Ocean and Coastal Management

Testing Best Practices in small scale fisheries management: evidence from a collaborative intervention in two Marine Protected Areas of the Central Mediterranean Sea

--Manuscript Draft--

Manuscript Number:	
Article Type:	Research Paper
Keywords:	selective fishing gears; social-ecological outcomes; small-scale fisheries (SSF); participatory management; sustainable fishing practices
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	increased dialogue between fishers and decision-makers can generate more positive perceptions towards the MPA and improve mutual understanding, helping to reconcile biodiversity conservation with human wellbeing for SSF.
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Abstract

Adopting best practices (BPs) in small scale fisheries (SSF) is generally acknowledged to enhance ecological and social conditions, improving SSF management overall. Yet studies that empirically assess the social-ecological effects of BPs on social-ecological outcomes (e.g., fishers' catches, revenues, and level of support towards management measures) remain limited. This study aimed to assess the effect of adopting BPs on catch per unit of effort (CPUE), revenue per unit of effort (RPUE) and small-scale fishers' perceptions in two Marine Protected Areas (MPAs) in Campania, Italy (Santa Maria di Castellabate (CAS-MPA) and Regno di Nettuno (NET-MPA)). Two BPs were implemented and tested in the two MPAs: i) five selective gears with three different mesh/hook sizes and ii) a participatory approach to increase dialogue between fishers and managers.

The results from eight stakeholder focus groups, 36 surveys with small scale fishers and 158 SSF operations monitored using photo-sampling and image analysis techniques (between 2020-2022) are presented. Analyses of landings showed that significant differences in CPUE and RPUE between mesh/hook sizes were found in a limited number of cases (i.e., combination of fishing gears used in the 2 MPAs). Significant but divergent effects were found on CPUE in the two MPAs for gillnet used to target amberjack (GNA) only. RPUE was significantly higher in the NET-MPA when adopting the largest mesh size for GNA and the largest hook size for bottom longlines (BLL). When analyzing perceptions, fishers generally reported that the BPs adopted had a positive impact on their revenues, improved their relationship with MPA managers and increased their support for the MPA. The study concluded that increasing mesh/hook sizes, within the range tested here, does not negatively impact fishers' revenues, while likely improving the status of target populations. Moreover, the increased dialogue between fishers and decision-makers can generate more positive perceptions towards the MPA and improve mutual understanding, helping to reconcile biodiversity conservation with human wellbeing for SSF.

1. Introduction

Small-scale fisheries (SSF) play an important role in providing essential coastal livelihoods, supporting food security and providing jobs globally (FAO 2022). In the Mediterranean, SSF have historically played a primary role in human coastal communities and currently encompass over 82% of the fishing vessels, 27% of total revenue and 15% of the total catch, providing essential food, and employing on average 0.1% of coastal residents in the Mediterranean region (FAO 2022). Fifty-nine percent of the total employment on board fishing vessels in the Mediterranean comes from SSF (FAO 2022). Despite their importance at the regional level, SSF generate a low profit margin: 17% of total annual revenue, compared to 27% for the large-scale fleet (FAO 2022). The continued overexploitation of fisheries resources is having detrimental consequences on fish stocks, threatening the future of the SSF sector (Penca et al., 2021). The most recent assessment of fish stocks has highlighted a critical state for fisheries, revealing that 73% of the Mediterranean and Black Seas' commercial fish stocks are fished at unsustainable levels (FAO 2022). This has contributed to a decline in the number of SSF vessels and associated jobs (Guyader et al. 2013, Di Cintio et al. 2022) which is further compounded by the current poor turnover within the sector (Gomez et al., 2006; Christy et al., 2021).

However, with the global population expected to reach 8.5 billion by 2030 and 9.7 billion by 2050, there is substantial pressure on fish stocks to provide the essential food security required, demanding more sustainable fisheries production and crucially more appropriate and accepted management measures. Adopting "best practices" (BPs) (such as, more selective gears and environmentally responsible fishing techniques, broad engagement, inclusiveness, and communication in support of effective SSF management) represents a key strategy to reconcile the health of fish stocks and human well-being (Guidetti et al. 2010, Claudet and Guidetti 2010, Di Franco et al. 2016, Westlund and Zelasney 2019). The set of BPs that are currently gaining traction as standalone BPs are those focused on participatory approaches and social responsibility, broad engagement, inclusiveness and partnerships, the power of communication, and gender equality (Lawless et al., 2021; Mangubhai et al., 2022). To address the complex challenges facing SSF, adopting these bottom-up processes, gives a greater understanding of where the problems lie and offers context within local realities, ensuring that the management measures implemented are fit for purpose and suit the local context (Cavallé et al 2020). Increased participation, in all its forms, allows for increased dialogue among various stakeholders and managers, thus bringing multiple points of view to define problems and reach potential solutions, that consider the complexity of the ecosystems while also recognizing the multiple interests of stakeholders, including fishers (Di Franco et al., 2020). Among the main advantages, the increase in dialogue provides more transparent and inclusive decision-making processes. This in turn can lead to a: 1) greater sense of ownership and perceived legitimacy of management decisions by local fishers that in turn encourages responsible fishing; 2) greater consideration of local socio-economic and ecological conditions; 3) improved management through the use of local awareness; 4) increased compliance with regulations through peer pressure; and 5) enhanced voluntary monitoring, control and surveillance by fishers (Gutiérrez et al. 2011, Di Franco et al. 2016). Marine Protected Areas (MPAs) provide a natural laboratory for testing the effectiveness of BPs, and in turn, a tool to promote marine ecosystem conservation and fisheries management strategies (Gaines et al., 2010). MPAs' effectiveness (i.e., the ability to reach their goals; Hockings et al., 2006) has been predominantly evaluated from an ecological viewpoint. Yet, in recent years, it has been better understood that MPAs can be both an ecological success and social failure (Christie 2004) and that their success is dependent on an array of socio-cultural and socio-economic factors (Scianna et al., 2019, Blount and Pitchon, 2007) including community support (Bennett et al., 2019, 2020; Christie et al., 2017; Mascia et al., 2010, Lundsquist and Granek 2005). Fishers are key stakeholders whose activities and behaviors are often directly curtailed or regulated when MPAs are created, often leading to opposition and dissatisfaction with MPA management (Miles et al., 2020). Given that top-down MPA and fisheries management structures still predominate, fishers' dissatisfaction could stem from their exclusion from the decision-making processes that directly impact their livelihoods (Bennett et al. 2019, Di Franco et al. 2020), rendering them as passive recipients of regulations and powerless to decide the fate of their futures (Di Franco et al. 2016). In the Mediterranean, several studies have investigated the effect of implementing spatial and/or temporal regulations designed to improve fisheries management (e.g., Guidetti et al., 2010; Claudet and Guidetti, 2010; Emery et al., 2016; Hogg et al., 2019) as well as of adopting more selective fishing gears to reduce fishing mortality for juvenile and under-sized individuals and to protect key habitats (e.g., Vitale et al., 2018; Lucchetti et al., 2020;Petetta et al 2021). Others have focused on elements that could improve the socio-economic conditions of fishers (Maynou et al., 2013; Marzo et al., 2023); reduce conflicts among marine resource users (Gomez et al., 2021); offer alternative sales circuits and encourage diversification such as fish-tourism and itti-tourism (Carrà et al., 2014; Herrera-Racionero et al., 2019); or help recover lost fishing gears and waste (Ronchi et al., 2019; Gilman et al., 2022). But in general, there is relatively limited information on the social-ecological effects of adopting BPs, such as selective gears and increased dialogue among stakeholders, on fishers' revenues, their perceptions of their effectiveness and support for their implementation (Gill et al., 2019). The current study aims to contribute to the topic of BPs and their impact on fishers using two central Mediterranean MPAs as case studies: Castellabate MPA and Regno di Nettuno MPA. Two BPs have been tested employing an action research approach and engaging local stakeholders: 1) the "adoption of selective fishing gears" and 2) the "increased dialogue between fishers and decision makers". First, we tested the hypothesis that increasing mesh/hook size in five commonly used fishing gears (i.e., gillnet for hake, gillnet for amberjack, standard trammel, trammel for mullet, and bottom longline) would not negatively affect RPUE, while likely improving the status of fish populations by reducing undersized catches. Then we facilitated the dialogue between fishers and MPA managers and public authorities through a series of focus group meetings organized in each MPA. Finally, we assessed the social-ecological effects of the two tested BPs perceived by small-scale fishers.

2. Materials and methods

2.1 Study sites

Santa Maria di Castellabate MPA (CAS-MPA), located in Campania region, Southwest Italy, was established in 2009 with the objective of protecting marine biodiversity and supporting sustainable development. The MPA covers 7,095 ha and its management is entrusted to the Cilento and Vallo di Diano National Park Authority. The MPA includes 4 zones: A (no-take/no-access), B+ (special partial reserve to protect the bio-construction of *Dendropoma petreum*), B (partial reserve), and C (general reserve) (Fig. 1). Access to Zone A and B+ is restricted to scientists, reserve personnel and police authorities (e.g., coast guard). Professional fishers are allowed to fish in Zone B following specific restrictions. In Zone C, both professional and regulated recreational fishing are allowed (see Text SM1 for additional details on fisheries regulations). Twenty-four professional small-scale fishers are authorized to fish in the MPA and all regularly fish inside the MPA's borders.

Regno di Nettuno MPA (NET-MPA), located in Campania region, Southwest Italy, which covers 11,256 ha, was established in 2007 and is managed by a public consortium composed of the seven local councils that have territorial responsibility: the six councils on Ischia Island (Ischia, Casamicciola Terme, Lacco Ameno, Forio, Serrara Fontana and Barano) and Procida's local council. The MPA has the same objective as CAS-MPA and is zoned in the same way, following a pattern of protection from A-C with A being the most protected (Fig. 1), in addition it includes two Bnt (B no-take) areas where only scuba- diving tourism is allowed. A large pelagic area (zone D) to the north of the MPA protects one side of the Cuma Canyon; which hosts an important Mediterranean population of *Delphinus delphis* (common dolphin), a species declared to be at high risk of extinction on the IUCN red list and is linked to a regulation which aims to preserve the cetacean population. SSF and recreational fishing activities are allowed in zones B, C and D following specific restrictions. Exclusively in Zone D purse seining and trawling are allowed, and cetacean observation is authorized following specific restrictions and conditions. Eighty-nine professional fishing licenses are issued, but approximately 40 are granted to vessels regularly operating within the MPA.

