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An urgent call for more ambitious ocean literacy strategies in marine protected areas: a collaboration project with small-scale fishers as a case study

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Cold-Water Corals play a paramount role in marine benthic ecosystems, increasing their complexity and providing spawning and nursery habitats to many species. However, due to their sessile lifestyle and ramified shape they are commonly entangled in nets and even by-caught during the practice of bottom-contact fishing, which includes impacts from both large-scale activities such as trawling and small-scale fishing (e.g., trammel nets or pots). In this context, passive and active restoration measures are crucial to avoid their damage and disappearance, which might cause the consequent loss of complexity and biodiversity of marine benthic communities. With the aim of modifying these fishing practices in the Marine Protected Area of Cap de Creus (North-Western Mediterranean), small-scale fishers and scientists (marine biologists) started a Participatory Process in which they agreed to develop a joint marine conservation program combining two distinct projects: a restoration project of the Cold-Water Corals incidentally captured on fishing nets for their subsequent reintroduction at sea (RESCAP project) and also a project on mitigation of fishing impacts on marine benthic communities (MITICAP project). Collaborative actions were carried out including interviews and exchanges of information with the purpose of collecting all the knowledge required for conducting the actions of the projects. This study shows the results of the assessment throughout five years (2017-2022) of cooperative work and highlights how crucial it is to develop long-term and revisable ocean literacy strategies for ensuring a sustainable ocean governance. An ocean literacy test evaluated the scientific knowledge of fishers at the end of the projects and revealed that despite all the efforts applied, still more work is needed, which reinforces the importance of improving the strategies of knowledge transfer for MPA management. Under the coordination of marine social anthropologists, a Cultural Consensus Analysis was conducted with the fishers. Results revealed a protoculture that should be characterized and considered when developing management strategies in the area. Additionally, the Personal Network Analysis showed that fishers have become agents of change and transmitted the learnings of the projects to their communities, fishers from nearby guilds, local educational centers and even the press. Furthermore, a list of recommendations is provided to optimize the multisector opportunities emerging from collaborative projects with marine scientists and fishers in MPAs.

KEYWORDS

small-scale fishing, marine restoration, Cap de Creus, Gorgonian, Mediterranean Sea, environmental management, cultural consensus analysis, personal network analysis

1 Introduction

Gorgonians are marine sessile colonial animals, which thrive on the seafloor as benthic suspension feeders (Gili and Coma, 1998; Gili et al., 2001). Several gorgonian species may appear in dense assemblages, forming the so-called "animal forests" on the seabed (Rossi, 2013). These forests are commonly built up intricate and complex three-dimensional structures, offering plenty of spaces that serve as refuge, spawning and nursery habitats to many other marine species, including highly valuable commercial species (Roberts and Hirshfield, 2004; Rossi et al., 2017; Baena et al., 2023). At different latitudes and from shallow to great depths around the globe, gorgonians play a paramount ecological role and conform to communities that are commonly considered as hotspots of biodiversity (White et al., 2012; Henry and Roberts, 2017). Moreover, benthic ecosystems dominated by corals and gorgonians contribute to nutrient cycling through benthic-pelagic coupling (Gili and Coma, 1998; Wild et al., 2009); also, they are commonly considered to embellish the seascape (valuable, among others, for recreational activities, e.g. scuba diving or underwater photography and filming) (Ponti et al., 2016).

