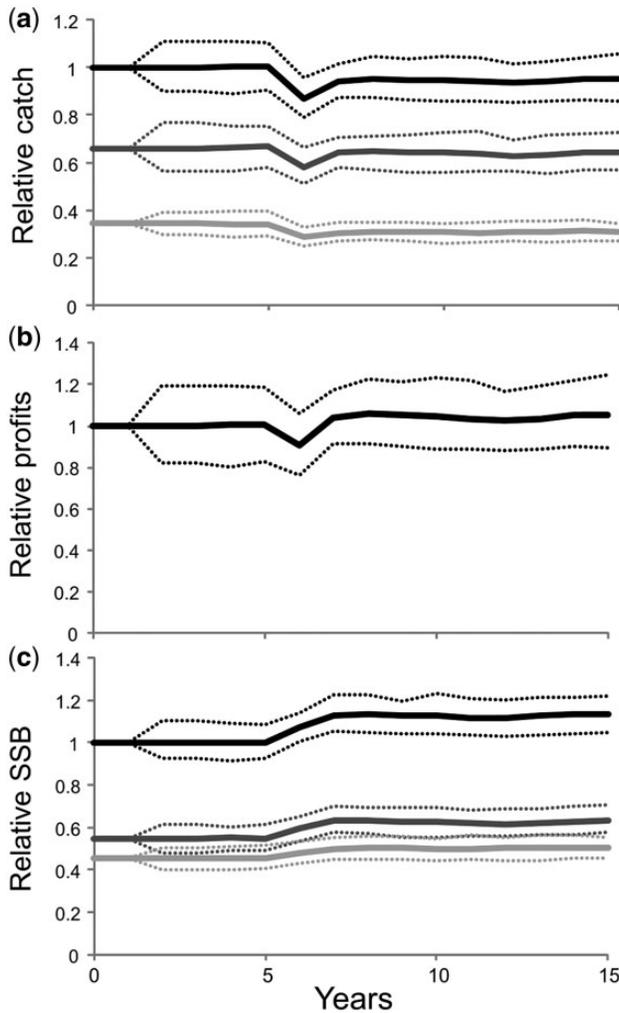
Figure 4. Scenario 3 outputs (fishing period open: May–August, closed: September–April) on relative (a) catch, (b) profits, and (c) SSB. Implementation year: 5. Black line: total values, dark grey: females, light grey: males, dotted: confidence intervals.

Figure 5. Scenario 4 outputs (30% reduction of fishing effort) on relative (a) catch, (b) profits, and (c) SSB. Implementation year: 5. Black line: total values, dark grey: females, light grey: males, dotted: confidence intervals.

Reduction of effort

A reduction of exerted effort by 30% and the associated reduction of Fbar to levels close to $F_{0.1}$, either through scrapping of vessels (modelled here) or by reducing the number of gears employed, was beneficial for both the stock and fishery (Figure 5). It should be noted that, though in theory this is economically beneficial for the remaining vessels, there is a possible negative impact on the employment due the scrapping. Expectedly, in year 1 catch (20%) and profits (10%) declined. In year ≥ 2 the catch was slightly lower than the status quo, while profits increased by approximately 20% (Figure 5a and b) due to the reduced operating costs/ expenses of the smaller fleet. An increase in female biomass also led to a higher SSB (ca. 15%) (Figure 5c).