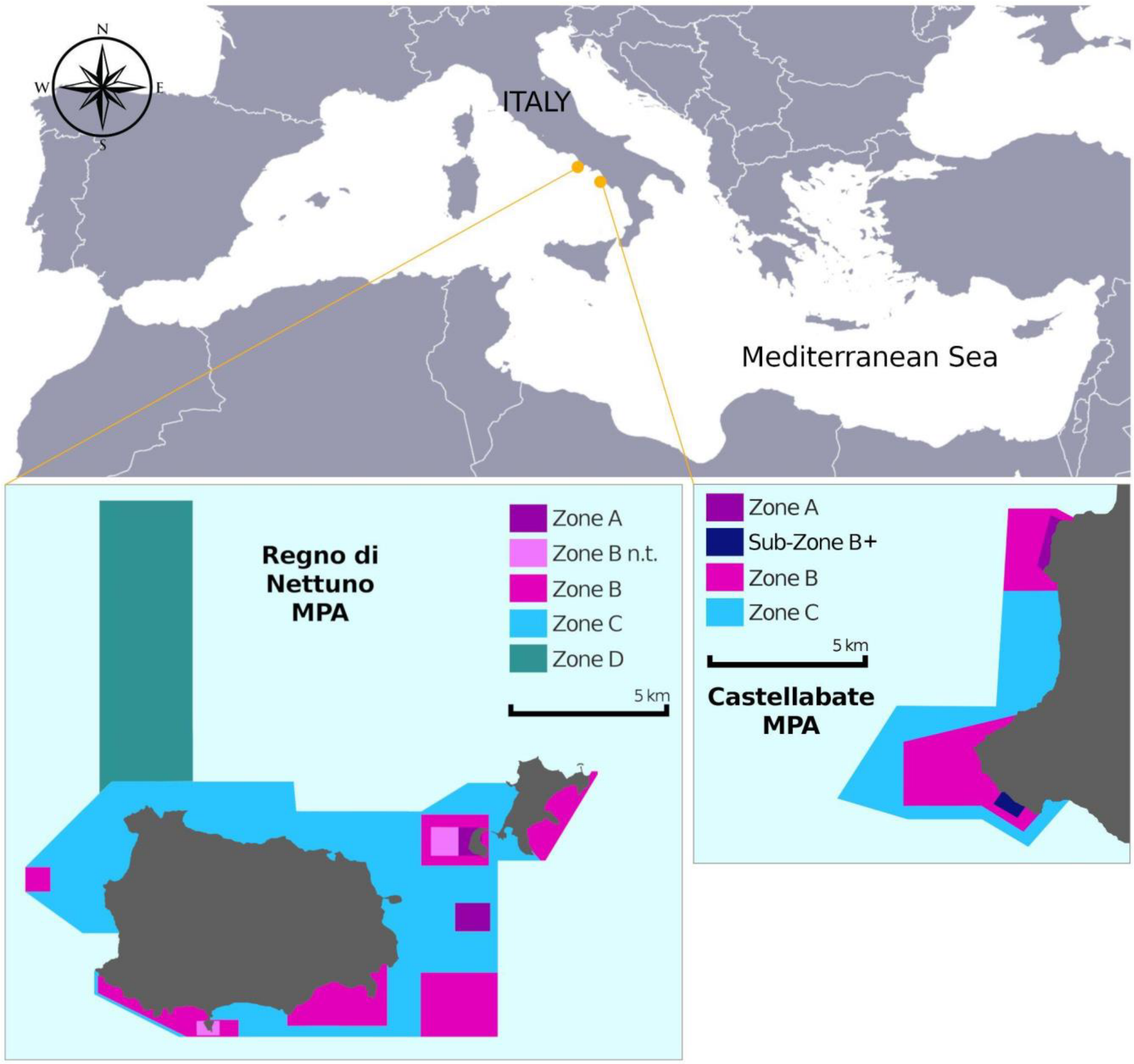

Figure 1. **Study site locations and respective zoning** for Santa Maria di Castellabate MPA (CAS-MPA) and Regno di Nettuno MPA (NET-MPA) (TO BE PRINTED IN COLOUR)

2.2 Adopting and testing BPs

The BP related to the implementation of more selective fishing gears (in terms of increased mesh/hook sizes) was decided following a participatory process (involving active discussions and exchanges) with the local fishers in both MPAs. After a characterization of the gears and their technical futures used in the MPAs, it was decided together with the local fishers, to adopt gears with a larger mesh/hook size than those normally used by most of the local fishers. After a preliminary survey to characterize the gears and the mesh/hook size generally used, the experiment foresaw the testing of five different fishing gears. For each gear, three mesh sizes for the nets (half mesh expressed in mm) and three hook sizes for the longline (hook size in number) were tested: gillnet for hake (GNH) (mesh sizes: 28, 33, 38 mm), gillnet for amberjack (GNA) (mesh sizes: 36, 41, 46 mm), standard trammel net (STN) (mesh sizes: 31, 36, 42 mm), trammel net for mullet (TNM) (mesh sizes: 20, 22, 25 mm) and bottom longline (BLL) (n° 7, 8, 9, with 7 being the largest and 9 the smallest). Fishers generally used the smallest or medium mesh/hook size among the ones selected for the test. Nine local fishers from CAS-MPA and 7 from NET-MPA voluntarily participated in the trials and were asked to deploy the gears according to their normal fishing habits (e.g., in terms of fishing grounds, depth range, etc...). In the NET-MPA 102 fishing operations were carried out using the gears provided (GNH, GNA, BLL, TNM and STN), and 56 fishing operations were carried out in CAS-MPA, with the same gears minus the BLL, all between June 2021 and March 2022 (Table SM1). During each operation fishers deployed the gears with three different mesh/hook sizes, using the same amount of net for the different mesh sizes or the same number of hooks for the different sizes each time.

The BP based on stakeholders' engagement, or rather on increasing dialogue between fishers and MPA managers was facilitated through a series of four focus group meetings organized at CAS-MPA and four at NET-MPA between July 2020 to May 2022. Meetings were attended by fishers, representatives of the MPAs, researchers, Coast Guards, as well as the respective local council representatives. The meetings were designed to use a variety of participative processes and approaches with the aim to allow open discussions ofthe results of the fishing operations, promote the sharing of knowledge and acquisition of more awareness, as well as to foster the dialogue between the different stakeholders, highlighting the strengths and weaknesses of the two MPAs management, and optimization of the benefits.

2.3 Data collection

Fishing operations were monitored following the method described by Calò et al., 2022 (and used in Di Lorenzo et al. 2022, Calò et al. 2023). Following each fishing operation, a scientific operator waited for the fishing vessel at the port to start the photograph-sampling methodology adopted for catches at landing. For all the fishing operations monitored, information was gathered prior to the photograph-sampling through interviews with fishers, on fishing gears used, and mesh/hook size. Fishers were asked to indicate on a map the approximate geographic position of the fishing operation. The operator spread out the catch over a flat horizontal surface and took pictures to capture the entire catch, along with a ruler (as a length reference) placed within the same frame. Each picture was given a unique reference code associated with the fishing operation that was used as an ID in the subsequent image analysis using the free software ImageJ (Fig. 2) (Abràmoff et al., 2004). Using the software in the laboratory the operator measured the total length of each individual fish, the length of the carapace for crustaceans and the length of the mantle for cephalopods (mollusks) to the nearest 1 mm using the ruler in the picture to calibrate the measurement tool. Individual specimens were identified down to the lowest possible taxonomic level (usually species).

Figure 2. **Example of a typical photo for a haul using a set net.** Picture displaying the photo-sample of a set net catch (TO BE PRINTED IN COLOUR)

Individual biomass (i.e., wet weight in grams) of each fish specimen was estimated using specific length-weight relationships (LWR) available from www.fishbase.org (Froese and Pauly, 2019). For crustaceans and cephalopods individual biomass was estimated using LWR information available from www.sealifebase.ca (Palomares and Pauly, 2022). We built an ex-vessel price (i.e., the price that fishers receive directly for their catch; Tai et al., 2017) database for all species appearing in the catches. To build the database fishers were asked about the yearly average price per kilogram they charge to sell their fish. Additionally, for each species, fishers were asked to detail, when present, size-specific prices (i.e., price change depending on the size of individuals within each species), indicating size categories and the associated prices. We then used the ex-vessel price to calculate the RPUE for each fishing operation and for each species within it, by combining ex-vessel prices with the previously calculated CPUEs (see Calò et al. 2022, and Calò et al. 2023 for further details).

To assess the perceived social-ecological impacts of the tested BPs, 36 interviews were conducted using a semi-structured questionnaire with small-scale fishers from the two MPAs. Fieldwork was carried out by a trained researcher in each MPA between November 2021 and January 2022, who approached all 21 fishers operating at CAS-MPA (out of the 24 licensed) and 22 fishers operating at NET-MPA (out of the 40 regularly operating inside the MPA) representing approximatively 87% and 55% of the fishers operating respectively inside CAS-MPA and NET-MPA. The questionnaires were addressed to both the fishers who participated in the monitoring and those who did not take part. Response rate was 63.6% of CAS-MPA (14 fishers agreed to participate in the interview) and 100% at NET-MPA (22 fishers). Prior to being asked for verbal consent and proceeding with the survey, small-scale fishers were informed about the purpose of the survey and the intended use of the data, how data would be stored and treated anonymously and confidentially. The questionnaire has been approved by the Bioethics Committee of the University of Palermo (58/2021). The questionnaire collected data on fishing behavior, fishers' perceptions of MPA management/governance and the tested BPs. Household and demographic information from resource userswere also gathered. Fishers were asked if they were aware of the initiative and BPs tested, which gave an indication of how well informed the fishers, beyond those directly involved in the BPs, were. Following this, they were asked to rate their opinions, (using a 5-point Likert scale from very negative to very positive impact), on a series of statements related to the impact/potential impact of each BP (adoption of selective gears and increase of dialogue) on a set of social-ecological variables: specifically fishers were asked about the effect of the adoption of selective gears on a) the number of fish, b) habitat quality, c) the amount of fish and invertebrates that fishers can catch, d) fishers incomes, e) protected or undersized species caught, f) the status of the *Posidonia oceanica* meadows; and about the effect of increased dialogue on a) the number of fish, b) habitat quality, c) the amount of fish and invertebrates that fishers can catch, d) fishers incomes, e) the relationship between fishers and MPA managers, f) the relationship between fishers and other users in the MPA, g) the participation of fishers in decision making processes, h) the amount of illegal fishing or poaching activities within the MPA, i) the support of fishers toward the MPA and j) awareness of the importance to protect marine biodiversity (see Table SM2 for the set of items used in the questionnaire). Finally, fishers were asked to propose an additional third BP that they considered would be useful for the management of SSF.

2.4 Data analysis

An analysis of variance (ANOVA) was carried out to estimate the potential effect of the different mesh and hook sizes adopted, on CPUE and RPUE. The variable “mesh size" or "hook size" was transformed into an ordinal factor, to inform the model about the “directionality” of the levels of the variable, and thus be able to grasp the linear regression linking the response variable to the predictive one (Bennett et al., 2020). Three response variables were considered: 1) CPUE (the total biomass per fishing operation standardized over 500 m); 2) RPUE (the total revenue per fishing operation standardized over 500 m); 3) RPUE only for individuals above their minimum conservation reference size (MCRS) (hereinafter referred to as “legal revenue”). The MCRS of each species was obtained from the “Regulation (EU) 2019/1241 of the European Parliament and of the Council of 20 June 2019 on the conservation of fisheries resources and the protection of marine ecosystems through technical measures.” If species were not listed in the above regulation directive, the size of first sexual maturity (L50M) was used and compiled using FishBase and Sealifebase or scientific literature, if the information requested were not available on FishBase and Sealifebase (see Table SM3 for the full list). For individuals above MCRS we tested only RPUE and not CPUE, as the first is a synthetic measure accounting for number of individuals, size, and ex-vessel price.

For each response variable and for each type of fishing gear, the analysis carried out followed two steps: a two-way ANOVA model was implemented, including the factor “MPA” (fixed with two levels "CAS-MPA" and "NET-MPA"), the factor "mesh or hook size" (ordinal categorical factor) and their interaction. If the interaction was found to be non-significant (p-value > 0.05), the model was finalized considering only 1 test pooling the two MPAs together (“Pooled” in Table 2, 3, 4). If the interaction was significant, two separate models were built for the two MPAs, to verify the relationship between revenue or biomass and the effects of the gear adopted in each MPA. Once the model was run, model assumptions were verified by visually checking the absence of any pattern dealing with the residuals and their distribution of normality through qq-plot and residuals vs fitted plot (Zuur and Ieno 2016). Model validation indicated no problems existed. The statistical analyses were performed using R software, version 4.0.3 (R Core Team, 2020).

Descriptive charts and analyses were used to examine the demographic characteristics of the small-scale fishers interviewed and their perceptions about the effect of the two management BPs adopted (i.e., selective fishing gears and increased dialogue with the MPAs), and an additional management measure, surveillance, which was put forward by fishers to be the most important additional management tool for improving the status of fishing in the MPAs (see result section). For each of these 3 BPs, the scores of the single items (i.e., perceptions about social-ecological aspects potentially affected by the implementation of the BPs, from 1 to 5 following the Likert scale used) were used to generate a compound score capturing the overall effectiveness of the 3 BPs. Each compound score was generated by summing the single items and then normalizing the sum on a scale from 1 to 5. Prior to summing the scores of the single items, internal coherence of the items was checked using Chronbach's alpha coefficient for all scores. No issue with internal coherence was found for any of the 3 groups of items (each group referring to one of the three BPs tested or suggested, always > 0.9, very high coherence, Table SM5). To identify potential predictors of the perceived social-ecological effectiveness of the two implemented interventions and the additional intervention (surveillance), the three composite scores were tested against a set of variables which could potentially shape fishers' perceptions in the context of Mediterranean MPAs (see Bennett et al, 2020; Di Franco et al, 2020). The initial set of potential predictors included: a) fisher demographic characteristics (age class, education level, level of satisfaction with the incomes deriving from fishing, proportion of household incomes deriving from SSF); b) individual perceptions of MPA governance (level of fishers' perceived participation in MPA management and decision-making); and c) fishing habits of interviewees (number of different fishing gears used, number of days fishing within the MPA); d) a factor 'MPA' accounting for the spatial variability between the 2 areas was considered. No issue with collinearity among predictors was highlighted after checking correlation plots (see Supplementary materials Text SM2 (Fig. SM1, 2, 3, 4)). Drivers of perceptions were investigated through a model-selection approach (see Supplementary materials for modelling details (Fig. SM 1, 2, 3, 4)). Given that single response items and the relative scores were recorded as ordered categorical variables (on a scale from 1 to 5), analysis was carried out using proportional odds models, implementing in R the function 'clm' of the 'ordinal' package (Christensen, 2018). Item-specific models were not run due to the high level of collinearity between pairs of items (social-ecological perceptions about the management measures) within the 3 groups of perceptions associated to the measures (see Supplementary materials (Fig. SM 1, 2, 3, 4)), likely producing redundant results with the relative scores. A full model containing all terms was initially constructed. Significance level on the final model was calculated using analysis of deviance based on Wald Chi-Square test. Due to model convergence issues, the predictor "Fishers' participation in MPA management and decision making" was dropped from the analyses in all three models built.