Precisely, due to their three-dimensional shape and sessile lifestyle, combined with other characteristics such as low recruitment success, slow growth and late sexual maturity, gorgonians are highly vulnerable to anthropogenic pressures (Andrews et al., 2002; Brooke and Young, 2003; Watling et al., 2011). Anthropogenic threats to gorgonians can be translated into infections and even compromise their survival, as reported by Calvo et al., 2011 and Rivetti et al., 2014. Among the great menaces they face, there are disturbances related to global climate change, in particular exceptional storms and thermal anomalies such as marine heatwaves (Linares et al., 2008; Teixido et al., 2013) as well as mechanical damage by fishing lines and nets, anchorages and recreational divers (Bavestrello et al., 1997; Markantonatou et al., 2016). Additionally, gorgonians are threatened by other stressors like pollution (e.g., Chan et al., 2012; Frometa et al., 2017) and competition with non-indigenous species or mucilaginous benthic algal aggregates which may suffocate their polyps (Cebrian et al., 2012). Furthermore, run-off waters from poor land management often translate into increases in sedimentation rates and water turbidity in marine coastal environments, which highly affects the survival of gorgonians (Mateos-Molina et al., 2015). Moreover, the time required by gorgonians to recover from anthropogenic impacts has been quantified and it ranges from decades to centuries; it should also be considered that the recovery of gorgonian assemblages has often been identified as impossible at all (e.g., Althaus et al., 2009).

Given their crucial ecological importance and their high vulnerability, some conservation measures regarding gorgonians have appeared lately (Resolution U. N. G. A., 2006). In 2009, the Food and Agriculture Organization of the United Nations (FAO) (Food and Agriculture Organization, 2009) recognized gorgonians among the main contributors to coral forests, sensitive and potentially vulnerable to Deep Sea Fisheries and consequently part of Vulnerable Marine Ecosystems (VME), and therefore, they appeared as priority species in several conservation plans (Armstrong et al., 2014; Otero and Marin, 2019).

Moreover, despite being still insufficient, the declaration of Marine Protected Areas (MPAs) aims to protect marine benthic ecosystems. Several MPAs have been established to safeguard gorgonian-dominated ecosystems as well as to other relevant marine habitats (Liconti et al., 2022).

In 2008, Dudley (2008) defined the MPA concept as "a clearly defined geographical space, recognized, dedicated, and managed through legal or other effective means, to achieve the long-term conservation of nature with its ecosystem services and cultural values". In this sense, the Mediterranean Sea has been largely reported and positioned as a priority area for conservation efforts due to its high ecological richness plus being at the same time threatened by intense human impacts (Mittermeier et al., 1999; Myers et al., 2000; Shi et al., 2005). It has even been estimated that the Mediterranean Sea contains around 4 to 18% of the world's marine species at a macroscopic level despite representing only around 0,3% of the volume of the world ocean (Bianchi and Morri, 2000). The first Mediterranean MPAs appeared in the 1960s, with the Port-Cros National Park's MPA being the first one, recognizing local areas of high ecological value and allowing multiple-use by different stakeholders (Claudet et al., 2008). Soon afterwards, several studies conducted in the North-Western Mediterranean unveiled the high natural value of the area, so in 1998 the MPA of Cap de Creus was declared [Law 4/1998 (BOE, 1998)]. On the other hand, the area also benefited from protection by the European Union Natura 2000 network that emerged with the aim of preserving specific habitats and species, but still presents some weaknesses as it lacks consistent fisheries management measures under the Common Fisheries Policy (Fock, 2011).

Despite being theoretically controlled by rules and limitations, anthropogenic activities have been and are still impacting the seabed of MPAs such as Cap de Creus in the Mediterranean Sea. As a matter of fact, small-scale fishing has intensified in the area since the 1960s (Gómez et al., 2006). This practice has changed through time, changing traps made of natural materials and cotton nets for more resistant and easier to clean nylon trammel nets and traps (Carbonell, 2020). The fishing gear made of these long-lasting materials worsens an already existing problem: this gear continues fishing when lost at sea (personal communication of a fisher). In fact, abandoned, lost or otherwise discarded fishing gear (ALDFG) is an increasing concern addressed by the United Nations Environment Programme (UNEP) and FAO, who highlighted among other impacts alterations in benthic ecosystems (Macfadyen et al., 2009). In the MPAs, impacts on benthic ecosystems can also increase due to recreational fishing through direct capture (spear fishing and angling) as well as leisure boating through anchoring (Gómez et al., 2006). Moreover, the expected growth of the already present tourist sector, together with added pressures such as chemical pollution and coastal erosion in the Mediterranean Sea are predicted to increase environmental impacts (Plan Bleu, 2017). Therefore, it is important to address this emergency as soon as possible, as the cumulative effects of anthropogenic activities under a global change scenario may produce irreversible damage, further reducing both the local natural and social communities' capabilities to face the challenges of a changing environment. Consequently, it is extremely important to reduce anthropogenic impacts as soon as possible.