Discussion

This study describes a participatory modelling approach to a SSF management in the Mediterranean Sea. Similar approaches have been implemented in mid-scale fisheries in the Mediterranean Sea (Röckmann *et al.*, 2012; Lembo *et al.*, 2017) and small-scale fisheries in other global marine areas (Wiber *et al.*, 2004; Trimble
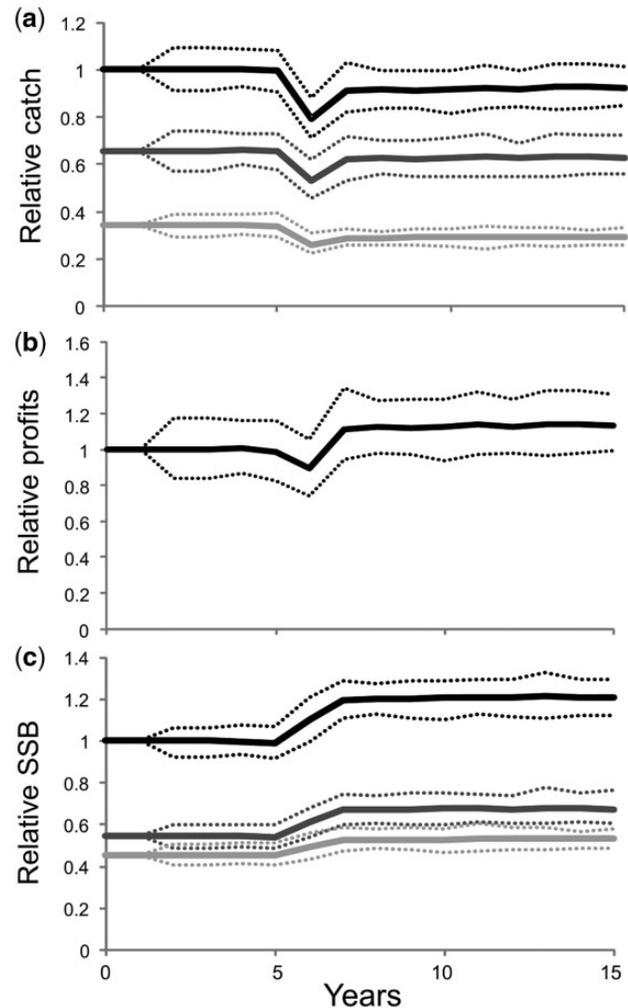
and Berkes, 2013, 2015; Glaser *et al.*, 2015; Pita *et al.*, 2016), but this is the first documented attempt to use such a participatory modelling approach in a Mediterranean SSF. Our results indicate that seeking stakeholder involvement throughout the management process, i.e. proposal preparation, negotiation phase, project kick-off, conception of management scenarios, model parameterization, and evaluation of model outputs, advanced the identification of realistic and sustainable management measures with high levels of acceptance from stakeholders. The sector also developed a sense of responsibility to manage the fishery that comprises a vital element of the reformed CFP and its regionalization approach. An increased transparency and legitimacy of management measures through a greater stakeholder involvement is a step towards a successful self-management and co-management of fisheries resources exploited by small-scale fleets (Pita *et al.*, 2012; Trimble and Berkes, 2013; Stevenson and Tissot, 2014). When high value fisheries resources are exploited by small-scale fleets operating over a vast coastline of different islands and islets, as is the case with the narwal shrimp fishery in the Dodecanese, participatory management could be the remedy

to the highly problematic monitoring and enforcement of challenging top-down rules and regulations. Such an approach may also constitute a first essential step towards regionalization. A proactive role for the fishing industry would foster a culture of involvement, responsibility, and compliance.

The selectivity scenario was found to have the greatest effect on both the stock and the fishery. A change to an 8 mm mesh had pronounced negative effects on mid-term catch, profits and SSB, due to the removal of individuals before they reach the size where the highest yield-per-recruit is attained (growth overfishing) (Froese *et al.*, 2008) and size at maturity (Anastasopoulou *et al.*, 2017). The negative effects from removing too many juveniles too early have been illustrated by previous studies (Myers and Mertz, 1998; Vasilakopoulos *et al.*, 2011, 2016), and constitute a central problem of Mediterranean fisheries (Vasilakopoulos *et al.*, 2014). The levels reached by the indicators in the prediction are under the assumption of 100% survival after escapement of the shrimps from the traps.

Scenario 2 (avoidance of large ovigerous females) did not result in a substantial increase in SSB, due to age-class 2+ representing a low part of the stock, and no stock–recruitment relationship having been considered. In any case, the protection of large ovigerous females via spatial effort restrictions could achieve an increase in the survival of these highly fecund individuals and potentially improve stock levels (Cardinale and Arrhenius, 2000; Froese, 2004). Although few fishers were sceptical towards the closure of the shallower areas, most fishers agreed that the fleet can easily change their fishing behaviour to avoid shallower waters.