3. Results

3.1 Effect of selective fishing gears on CPUE and RPUE

The CPUE showed significant interaction between factor "MPA" and the factor "mesh or hook size" only for the GNA and GNH (P-values: 1.55 e-06 and 0.0076 respectively). For GNA at CAS-MPA the highest CPUE value (1668.3 ± 533.06 g/500 m) was associated with the smallest adopted mesh size (36 mm), while the lowest value (378.80 ± 131.31 g/500 m) was observed for the largest mesh size (46 mm) (Table 1, Fig. 3). In the NET-MPA the pattern was reversed with the highest CPUE value (2701.54 ± 284.33 g/500 m) associated with the largest mesh adopted (46 mm), and the lowest CPUE (1335.20 ± 400.01 g/500 m) with the smallest mesh size (36 mm) (Fig. 3). When running the analysis separately, one per each MPA, for the data from GNH no significant effect of the factor "mesh or hook size" was highlighted.

Table 1. Results of ANOVA on CPUE (catch per unit of effort) for the fishing operations carried out at the two MPAs CAS and NET. Results of the test are reported for the factor “mesh or hook size”. “Pooled” in “MPA ID” refers to the test performed with pooled data from the two MPAs when the interaction between factor “MPA” and the factor "mesh or hook size" was not significant.

Type of Gear	**MPA ID**		**t Value**	**P Value**
BLL	NET		-1.759	0.0853
GNA	NET		3.286	0.00198
GNA	CAS		-5.743	7.50e-07
GNH	NET		-0.232	0.8173
GNH	CAS		-1.386	0.1802
STN	Pooled		0.8680	0.4225
TNM	Pooled		0.6137	0.5405

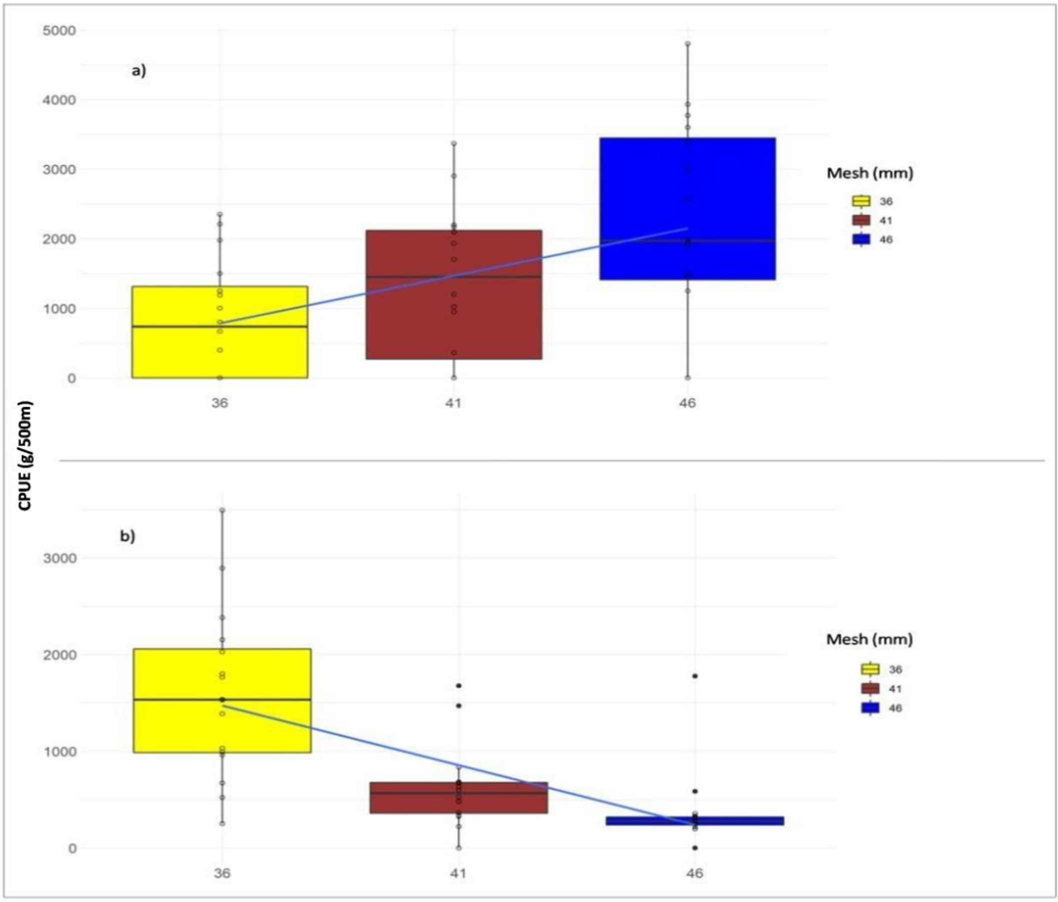

Figure 3. **Effect of selective fishing gears on CPUE.** Box-plots of CPUE (catch per unit of effort) values for the fishing operations of GNA, carried out at (a)NET-MPA and (b) CAS-MPA for each level of factor "mesh or hook size". The blue line illustrates the linear model fit for factor "mesh or hook size" (TO BE PRINTED IN COLOUR).

The results on the estimation of the RPUE for the fishing operations showed significant interaction between factor “MPA” and the factor "mesh or hook size" for GNA and GNH (P-values: 7.04e-05 and 0.95726 respectively). A significant difference in RPUE among mesh size was recorded for GNA at the NET-MPA, but not at CAS-MPA (Table 2). The highest RPUE value (33.03 ±7.83 €/500 m) estimated for the GNA in the NET-MPA was associated with the largest mesh size adopted (46 mm) while the lowest value (9.82 ± 3.38€/500 m) was associated with the smallest mesh size (36 mm). Significant differences in RPUE between hook size for the BLL were recorded at the NET-MPA (Table 2). The highest value (51.73 ± 6.5€/1500 m) estimated for the BLL was associated with the largest hook adopted (n° 7) and the lowest revenue value (27.36 ± 2.28€/1500 m) was associated with the smallest hook (n° 9) (Fig. 4). A significant effect of mesh size was recorded for STN in both MPAs (Table 2). At NET-MPA the highest RPUE value estimated for STN was associated with the smallest mesh size (31 mm) (34.02 ± 2.54 €/500 m) while the lowest value was associated with the intermediate mesh size (36 mm) (23.76 ± 1.92 €/500 m). At CAS-MPA, the highest RPUE value estimated for STN was associated with the largest mesh size (42 mm) (19.53 ± 8,32€/500 m) while the lowest value (14.42 ± 3.32€/500 m) was associated with the smallest mesh size (31 mm).

Table 2. Results of the ANOVA on the RPUE (revenue per unit of effort) for the fishing operations carried out at the two MPAs - CAS and NET. Results of the test are reported for the factor “mesh or hook size”. “Pooled” in “MPA ID” refers to the test performed with pooled data from the two MPAs when the interaction between factor “MPA” and the factor "mesh or hook size" was not significant.

Type of Gear	**MPA name**		**t Value**	**P Value**
BLL	NET		-2.678	0.0104
GNA	NET		4.379	7.04e-05
GNA	CAS		0.356	0.724
GNH	NET		-0.054	0.95726
GNH	CAS		-1.797	0.0867
STN	Pooled		4.1603	0.01803
TNM	Pooled		0.6655	0.5161

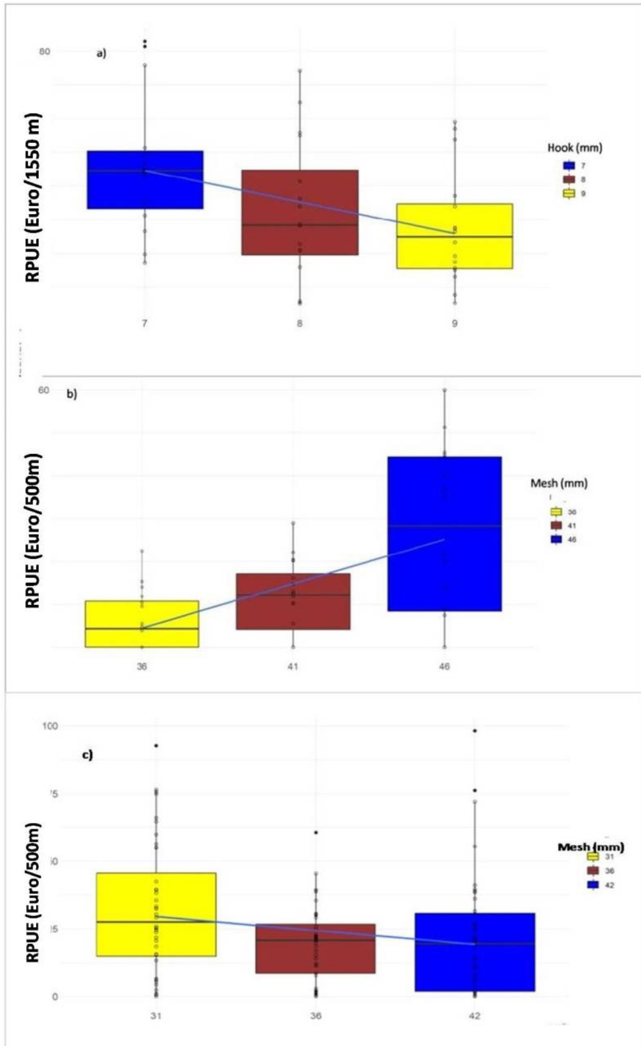

Figure 4. **Effect of selective fishing gears on RPUE.** Box plot of RPUE (revenue per unit of effort) values for the fishing operations of (a) BLL at NET-MPA, (b) GNA at NET-MPA and (c) STN (Pooled NET and CAS), for each level of factor "mesh or hook size". The blue line illustrates the linear model fit for factor "mesh or hook size" (TO BE PRINTED IN COLOUR).

The results for the estimated legal RPUE (i.e., including only the individuals caught above the minimum conservation reference size), did not show significant interaction between “MPA” and the mesh/hook size for any of the gears adopted. The only significant effect of mesh/hook size was recorded for BLL exclusively adopted in the NET-MPA (Table 3). The highest revenue value (382.33 ± 6.78€/1500 m) was associated with the largest hook adopted (n°7) and the lowest (145.14 ± 2.10€/1500 m) to the smallest hook size (n°9) (Fig. 5). No significant variability was detected for the other tests.

Table 3. Results of the ANOVA of RPUE (revenue per unit of effort) including only individuals caught above the minimum catch size for the fishing operations carried out at the two MPAs CAS and NET. Results of the test are reported for the factor “mesh or hook size”. “Pooled” in “MPA ID” refers to the test performed with pooled data from the two MPAs when the interaction between factor “MPA” and the factor "mesh or hook size” was not significant.