The reversal of anthropogenic impacts depends on whether economic activities go hand in hand with restoration and/or preservation of ecosystems. It has been pointed out that adopting a holistic and integrated approach to ecosystem management is necessary to limit multiple human pressures (Plan Bleu, 2017). In this sense, considering education as a transversal tool to bring awareness, prevention and/or solutions to marine issues, the development of ocean literacy (OL) strategies may play a paramount role. OL is an understanding of "the ocean's influence on you and your influence on the ocean" and it is one of the main points in the agenda of the UN Decade of Ocean Science for Sustainable Development 2021-2030 (UN, 2018). The Decade aims not only to achieve major scientific and technological progress but also to generate societal outcomes, one of which is "an inspiring and engaging ocean where society understands and values the ocean in relation to human wellbeing and sustainable development" (UN, 2018). This includes improving OL among citizens, from different contexts, encompassing formal and non-formal education but also decision-makers and society at large (UN, 2018). Although OL emerged with the clear educational purpose of establishing a curriculum for embedding OL in formal education, it broadened its scope and evolved to a movement that includes science and policy, and which is currently a UNESCO priority adopted overseas (Koutsopoulos and Stel, 2021) (see Figure 1 and for more information also check Supplementary 1).

On the other hand, considering the need for a holistic approach to ecosystem management, it turns out necessary to consider existing traditional ecological knowledge (TEK) in conservation and OL studies. TEK was first defined as "a cumulative body of knowledge, practice, and belief evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes et al., 2000). Given that biological conservation is inextricably affected by local activities and pressures, struggling with socioeconomic inertia is crucial and TEK may play a key role (Gómez and Maynou, 2020). As Drew stated in 2005 (Drew, 2005), through the exchange of information between marine scientists and locals, not only is access to new bodies of knowledge gained but local people also acquire a sense of stewardship and ownership, which may be crucial for marine conservation purposes. Interest in TEK has increased in the last years, probably due to the recognition in 1993 that TEK could be a major contributor to important current environmental challenges like conservation and biodiversity (Gadgil et al., 1993), protected areas (Johannes, 1998) or sustainable behavior (Schmink et al., 1992 and Berkes, 1999). When talking about the knowledge of specific individuals, we should use the term Local Ecological Knowledge (LEK) and since its importance was highlighted in the 90's several studies were conducted around this topic (Aswani et al., 2018) (see Figure 2 and for more information also check Supplementary 1).

The establishment of the Natural Park of Cap de Creus in 1998, as well as its management, have produced controversies between the different stakeholders and their maritime activities, which reveal different conceptions of heritage, resource appropriation, and preservation (Gómez and Lloret, 2017; Gómez et al., 2021). The lack of an effective regulation of uses and management plan has activated bottom-up initiatives from scientists and small-scale fishers to implement actions addressed towards protecting and restoring marine benthic ecosystems (Santín et al., 2022a).