The scenarios involving a decrease in the total fishing effort, either through a change in the closed period (Scenario 3) or through a reduction in the number of vessels/traps (Scenario 4), involved substantial mid-term benefits for both the stock and the fishery. This is not surprising, given that the narwal shrimp stock in the Dodecanese is perceived as overfished (Kalogirou *et al.*, 2016) and reduction of fishing mortality in overfished stocks usually results in mid-term gains in catch (Merino *et al.*, 2007; Maravelias *et al.*, 2014). In this case study, the fishers clearly preferred the reduction in effort to be realized through a shift of the banned period to September–April, rather than through decommission of vessels or reduction in the total number of traps. If this condition was met, the fishers were willing to adopt improvements of gear selectivity, avoidance of shallow areas with high concentrations of large ovigerous females, and adoption of an upper limit for the number of traps allowed on board. The authorities' representatives expressed their support, as well as some concerns on their capability to enforce a longer closed period (September–April) and on the need of landing ports for the control of landed catches.

Many coastal communities, as those examined here, remain dependent on fisheries for their income, some of them with limited potential for economic diversification. It is therefore essential to secure a future for coastal, small-scale fishers taking fully into account the particular situation of the small- and medium-sized enterprises. The top-down micro-management, lacking flexibility and adaptation to local and regional conditions, and the low attractiveness of the fishing activities alongside the population decline of several coastal communities dependent on fishing have been recognized among the shortcomings of previous policies. The lack of attractiveness is the result of relatively low wages (compared to jobs ashore), combined with hard working

conditions and safety concerns. In addition, the number of jobs depending on the fisheries sector is declining in the majority of European coastal areas (STECF, 2017), which puts some of them at risk of not being viable in the future. Compared to the whole of the EU economy, the EU fisheries sector represents less than 0.1% of total EU employment (STECF, 2017). However, in some Member States (e.g. Greece, 1.5%), regions (e.g. Galicia, Spain, 3%), or coastal communities (e.g. Killybegs, Ireland, 68%) the sector is an important source of jobs (European Commission, 2009), yet employment trends are negative (STECF, 2017). Bringing and keeping the capacity of the fishing fleets in line with fishing opportunities will inevitably lead to less overall employment in the catching sector. However, fishing at MSY levels has the potential to create new jobs in the catching sector very similar to those proposed by the CFP reform (European Union, 2013), ultimately resulting in increases in catches and, consequently, in employing more capital and manpower in the fleets. The participatory approach undertaken here, allowed for the identification of management measures that could promote sustainable fishing at MSY levels in the study area. Currently, these measures are considered by relevant authorities and stakeholders to launch a multiannual management plan for the Dodecanese narwal shrimp fishery. Achieving environmental sustainability as quickly as possible is a precondition for social sustainability, one of the core CFP objectives, with the aim to ensure the viability of coastal communities by promoting economic growth and creating jobs (European Union, 2013). To this end, our work can be used as a role model for other SSFs.

It should be noted that no quantitative analysis of the stakeholder engagement was carried out for this study to formally investigate how different stakeholder viewpoints were taken into account in the design and implementation of management scenarios (Sampedro *et al.*, 2017). Such a quantitative analysis could implement the Q methodology (Cavanagh *et al.*, 2016), cognitive map methodology (Prigent *et al.*, 2008), or a Multi Criteria Decision Analysis (Estévez and Gelcich, 2015). This is something to be considered for similar studies in the future. However, in this particular case study, there was not much conflict involved as the process was initiated from the stakeholders' side, with a clear objective of improving an out-dated legislation for the benefit of the fishery. In addition, the openness of the meetings before, during and after the course of the project, ensured that all viewpoints were clearly expressed and taken into consideration for the formulation and assessment of the management scenarios. Owing probably to the small scale of the local communities, all parts involved were more or less on the same page: that of ensuring the sustainable management of a traditional fishery. Therefore, generally there was a consensus regarding the management priorities and optimal management scenarios.