Type of Gear	**MPA ID**		**t Value**	**P Value**
BLL	NET		10.673	0.000575
GNA	Pooled		0.0793	0.9238175
GNH	Pooled		1.4105	0.2497
STN	Pooled		1.3521	0.2629
TNM	Pooled		0.6727	0.5125

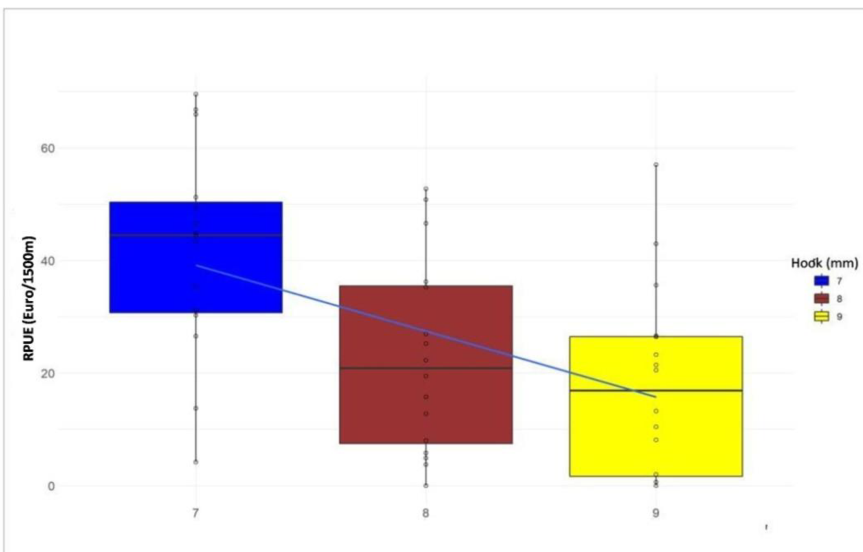

Figure 5. **Effect of selective fishing gears on RPUE of legal size of catch.** Box plot of RPUE values including only individuals caught above the minimum catch size for the fishing operations of BLL exclusively adopted in the NET-MPA for each level of factor "hook size". The blue line illustrates the linear model fit for factor "hook size" (TO BE PRINTED IN COLOUR).

3.2 Survey sample and perceptions on BPs implementation

Respondents were on average younger in NET MPA than in CAS MPA (CAS 43% (N= 6) fishers >60 years; NET 78% (N= 17) <60 years (Fig. SM5)). This is reflected in the level of education with a greater proportion of respondents in CAS 57% (N= 8) having reached middle school, 36% high school and 7% elementary school; while in NET 45% (N= 10) having reached high school, 41% middle school, 9% elementary school and one (5%) fisher with a university degree (Fig. SM6). In both MPAs respondents declared a strong household income dependency on SSF (CAS 64% (N= 9); NET 68% (N= 15) (Fig. SM7). Respondents stated the relationship between local fishers in CAS-MPA to be good, but moderate and strong conflicts were indicated to exist between local and recreational fishers (71%, N= 10). In the NET-MPA poor relationships were declared to exist with fishers from other communities (54,55%, N= 12), with recreational (40,91%, N= 9) and between local fishers (36,36%, N= 8). Perceptions regarding the MPAs management differed, with low levels of participation in decision making processes declared by fishers from both MPAs (86% at CAS and 55% at NET). All fishers (N= 14 fishers) from CAS and 64% of fishers (N= 14) from NET stated they are not involved in the MPAs management (Table SM4, Table SM5, Fig. SM10). At CAS fishers stated there to be a lack of transparency in decision making processes with 71% fishers (N= 10) indicating that information is not made available. In NET 73% of fishers (N= 16) indicated information is available on request from the MPA. Opposition towards CAS-MPA was indicated by 64% of fishers (N= 9) with the same number of fishers declaring there to be a lack of trust in the MPA. In contrast, 82% (N= 18) of fishers in NET declared themselves to be supportive of the MPA with the same number of fishers declaring high levels of trust. Respondents indicated there to be high levels of poaching (50%, N= 7 at CAS, 59%, N= 13 at NET). Fishers (93%, N= 13) from CAS perceived poaching was carried out by recreational fishers. In NET-MPA 82% (N= 18) fishers perceived it to be large-scale fishers, 68% (N= 15) fishers from other communities, and 59% (N= 13) recreational fishers.

Perceptions of the social-ecological effectiveness of the two BPs implemented (adoption of selective gears and increased dialogue) were found to be positive. Sixty-five percent (N= 9) and 72% (N= 16) of fishers that adopted the gears perceived the adoption of selective gears to be positive at CAS and NET (Fig. 11) respectively; 98,5% (N= 13) and 96% (N= 21) perceived the increased dialogue to be positive (Fig. SM12).

For what concerns which additional actions fishers suggested to improve small-scale fisheries management in the two MPAs, both fishing communities perceived a high level of illegal fishing and deemed increasing surveillance and sea controls as priority actions. In CAS this action was perceived as a priority by 43% (N= 6) of respondents and 91% (N= 20) in NET (Fig. SM13).

Model results for the perceived social-ecological effectiveness of “increased dialogue with MPA” indicated it was significantly and positively predicted by fishers’ age, with older fishers perceiving, on average, more positive effects (associated to higher score values) of the BP (Fig. 6 and Table SM5).

No significant predictors were found in the models for the compounded scores of the other two BPs (i.e., “selective fishing gears” and “increased surveillance” (see Table SM4)).

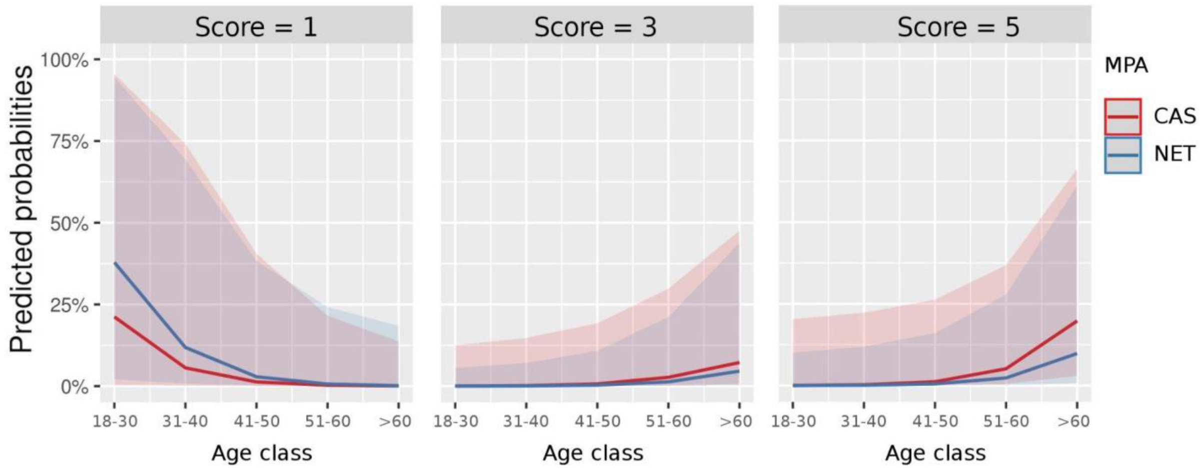

Figure 6. **Effect plot of predicted probabilities of perceived social-ecological effectiveness.** Socio-ecological effectiveness (measured on a scale from 1 to 5) associated with the management measure "increased dialogue with MPA" in relation to fishers' age in the two MPAs. Only score values equal to 1, 3 and 5 are shown to improve image clarity (TO BE PRINTED IN COLOUR).

4. Discussion

Overall, we observed somewhat mixed outcomes from an ecological and a socio-economic point of view for the BPs "selective fishing gears" tested in the two MPAs, with opposing patterns depending on the gear, the MPA, and the response variable considered. However, overall, the most common pattern was absence of effect of the "mesh and hook size" on CPUE and RPUE, followed by an increasing trend in CPUE/RPUE with increased mesh or hook size. Only in two cases we found a decreasing trend in CPUE and RPUE with increased mesh or hook size.Overall, we did not find a clear trend in revenues among the different mesh and hook sizes tested, in line with previous findings (Frid and Belmaker 2019 and references therein), but in contrast with others suggesting the adoption of selective fishing gear can have several benefits for the earnings of small-scale fishers (Calò et al, 2022). These gears are designed to catch specific target species and sizes of fish, minimizing the capture of unwanted or undersized species (Lucchetti et al., 2020; Petteta et al., 2021). This can lead to several economic advantages for small-scale fishers, such as catching higher-value species or larger-sized fish, which command better market prices. Additionally, catching fewer undersized fish reduces waste and associated costs for disposal, further enhancing profitability. Selective gear adoption can also help fishers comply with regulations, avoiding sanctions or fines for unsustainable fishing practices (Amos and Peter, 2018). It contributes to the conservation of marine resources, allowing non-target and undersized species to escape capture, thereby contributing to the long-term productivity of fish populations, and ensuring a sustainable income source for fishers. It can also open new market opportunities, particularly as consumers are increasingly interested in purchasing seafood from sustainable and certified sources (Garrau et al., 2023; Delabre et al., 2021; Maesano et al., 2020). In the Mediterranean Sea, various case studies have recently tested the adoption of new or modified fishing gears to evaluate their potential in achieving more sustainable small-scale fisheries (Marzo et al., 2023; Gilman et al., 2022; Petetta et al., 2021; Lucchetti et al., 2020; Herrera and Racionero, 2019; Hogg et al., 2019; Guidetti et al., 2010). The size of the mesh was found to be crucial in reducing the by-catch of individuals below the Minimum Conservation Reference Sizes (MCRS) The adoption of these practices has contributed differently to reducing bycatch and discards (Suuronen and Gilman, 2020).

To facilitate the adoption of more selective fishing gearsby fishers, new gears must be practical, safe and economically sustainable/beneficial. Economic profitability plays a key role in the long-term adoption and maintenance of BPs. The important finding that we found in the present study is that the economic impact on fishers when adopting more selective gears was negligible meaning they will be more likely to accept their adoption over the long-term allowing the time needed for ecological recovery.

Overall, we found a positive outcome in terms of the fishers' acceptance of the BPs tested in both MPAs. Fishers perceived positive effects, including positive impacts on their income. The selectivity of the adopted gears was perceived to maintain the gears effectiveness in catching specific sizes and target species while allowing for the reduction in by-catch of non-commercial and undersized individuals. Increasing mesh sizes in traditional fishing gear can therefore be considered a viable and acceptable measure, balancing potential economic losses for fishers. This finding suggests that this BP can be implemented without compromising the well-being of fishers while ensuring environmental benefits.

Fishers in both investigated MPAs generally perceived the increased dialogue between fishers and MPA managers (and the researchers involved in this study) positively. In both MPAs, fishers prioritize increased monitoring and surveillance as a primary action to monitor and reduce illegal fishing activities, which are consistently present in both areas and have negative consequences on their fishing activities. Although the results may suggest that this perception is less widespread among fishers in CAS-MPA, in reality, the lower percentage (43%) of respondents addressing this issue in CAS is likely due to the fact that, in addition to illegal fishing, fishers perceive multiple issues in their MPA, and various initiatives need to be implemented to improve their condition and the state of fishing in the MPA. Therefore, multiple actions are recognized as priorities. In the NET MPA, on the other hand, a more developed collaboration with the MPA management body could have fostered trust between fishers and management authorities. Over the years, this trust has led to the implementation of various actions that have improved the state of SSF, although 91% of fishers declared that stronger surveillance was still a management priority.

It is widely acknowledged in the literature, that the benefits to society and local economies resulting from the creation of MPAs depends not only on ecological aspects but also on socioeconomic and cultural factors (PISCO& UNS, 2016). In the same way, the evaluation of BPs' effectiveness involves considering various dimensions of environmental and human well-being. A crucial role is played by the acceptance of MPAs by local communities and the level of engagement of stakeholders in decision-making processes. Often, MPAs fail to reach their full potential because human well-being and satisfaction of local stakeholders are undervalued. Participatory approaches are vital for developing effective management policies, mitigating competition for marine resources, reducing fishing pressure within MPAs, and resolving conflicts among stakeholders. Increased dialogue between fishers and MPA authorities have been essential in bridging communication gaps and highlighting previously underestimated issues within MPAs, such as illegal fishing activities.

The more traditional top-down management approaches provide little to no opportunity for fishers and local communities to participate, resulting in poor recognition and legitimacy, which ultimately leads to negative perceptions towards the MPA and its regulations (Pita et al. 2020). Conversely, perceived social-ecological benefits of MPAs can be fostered through collaborative participatory processes and increased open communication (Di Franco et al. 2020). Good communication channels and open, on-going dialogue are necessary to overcome distrust between MPA stakeholders; particularly to help fishers feed their experiential knowledge into management decision-making (Coll et al., 2014; Damalas et al., 2015; Mackinson et al., 2011); and to enable managers to explain decisions taken and how fishers' information has been used (Cvitanovic et al., 2015; Yates, 2014). Increased communication can boost the level of satisfaction among fishers and other stakeholders and consequently their level of support and acceptance towards MPAs and the associated management measures (Di Franco et al., 2020; Miles et al. al., 2020; Perea Munoz et al., 2022). Our findings are indicative of a top-down approach to management in both MPAs investigated and these ideas are reflected in the different levels of acceptance in the two MPAs. In CAS-MPA fishers declared low levels of communication and trust, lack of transparency and information availability, which translated into a strong opposition towardsthe MPA. In NET-MPA, although also a rather negative picture was painted, fishers did indicate that even if participation in the MPA was low, information is made available if requested and that there were less conflicts within the community and between different user groups, which translated into a higher level of support for the MPA.