So, following the idea of holistic management, the MITICAP (Implementación de Medidas Innovadoras de Cooperación entre Pescadores y Científicos para una Mejor Gestión de la Pesca Artesanal con el Objetivo de Mitigar sus Impactos en Hábitats

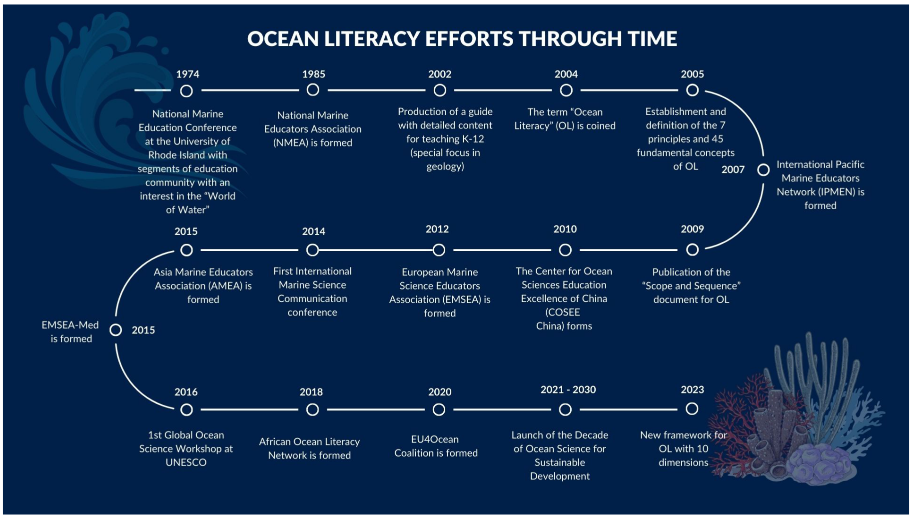

FIGURE 1
Timeline showing the evolution of global OL efforts through the years.

Marinos Sensibles) and RESCAP (Conservación y Recuperación de Poblaciones de Gorgonias de Profundidad mediante Restauración Ecológica y Mitigación de los Impactos de la Pesca) projects were developed specifically to address marine research on gorgonians, including a necessary tight cooperation between small-scale fishers from two guilds (Port de la Selva and Cadaqués-Port Lligat) of the Cap de Creus area and marine researchers from the Institut de Ciències del Mar in Barcelona (ICM-CSIC).

One of the main purposes of the projects was to engage fishers in ecosystem restoration and conservation. One objective has also been to try to get fishers to change some of their fishing habits in the future, by making them aware that they would thus contribute to a lesser impact on the ecosystems without significantly affecting their revenue. This would enhance their resilience to environmental challenges, empowering the fishers to act as agents of change and facilitate knowledge transfer on sustainable practices. The previous long experience of the ICM-CSIC with OL efforts (see Figure 3 and for more information check also Supplementary 1), included precedent efforts and projects like "ICM Divulga", "El Mar a Fons" or "Observadors del Mar" that unveiled the still poor marine scientific knowledge that society has (not only fishers but also students and policymakers) in relation to the conservation of marine benthic ecosystems (Salazar et al., 2022), and specifically holding misconceptions concerning gorgonians in the study area of Cap de Creus (Salazar et al., 2019). Therefore, along with marine conservation and ecosystem restoration several OLactions were also developed in the context of MITICAP and RESCAP to expand the dissemination of the scientific knowledge of the projects. Both projects highlighted the importance of collaborative studies between fishers and scientists for marine benthic studies, with contributions on the study of the