Identifying uncertainty in participatory bio-economic modelling is of particular importance to ensure transparency and legitimacy of the proposed management measures (Röckmann *et al.*, 2012). Here, the main sources of uncertainty identified were data uncertainty, model uncertainty, and implementation uncertainty. Regarding data uncertainty, both the authorities' representatives and scientists agreed that the findings of the participatory modelling process should be treated with caution as they were largely based on just a single season's data (2014–2015), and that a multiannual monitoring would be needed to ensure collection of more data and a more representative monitoring of the fishery. Regarding model uncertainty, it should be noted that the

implications of the equilibrium assumption by the LCA/VIT assessment are significant when the stock suffers from reduction in abundance and high exploitation (Rätz *et al.*, 2010). Due to the limited data available in this case study it was not possible to assess the degree of possible deviance of this stock from the equilibrium, and this is another reason why a strict quantitative interpretation of our findings is not appropriate. MEFISTO also provides a simplification of the actual future dynamics of the fishery, as it assumes stability in the stock and market-related processes, without considering, for example, the abrupt changes known to occur in the Mediterranean ecosystems (Vasilakopoulos *et al.*, 2017). In particular, the assumption taken here of a stable recruitment with some stochastic uncertainty is a strong one. Recruitment is expected to play a major role in the dynamics of the short-lived narwal shrimp; thus, a better understanding of the effects on recruitment of both fishery-dependent (e.g. fishing pressure on juveniles and/or large spawners) and fishery-independent processes (e.g. environmental stressors) needs to be developed. Regarding implementation uncertainty, while the authorities' representatives appreciated the fishers' willingness to adopt more sustainable practices to reach MSY levels and accept a closed period from September to April in return for an opening of the current closed period (May–July), they expressed their concern on their ability to control the implementation of the new measures. They argued that without a high degree of self-management, measures such as the new closed period or the avoidance of shallow areas would be really hard to enforce. Control, enforcement and compliance to fisheries regulations has always been problematic in the Mediterranean Sea (Smith and Garcia, 2014; Vasilakopoulos *et al.*, 2014). It is envisaged that via the participatory approach undertaken here, increased transparency and stakeholder participation will foster compliance and safeguard the sustainable exploitation of the resource. Currently, access to the fishery is controlled via a specific license system, that can and should be made conditional upon compliance by fishers. Designated landing ports could also promote fisheries monitoring and reduce unreported and unregulated fishing activities.

Recently, the Medfish4ever Ministerial Declaration organized jointly by the EU and GFCM reiterated the importance of the sustainable development of SSFs and urged for support to ensure the livelihood of coastal communities. To this end, Mediterranean member states agreed to set up as from 2018 a regional plan of action for SSFs, on the basis of the FAO Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries (FAO, 2015). This plan of action will streamline funding schemes to strengthen the support to local projects related *inter alia* to fisheries co-management, low-impact fishing techniques and fishing gear, social inclusion, valorization of catches, diversification, and the contribution of fishers to environmental protection, data collection and collective research efforts. Our work can be used as a typical paradigm of this new governance era for Mediterranean fisheries and for similar fisheries worldwide. It provides an example on how to develop a new comprehensive governance involving all stakeholders and empowering fishers, especially within the small-scale sector, to take direct responsibility in the participative management of fisheries, building on the Mediterranean self-regulatory tradition. It can also serve to promote and establish a culture of compliance and trust based on transparency, as well as on efficient prevention, detection and action, to ensure a rule-based management of fisheries. Furthermore, it may ensure adequate data collection and exchange in all types of fleets including small-scale and recreational fisheries, and reinforce scientific knowledge of fish stocks. To illustrate the power of the participatory process it is worth noting that in the case of the narwal shrimp fishery examined here it has been fishers in particular who currently push for the implementation of the accepted management scenarios developed during the Plesionika Manage project (SK, pers. comm.), something quite unusual in the traditionally top-down regulated Greek fisheries.

In conclusion, this work demonstrates how to develop fisheries management measures in the framework of a comprehensive participatory approach for an iconic commercial stock targeted by a low impact fishing method, taking into account the specificity of SSFs as a major source of food, income, and activity for coastal communities.

Supplementary data

Supplementary material is available at the *ICESJMS* online version of the manuscript.

Acknowledgements

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