The increased dialogue between fishers and MPA managers tested here has helped to better understand the needs and concerns of these two fishing communities, facilitating the potential identification and adoption of more effective and sustainable measures. The combined effect of these BPs if maintained and reinforced over the long-term could have positive impacts on the marine ecosystem in the two studied MPAs. However, the effectiveness of these BPs in reducing bycatch and promoting sustainable fishing depends on various factors, including the target species, local ecosystem, scale of fishing operations, and fishers' compliance with regulations and guidelines. It is essential to recognize that BPs should be adapted to specific regional, cultural, and ecological contexts to achieve the best results. Therefore, the results obtained in the CAS and NET MPAs may not be generalizable to all small-scale fisheries communities. Still, the involvement of fishing communities is crucial for the acceptance and success of BPs (and other management measures) and should therefore be given the utmost attention.

5. Conclusions

BPs have proven to be valuable tools in promoting sustainability and responsible management of marine resources in small scale fisheries, by fostering positive perceptions and attitudes in fishers, not inducing negative fisheries impacts (in terms of catches and revenues), and likely improving the ecological status of ecosystems. The adoption of selective fishing gear and active involvement of fishers and local stakeholders have been key factors in driving positive change. This study contributes to the growing awareness of the importance of BPs and emphasizes the need to continue promoting and adapting these practices to ensure a sustainable future for fishing communities and marine ecosystems. This study promotes the value of collaborative initiatives that involve local fishers in action research and knowledge co-production processes to break down institutional barriers and better inform fisheries management. The dialogue channels opened between fishers, MPA managers and the researchers behind this study, has contributed to positive perceptions and the successful adoption of sustainable fishing gears. The results presented in this study reiterate to decision makers that it is societal acceptance that ultimately influences the success of conservation and management measures. Highlighting that increased dialogue, open channels of communication between fishers and MPA managers, and participatory decision-making processes, together with consideration for the economic and ecological impacts, are crucial in maintaining local support and should therefore be prioritized.

Ethics statement

Ethics approval was obtained through submission of an ethics assessment to the University of Palermo's Bioethics Committee (58/2021). Prior to being asked for verbal consent and proceeding with the survey participants were informed of the aims of the project, how data would be used, and how they could access the study results. Researchers obtained oral consent from participants before conducting interviews. Personal identifying information was replaced with respondent ID numbers to ensure anonymity.

Declaration of competing interest

The authors declare that they have no known competing financialinterests or personal relationships that could have appeared to influencethe work reported in this paper.

CRediT authorship contribution statement

Antonio Di Franco: Conceptualization, Methodology, Writing - Review & Editing, Supervision. **Serena Zampardi**: Investigations, Resources, Data curation, Writing - Original Draft, Writing - Review & Editing. **Antonio Calò** and **Giacomo Milisenda**: Software, Formal analysis, Writing - Review & Editing. **Marco Ranù** and **Emanuela Di Meglio**: Investigations, Resources, Data curation. **Katie Hogg**, **Giorgio Aglieri**, **Claudia Scianna**, **Teresa Romeo**, **Maria Cristina Mangano** and **Giulia Prato**: Writing - Review& Editing. **Francesco Colloca**: Conceptualization, Writing - Review & Editing, Project administration, Funding acquisition.

Acknowledgements

We thank the management consortium of Regno di Nettuno MPA, and the Cilento and Vallo di Diano National Park Authority for Santa Maria di Castellabate MPA, and fishers from both MPAs for their collaboration. This research was funded by the project ISSPA "Innovazione, Sviluppo e Sostenibilità nel settore della Pesca e dell'Acquacoltura per la Regione Campania", European Maritime and Fisheries Fund, PO FEAMP Campania 2014/2020 - DRD n. 35/2019.The funders had no role in study design, data collection and analysis, preparation of the manuscript, or decision to publish.

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Supplementary Materials

Text SM1 *- Study sites*

SSFs in general employ mostly gillnets and trammel nets in both MPAs and they are allowed only in zones B, C, D with the consent of the management body. In detail, in CAS-MPA the fishing gears permitted are fixed gillnets (2000 meters maximum length, 30 mm mesh size), longlines (700 hooks maximum), fishing lines and towed line. “Menaide” driftnets, also called “menaica”, used to catch sardines are allowed in zone C.

In NET-MPA the fishing gears allowed are seines and small purse seines, fixed gillnets, longline, drifting fishing lines and towed lines. The anchoring of both fishing gears and boats is permitted in zones B and C.

Table SM1. Number of fishing operations carried on the two MPAs, CAS and NET, for each gear (GNA, TNM, STN, BLL and GNH)

Gear	NET-MPA	CAS-MPA
GNA	16	16
TNM	22	16
STN	24	16
BLL	16	0
GNH	24	8

Table SM2. Items considered for small-scale fishers' perceptions about the effect of the BPs adopted (selective gears, increased dialogue) and the potential management intervention they suggested (Surveillance, see Results).

Table SM2 provides a series of questions that fishers were asked to gather their perceptions on the impact/potential impact of the BPs tested (adoption of selective gears and increased dialogue) on a set of social-ecological variables (i.e., "items"). They were asked to rate on a 5-point Likert scale the effect of the BP on each item. At the end of each questionnaire, as additional information not provided in the questionnaire, each fisher was asked to indicate their priority actions for improving the status of fishing in the MPAs.

BPs	**Items**
Selective gears	Abundance of fish in the MPAs
	Quality of the habitats in the MPAs
	Amount of fish and invertebrates that fishers can catch
	Fishers' incomes
	Protected or undersized species caught
	Posidonia oceanica
Increased dialogue	Number of fish in the MPAs
	Quality of the habitats in the MPAs
	Amount of fish and invertebrates that fishers can catch
	Fishers' incomes
	Relationship between fishers and MPAs managers
	Amount of conflicts between fishers and other users in the MPAs
	Participation of small-scale fishers in decision making process
	Amount of illegal fishing or poaching activities within the MPAs
	Support of small-scale fishers for the MPAs
	Importance of biodiversity and marine ecosystems protection

Surveillance	Number of fish in the MPAs
	Quality of the habitats in the MPAs
	Amount of fish and invertebrates that fishers can catch
	Fishers incomes
	Relationship between fishers and MPAs managers
	Amount of conflicts between fishers and other users in the MPAs
	Participation of small-scale fishers in decision making process
	Amount of illegal fishing or poaching activities within the MPAs
	Support of small-scale fishers for the MPAs
	Awareness of the importance of biodiversity and marine ecosystems protection

Table SM3. List of minimum conservation size (MCRS) and length at first maturity (L50M) values foreach species fished (NS = not sold, NC = not considered, NA = not available)

Species Name	MCRS (cm)	L50M (cm)	Sex (U-M-F)	Source
Apogon imberbis	NS	NS		NS
Boops boops	NA	13,06		FishBase
Bothus podas	NA	21	M	Abid et al., 2010
Brama brama	NA	NA		NA
Callistoctopus macropus	NA	NA		NA
Chelidonichthys cuculus	NA	26,6		FishBase
Chelidonichthys lucerna	NA	24,7		FishBase
Citharus linguatula	NA	12		FishBase
Conger conger	NA	200		FishBase
Coris julis	NA	NA		NA
Coryphaena hippurus	NA	55,8		FishBase
Dactylopterus volitans	NS	19,5	U	Costa et al., 2018
Dentex dentex	NA	34,6		FishBase
Dicentrarchus labrax	25	NC		Directive 1241
Diplodus annularis	12	NC		Directive 1241
Diplodus puntazzo	18	NC		Directive 1241

Diplodus sargus	23	NC		Directive 1241
Diplodus vulgaris	18	NC		Directive 1241
Engraulis encrasicolus	9	NC		Directive 1241
Epinephelus spp	45	NC		Directive 1241
Euthynnus alletteratus	NA	41,8		FishBase
Galeus melastomus	NA	64,7		FishBase
Gobius cruentatus	NS	NS		NS
Helicolenus dactylopterus	NA	32		FishBase
Labrus merula	NA	17,5		FishBase
Labrus viridis	NA	NA		NA
Lepidorhombus boscii	NA	20,3	M	Ugrin et al., 2023
Lepidotrigla cavillone	NA	8		FishBase
Lithognathus mormyrus	20	NC		Directive 1241
Loligo vulgaris	NA	16,9		Sealifebase
Lophius piscatorius	NA	50		FishBase
Merluccius merluccius	20	NC		Directive 1241
Mora moro	NA	NA		NA
Mugilidae	NA	NA		NA
Mullus sp	11	NC		Directive 1241

Muraena helena	NA	75,5		FishBase
Naucrates ductor	NA	NA		NA
Oblada melanura	NA	18,8		FishBase
Octopus vulgaris	NA	12,0	F	Cuccu et al., 2013
Pagellus acarne	17	NC		Directive 1241
Pagellus bogaraveo	33	NC		Directive 1241
Pagellus erythrinus	15	NC		Directive 1241
Pagellus sp	NA	NA		NA
Pagrus pagrus	18	NC		Directive 1241
Palinurus elephas	NA	10		Sealifebase
Parapenaeus longirostris	2	NC		Directive 1241
Peristedion cataphractum	NA	21,2		Bottari et al., 2010
Phycis blennoides	NA	18,7	M	Rotllant et al., 2002
Phycis phycis	NA	33,0		Glavis et al., 2014
Platichthys flesus	NA	NA		NA
Pomadasys incisus	NS	NS		NS
Pomatomus saltatrix	NA	30		FishBase
Pteroplatytrygon violacea	NA	45		FishBase
Raja asterias	NA	44,2	M	Ferrà et al., 2016

Raja brachyuran	NA	90,2		FishBase
Raja clavata	NA	76,6		FishBase
Raja miraletus	NA	48,81	M	Porcu et al., 2020
Sarda sarda	NA	37		FishBase
Sardina pilchardus	11	NC		Directive 1241
Sardinella aurita	NA	NA		NA
Sarpa salpa	NA	16,5		FishBase
Sciaena umbra	NA	23,5		FishBase
Scomber spp	18	NC		Directive 1241
Scophthalmus rombus	NA	37		FishBase
Scophthalmus sp	NA	NA		NA
Scorpaena maderensis	NA	NA		NA
Scorpaena porcus	NA	14,4		FishBase
Scorpaena scrofa	NA	30	U	Matić-Skoko et al., 2010
Scyliorhinus canicula	NA	54,4		FishBase
Scyliorhinus stellaris	NA	78		FishBase
Sepia officinalis	NA	10,3	M	Duysak et al., 2014
Sepia officinalis	NA	12,04	F	Duysak et al., 2014
Seriola dumerili	NA	99,5		FishBase

Serranus cabrilla	NA	13,7		FishBase
Serranus scriba	NA	17,3		FishBase
Solea solea	20	NC		Directive 1241
Soleidae	NA	NA		
Sparus aurata	20	NC		Directive 1241
Sphyraena sphyraena	NA	27,16	M	Villegas-Hernández et al., 2014
Sphyraena viridensis	NA	44,5	M	Villegas-Hernández et al., 2014
Spicara maena	NA	11,5		FishBase
Spicara smaris	NA	9,1		FishBase
Spondyliosoma cantharus	NA	19,7		FishBase
Squilla mantis	NA	14,7		Sealifebase
Symphodus roissali	NA	6		FishBase
Symphodus tinca	NA	11,7		FishBase
Synodus saurus	NS	NS		NS
Todarodes sagittatus	NA	23,2		Sealifebase
Torpedo marmorata	NS	NS		NS
Torpedo torpedo	NS	NS		NS
Trachinotus ovatus	NS	29,1		Villegas-Hernández et al., 2016

Trachinus draco	NA	12		FishBase
Trachinus radiatus	NA	47,1	F	Stagličić et al., 2019
Trachurus spp	15	NC		Directive 1241
Trigla lyra	NA	21,9	M	Ismen et al., 2016
Chelidonchtys lastoviza	NA	15		FishBase
Trisopterus capelanus	NA	11,4	F	Ünlüoğlu 2015
Uranoscopus scaber	NA	15,8		FishBase
Xyrichtys novacula	NA	10		Battaglia et al., 2010
Zeus faber	NA	35,1		FishBase

Table SM4. Results from POLR models on the scores relative to the social-ecological effectiveness of the two implemented BPs (i.e., selective fishing gears and increased dialogue with the MPA) and the additional BP indicated to be important by fishers (i.e., increased surveillance). Significant predictors are highlighted in bold.