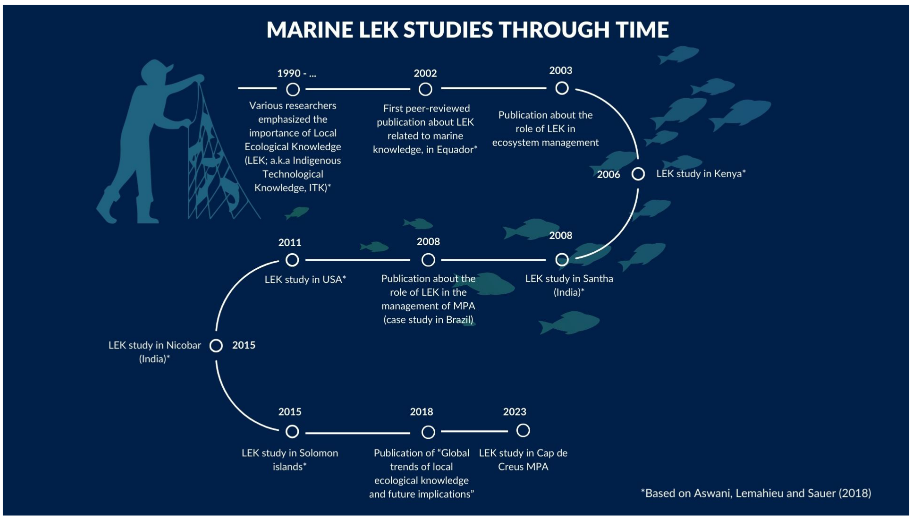

FIGURE 2
Timeline showing the evolution of marine LEK studies and related milestones through the time. Based on and edited from Aswani et al., 2018.

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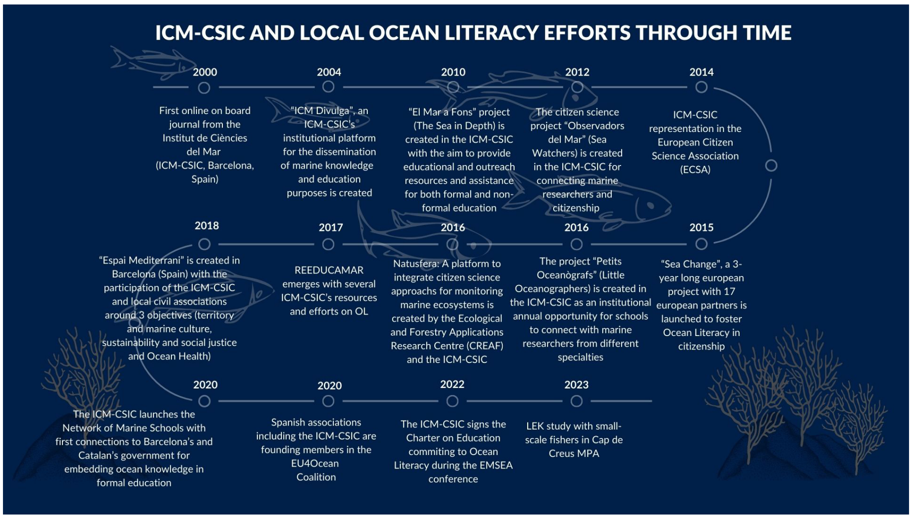


FIGURE 3
Timeline showing the evolution of the ICM-CSIC and local OL efforts through the years.

economic viability of joint conservation activities, the implementation of mitigation measures for reducing the impacts of fishing in the study area or the detection of possible threats to marine biodiversity (Montseny et al., 2021; Santín et al., 2022b; Biel-Cabanelas et al., 2023; Higueruelo et al., 2023). However, important dimensions related to social and educational aspects were not previously analyzed and reported.

The current research will focus on the social and educational aspects of the MITICAP and RESCAP projects not previously addressed. The main purpose of this study is to expose these results after 5 years of collaborative work among marine scientists and small-scale fishers in the Cap de Creus MPA. So, the present research focuses on the whole collaborative process of marine conservation and ecosystem restoration developed, including the several OL actions conducted, the assessment of scientific marine knowledge in fishers after the end of the projects, the characterization of their own knowledge systems, and the spreading of the projects that they have done: Hereby, this study conducted in the framework of the two above mentioned projects (MITICAP and RESCAP) will specifically:

1) Present the design and approach followed for the Participatory Process conducted in Cap de Creus MPA during the period 2017-2022.
2) Explain the different kinds of OL actions conducted for marine scientific knowledge dissemination.
3) Assess the marine scientific knowledge acquired by local small-scale fishers after 5 years of collaborative work.
4) Analyze if there exists a Cultural Consensus regarding marine biology among the small-scale fishers involved in the projects.
5) Evaluate the possible transmission of knowledge about the projects by fishers through Personal Network Analysis.

2 Materials and methods

2.1 Study area

The study area of the framework projects and the location of the two fishing guilds (Port de la Selva and Cadaqués-Port Lligat) involved in the study is located in the North-Western Mediterranean Sea, in the Cap de Creus area (42°19′12″ N, 03°19′34″ E) (Figure 4). The protection of this region was the result of several initiatives (Figure 5) which started in 1976 when Ramon Folch i Guillén envisaged desirable protection of the area (Guillén, 1976).

After several other conservation efforts (Generalitat de Catalunya, 2023), in 1998 Cap de Creus became the first Catalan maritime-terrestrial Natural Park, covering a total area of 13886 ha of which 3073 ha belong to the marine system [Law 4/1998 (BOE, 1998)]. In 2014, the Cap de Creus area was also declared a Special Protection Area (SPA) (Area ES5120007 of the Natura 2000 Network [Order AAA/1299/2014 (BOE, 2014)], Lugar de Interés Comunitario (LIC; in English Site of Community Importance, SCI) and 'Sistema de cañones submarinos occidentales del Golfo de León' (submarine canyons system of the Gulf of Lions, in English), which belongs to the European Union Natura 2000 Network [Area ESZZ16001 (BOE, 2014)].

The present study counted on the participation of the 8 fishers involved in the RESCAP and MITICAP projects, that is to say with all the small-scale fishers from the guilds of Cadaqués (Portlligat harbor) and Port de la Selva. It is important to highlight that small-scale fishing in the area involves challenging work conditions and experiences little generational turnover, which is why this number is quite low. The focus of the two framework projects was on the benthic ecosystems of these fishing grounds which are located on littoral and shallow continental shelf areas off the Cap de Creus. The

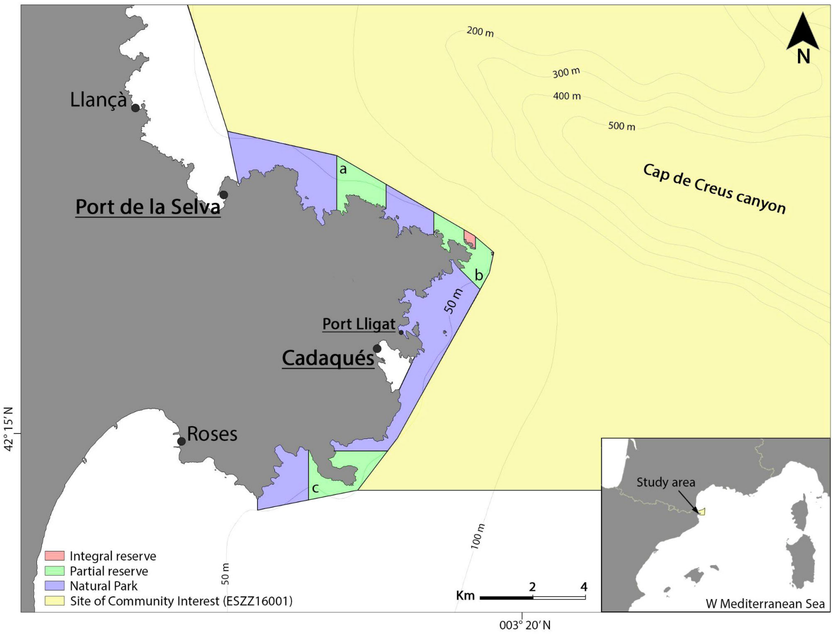


FIGURE 4
Map of the study area in the Cap de Creus MPA (Site of Community Interest ESZZ16001), in the North-Western Mediterranean. The different fishing guilds with small-scale fishers conducting their usual activity within the study area are marked with black dots. Underlined are the two fishing guilds of the fishers involved in this study: Port de la Selva and Cadaqués-Port Lligat. The different levels of protection of the marine protected area are coloured in red, green and purple (meaning integral reserve, partial reserve or Marine Natural Park, respectively).