		"Selective gears" score		**"Increased dialogue" score**		**"Increased surveillance" score**	
Predictor	**DF**	**Chi-square**	**p-value**	**Chi-square**	**p-value**	**Chi-square**	**p-value**
MPA	1	0.036	0.849	0.489	0.484	0.069	0.792
Age	1	0.138	0.709	**5.028**	**0.025**	3.157	0.075
Education level	1	0.007	0.931	1.461	0.227	2.498	0.114
Satisfaction with incomes from SSF	1	0.729	0.393	0.386	0.534	0.038	0.845
Proportion of household incomes from SSF	1	1.011	0.314	0.596	0.440	2.246	0.134
Number of gears used	1	0.218	0.639	0.032	0.859	0.056	0.812
Number of days of the week fishing in the MPA	1			0.580	0.446	0.662	0.415

Table SM5. Internal coherence of scores

SCORE	Cronbach Alpha	Lower CI	Upper CI
Score1 “selective fishing gears”	0.925	0.890	0.930
Score2 “increased dialogue”	0.976	0.972	0.979
Score3 – additional measure “increased surveillance”	0.989	0.987	0.991

Text SM2 - Multi-collinearity analyses

Prior to the analyses, dependent variables (i.e., the perceived effects of the BPs adopted) were tested for potential multi-collinearity to confirm the logic of distinct analysis and avoid redundancy in outcomes. A moderate to very high collinearity was found between all pairs of the perceived effects of the BPs both for the BPs adopted within the study (i.e., selective fishing gears (Fig. SM1) and increased dialogue with the MPA management body (Fig. SM2)) and the additional intervention indicated by fishers to be of importance (increased surveillance, Fig. SM3). In all cases, correlations between items and the relative scores always exceeded 0.8. For this reason, we decided to run single POLR models only on the composite scores, to avoid redundant results.

Before performing model selection, we also tested for potential multi-collinearity between predictors analyzing pairwise correlation between the explanatory variables using Spearman's correlation. Pairwise correlation was calculated through Spearman's correlation and visualized using a correlation plot (package 'corrplot' in R, Wei and Simko 2017). No issues of multi-collinearity were highlighted in the dataset (Fig. SM4).

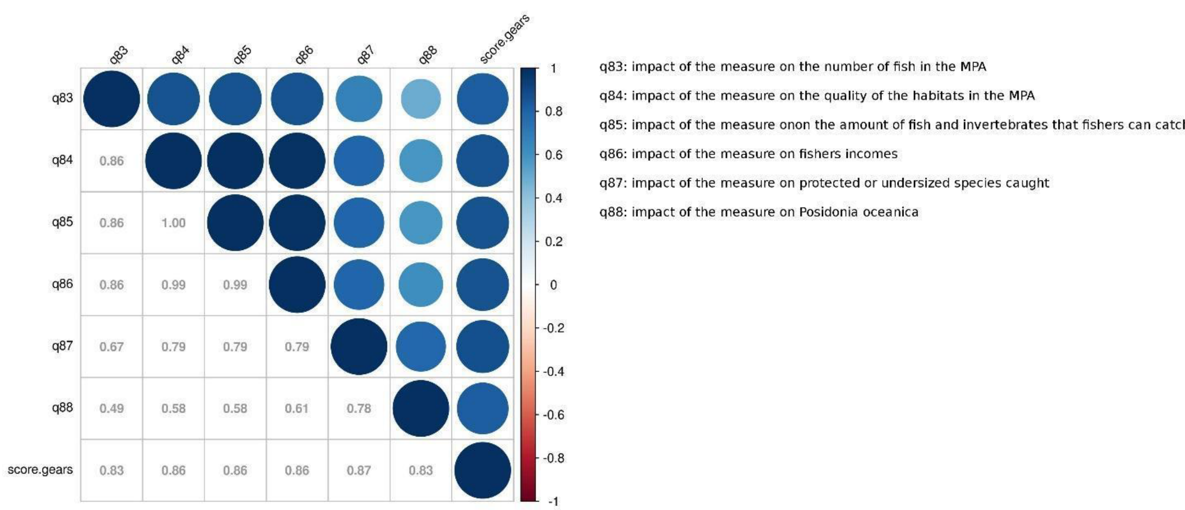

Figure SM1. Spearman's correlation between pairs of items (perceptions of social-ecological effectiveness) composing the compound score associated to the BP "selective fishing gears" (TO BE PRINTED IN COLOUR).

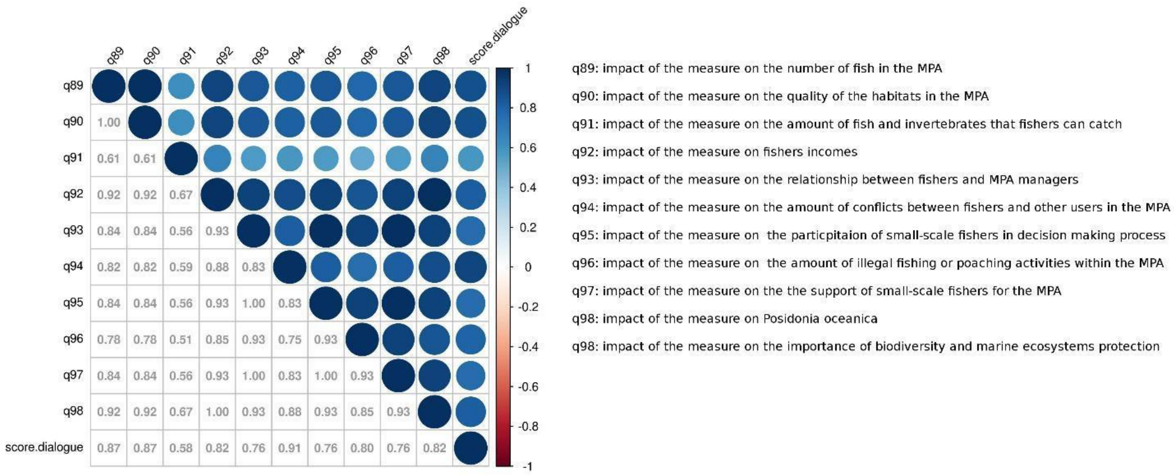

Figure SM2. Spearman's correlation between pairs of items (perceptions of social-ecological effectiveness) composing the compound score associated to the BP "increased dialogue with the MPA management body" (TO BE PRINTED IN COLOUR).

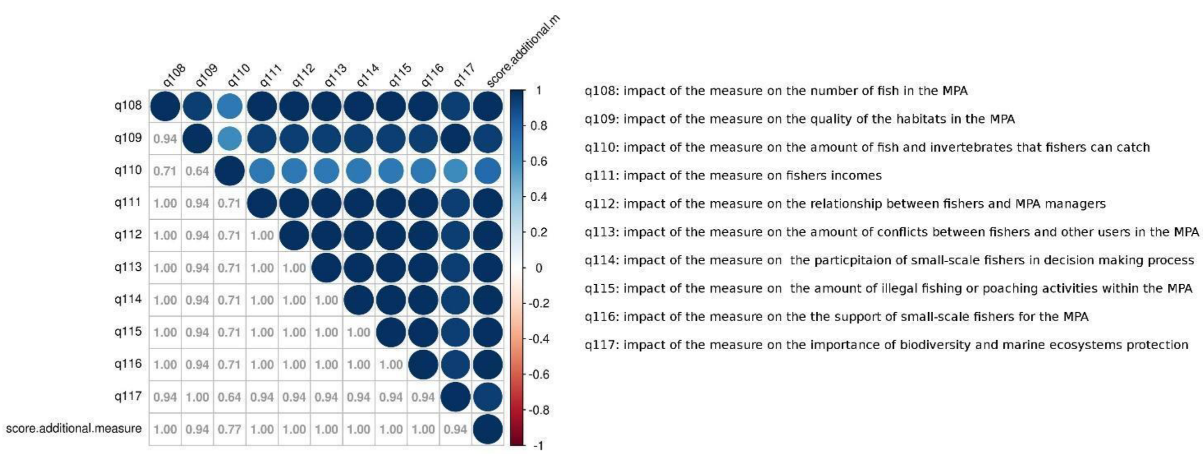

Figure SM3. Spearman's correlation between pairs of items (perceptions of social-ecological effectiveness) composing the compound score associated to the additional BP management measure ("increased surveillance") indicated to be important by fishers (TO BE PRINTED IN COLOUR).

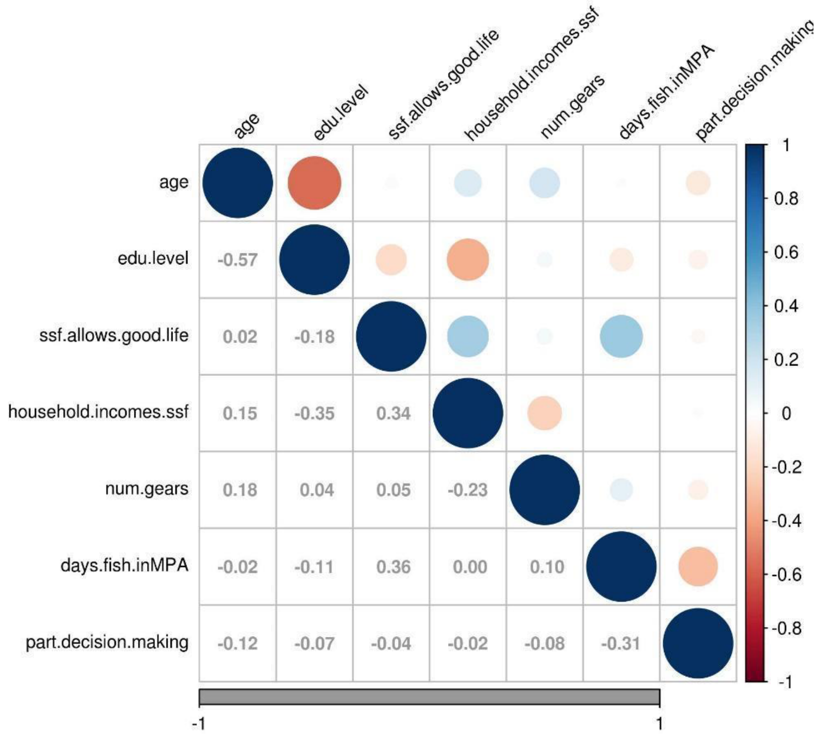

Figure SM4. Spearman's correlation between pairs of dependent variables (TO BE PRINTED IN COLOUR).