benthic ecosystems of the Cap de Creus area are found in a conspicuous topography with sea beds dominated by sandy and muddy sediments, but also rocky outcrops, relict bioherms, erosive features, and planar bedforms (Lo Iacono et al., 2012; Dominguez-Carrió et al., 2022). The Liguro-Provenzal-Catalan current (also known as Mediterranean Northern Current) and strong dominant winds bring inputs from the Rhône River and cause water mixing, resulting in the particularly high biological primary production in the area (Courp and Monaco, 1990; Lloret et al., 2008) and consequently, high abundance of fish and other species of commercial interest (Purroy et al., 2014).

2.2 Participatory Process followed to set the basis of RESCAP and MITICAP projects

The importance of including Participatory approaches (PP) in decision-making processes related to marine conservation has been

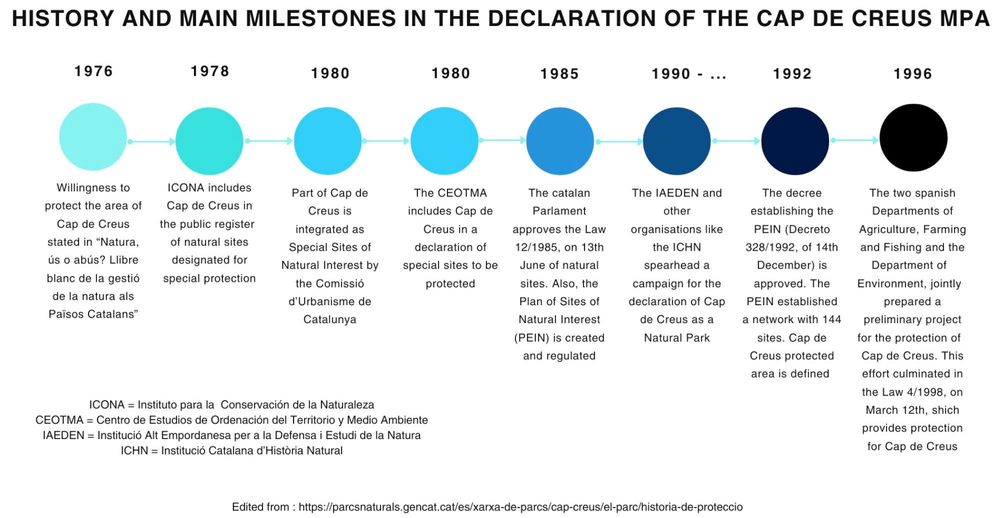


FIGURE 5
Storyline and milestones in the protection process of the Cap de Creus area that culminated with the declaration of the MPA in 1998.

previously highlighted (Gaymer et al., 2014). Among PPs, and after examining different approaches, Multi-criteria Decision Analysis promoting an active participation of stakeholders in the complete process has been identified as probably one of the best strategies to follow (Estévez and Gelcich, 2015). Following this approach, in 2017, the first contacts among marine scientists (with previous experience in benthic ecology and marine conservation), local and national policymakers, and local small-scale fishers from the Cap de Creus MPA were established after several calls and meetings in order to set up the basis of the two envisaged new conservation and restoration projects.