DESCRIPTIVE ANALYSES OF THE SAMPLE

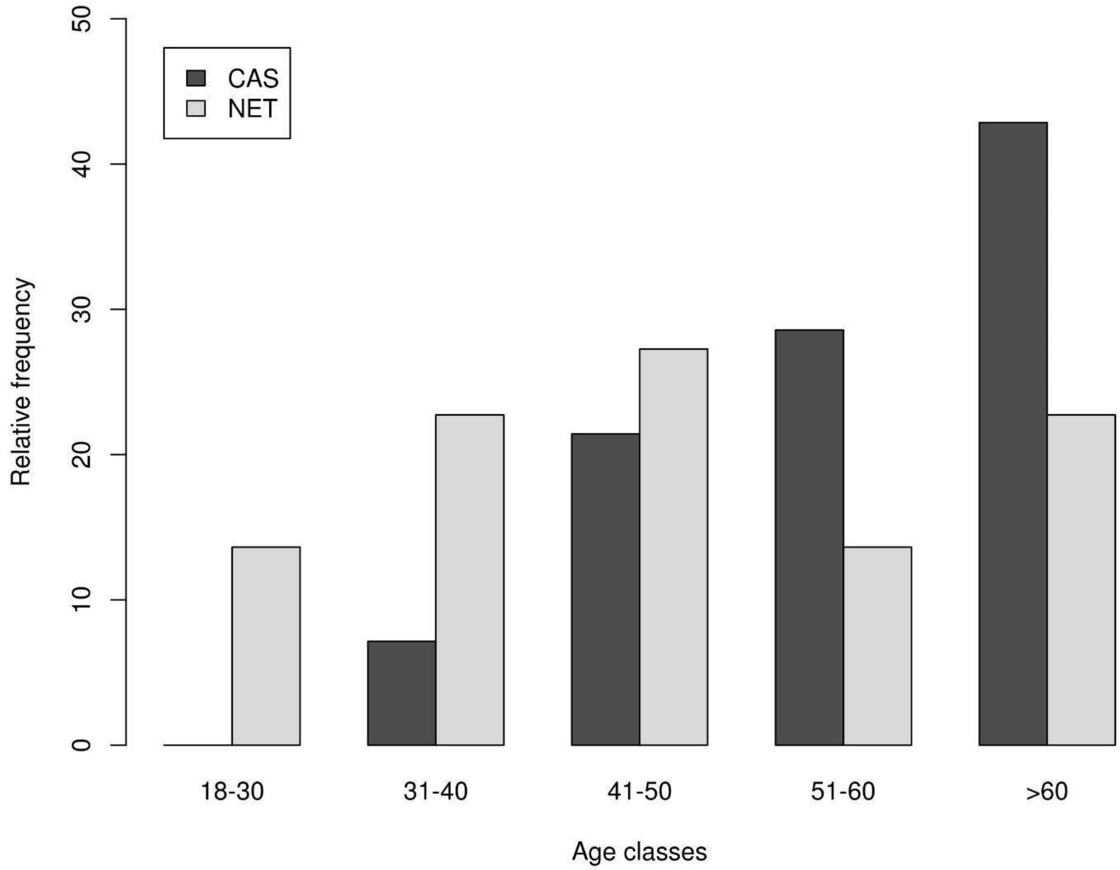

Figure SM5. Relative frequency of age classes of the interviewees for the 2 MPAs (CAS=Castellabate, NET=Regno di Nettuno)

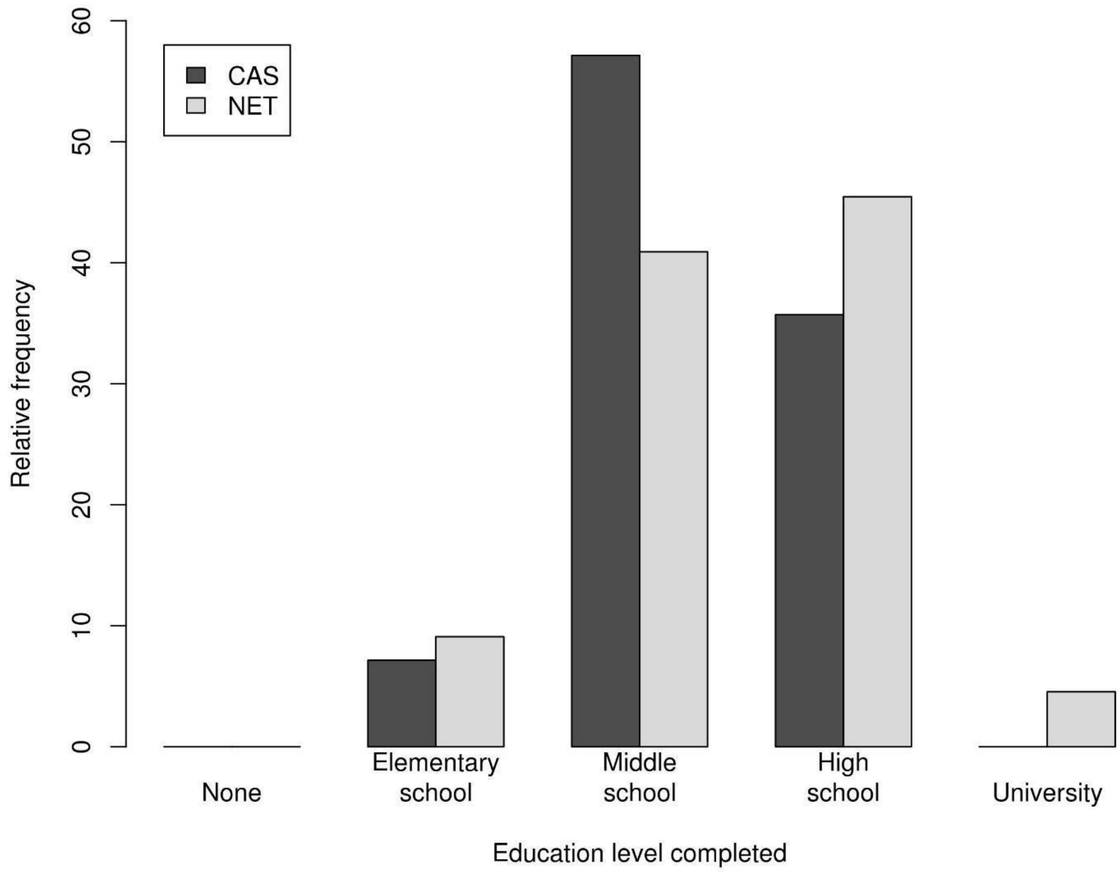

Figure SM6. Interviewees education level for the 2 MPAs (CAS=Castellabate, NET=Regno di Nettuno)

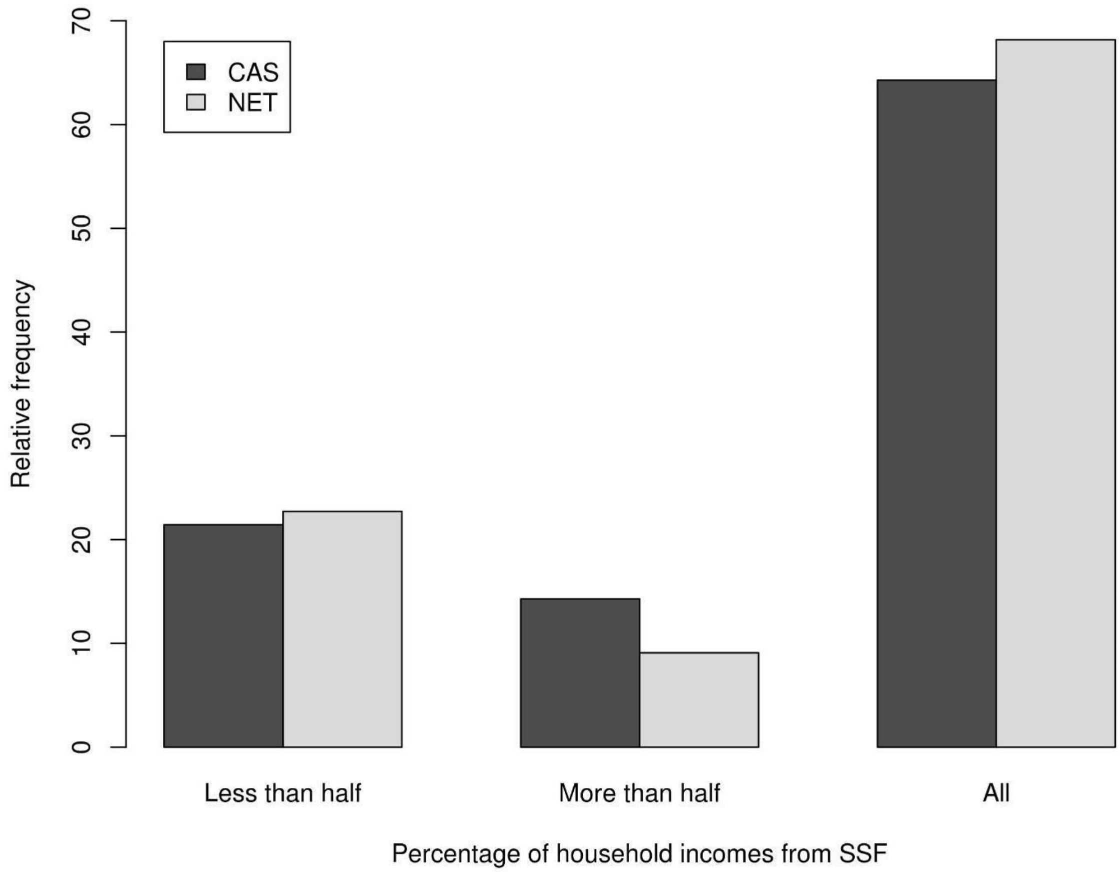

Figure SM7. Percentage of household income derived from small-scale fishing in the 2 MPAs (CAS=Castellabate, NET=Regno di Nettuno)

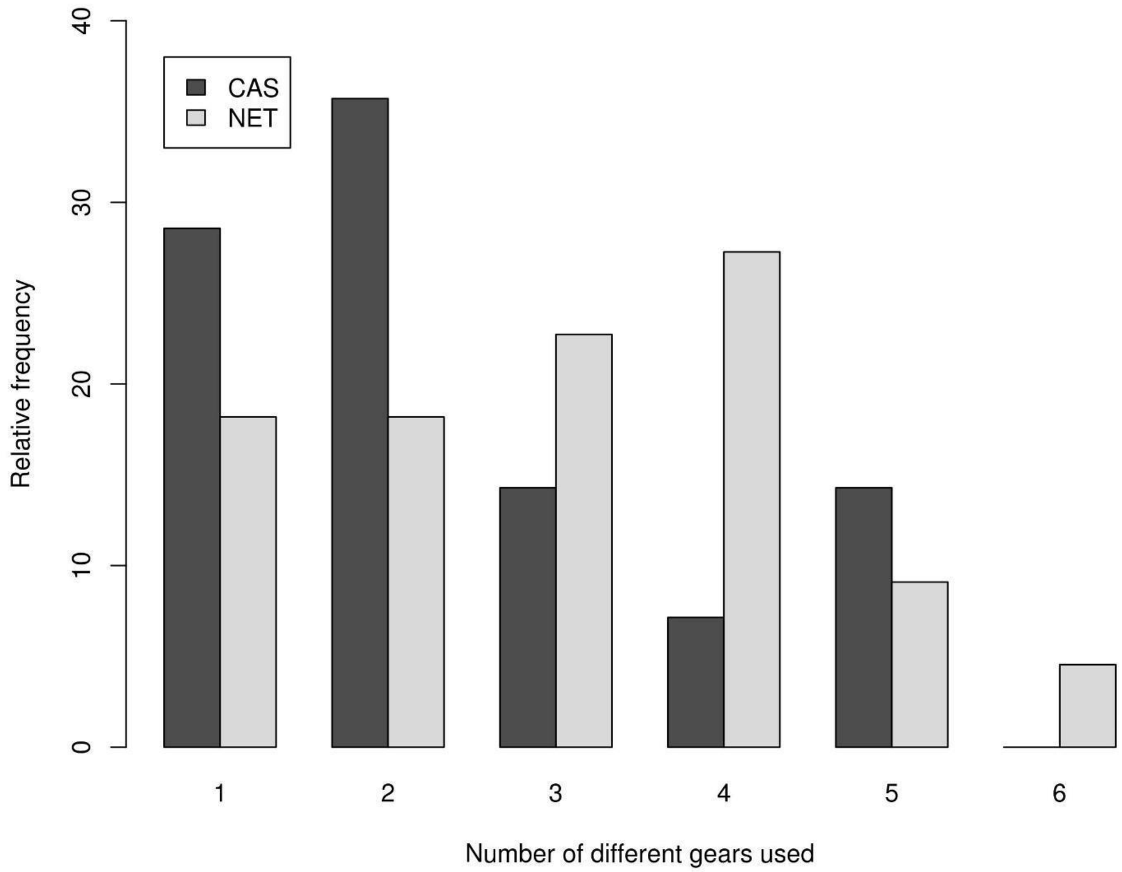

Figure SM8. Relative frequency of Number of different fishing gears used by interviewees in the 2 MPAs (CAS=Castellabate, NET=Regno di Nettuno)

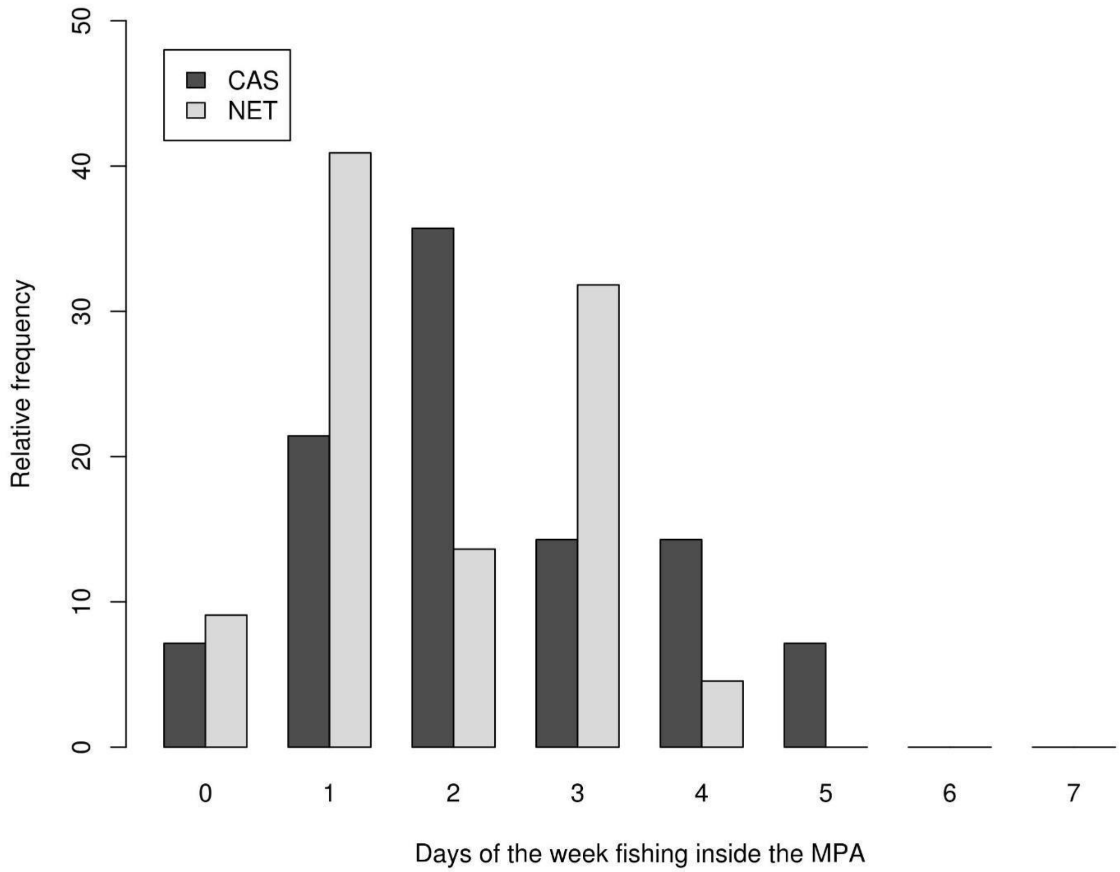

Figure SM9. Relative frequency of the average number of days spent fishing per week within the 2 MPAs considered (CAS=Castellabate, NET=Regno di Nettuno)

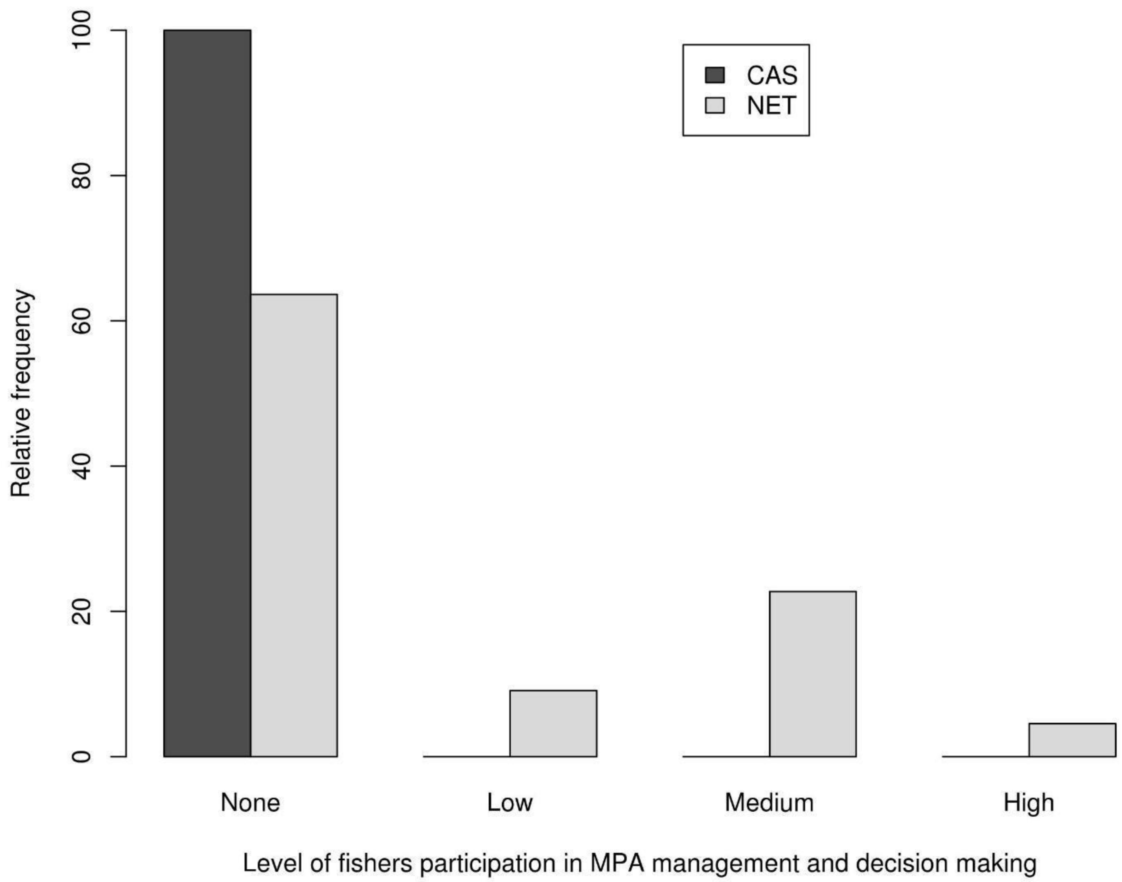

Figure SM10. Relative frequency of fishers' perceived level of participation in MPA management and decision-making in the 2 MPAs (CAS=Castellabate, NET=Regno di Nettuno) (TO BE PRINTED IN COLOUR).

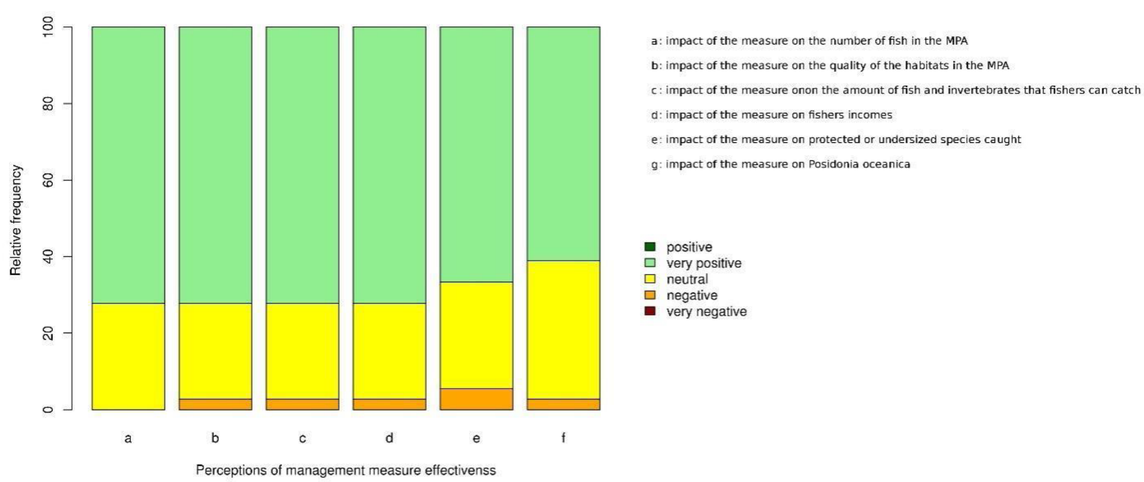

Figure SM11. Relative frequency of the perceived social-ecological effectiveness of the implemented BP "selective fishing gears" (TO BE PRINTED IN COLOUR).

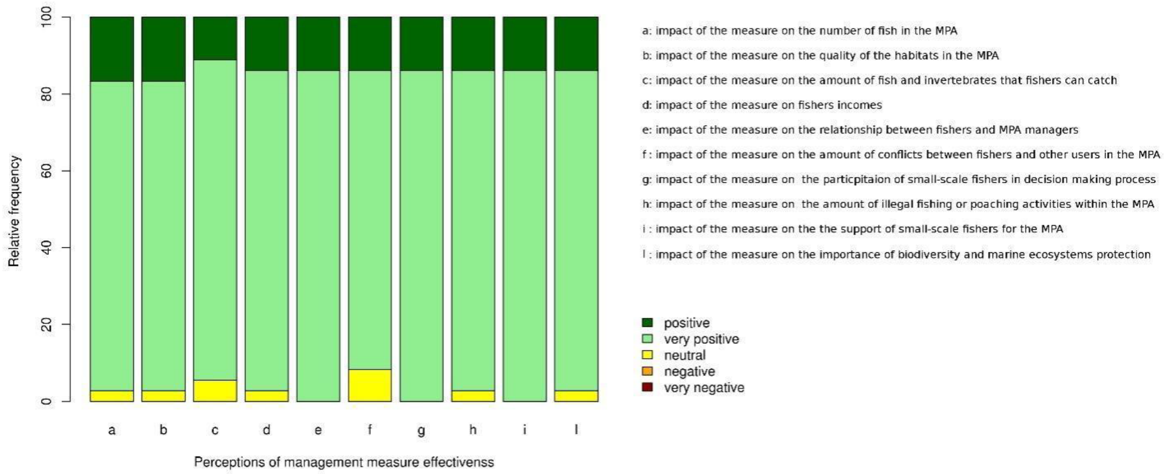

Figure SM12. Relative frequency of the perceived social-ecological effectiveness of the implemented BP "increased dialogue with MPA" (TO BE PRINTED IN COLOUR).

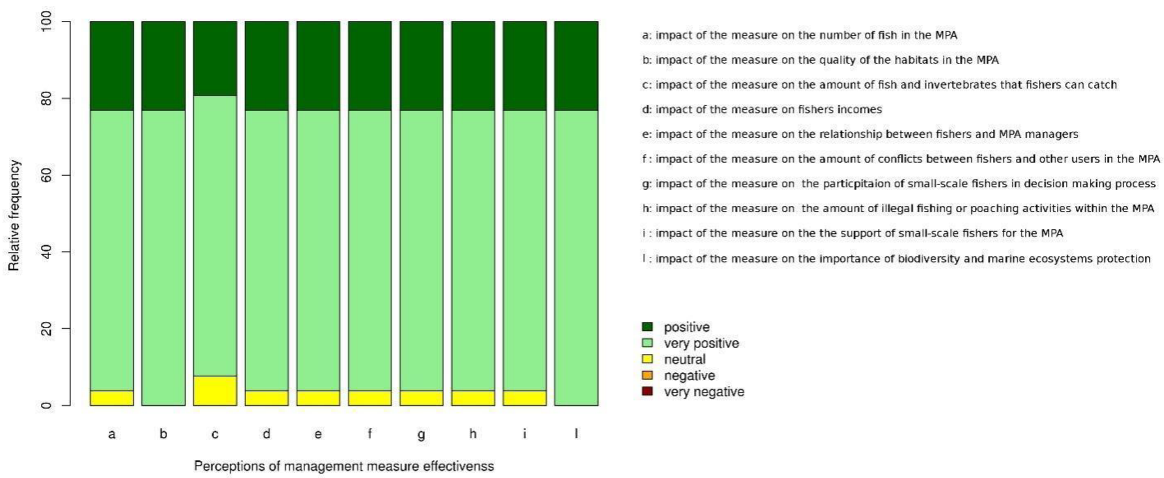

Figure SM13. of the perceived social-ecological effectiveness of the implemented BP "increased surveillance" (TO BE PRINTED IN COLOUR).

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Serena Zampardi reports financial support was provided by Campania Region. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.