After several exchanges of information, the two framework projects and their related conservation and restoration actions were specifically focused on gorgonians dwelling on rocky substrates. This was in part because they represent one of the most important groups of structural sessile animals that provide shelter and refuge to other species and so contribute to maintaining the biodiversity and conservation of marine ecosystems (Slattery and Lesser, 2021). Among gorgonians, those belonging to the group of Cold-Water Corals, can be found mostly at depths of between 50 and 4000 m (Orejas et al., 2019). Considering the fishing habits of small-scale fishers (fishing in around 90 m depth) in Cap de Creus MPA, these species were considered as the more suitable study species for restoration purposes. The RESCAP project offered a framework to recover gorgonians entangled in small-scale fishing nets, apply restoration methodologies, and return the specimens to natural areas for consequent monitoring to develop a pilot project (Montseny et al., 2021; Grinyó et al., 2022). On the other hand, the MITICAP project emerged to implement measures to mitigate the fishing impacts caused by small-scale fishing in the Cap de Creus MPA (Santín et al., 2022a). Both projects were designed to be developed in an interconnected way (Figure 6), involving a set of different activities. They also followed a Participatory Process and regular meetings that facilitated knowledge exchange between scientists and fishers. The projects also counted with the direct participation of the local government (the Cap de Creus Natural Park) offering facilities for the scientific team and providing boat and personnel to return the gorgonians back to the sea.

The RESCAP and MITICAP projects followed a Participatory Process consisting of 3 main phases (Figure 7):

1) Initial meetings to exchange points of view, set the conditions for conducting the projects, and design a collaborative action plan.
2) Implementation of the previously designed collaborative action plan through a set of actions which included joint fishing events, cartography and/or biological studies, an ecological restoration pilot project, as well as OL activities.
3) Closing meetings to evaluate the process conducted and to draw conclusions to produce a final report for policy purposes.

The projects were successfully developed during the period 2017–2022 in cycles of one year. The yearly renovation of the projects implied the approval and willingness to continue the different parts involved (marine scientists, fishers, and policymakers). Every year, marine scientists and the same fishers performed a convenient and successful collaborative work with the achievement of all the envisaged goals. Every year from 2017 until 2022 the two projects were conducted with the same fishers. Although the projects started with 9 fishers, due to the untimely passing away of one of the fishers, the final years of the projects were conducted with 8 of them, including two from Cadaqués'guild and the rest from Port de la Selva's guild.

Each part of the project included the direct participation of marine scientists, fishers, and both local and national policymakers. A collaborative approach with the highest possible horizontal perspective was always pursued. One of the goals was to engage and empower fishers in the restoration and protection of benthic ecosystems, empowering them as potential agents for knowledge transfer and environmental awareness, fostering their role as marine stewards. The restoration project was mainly focused on the bycatch colonies of cold-water corals and soft corals, being *Eunicella cavolini* (Koch, 1887) the most abundant gorgonian found and returned. The methodology used to recover and return the specimens was following the approach of Montseny et al. (2021). In brief, the gorgonians recovered from fishing nets were transferred to experimental aquariums in the fishing guild (for Port de la Selva) or a local from the Cap de Creus Natural Park (for Cadaqués-Port Lligat). Colonies were fragmented into medium size nubbins,

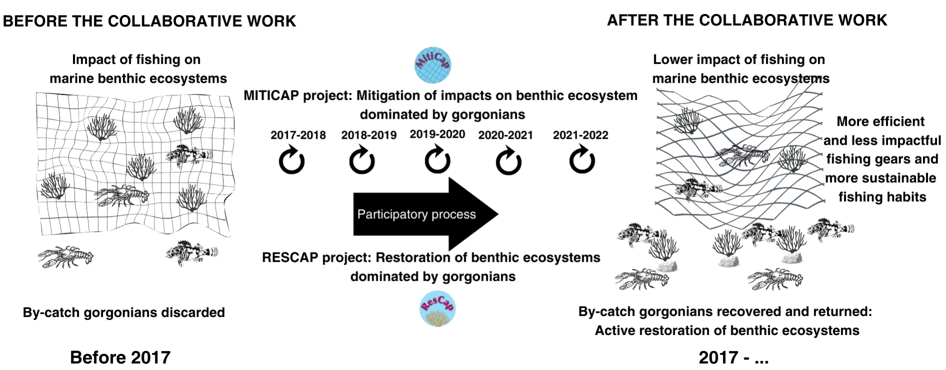


FIGURE 6
Conceptual graphic summarizing the aims and outputs of the two framework research projects (RESCAP and MITICAP).

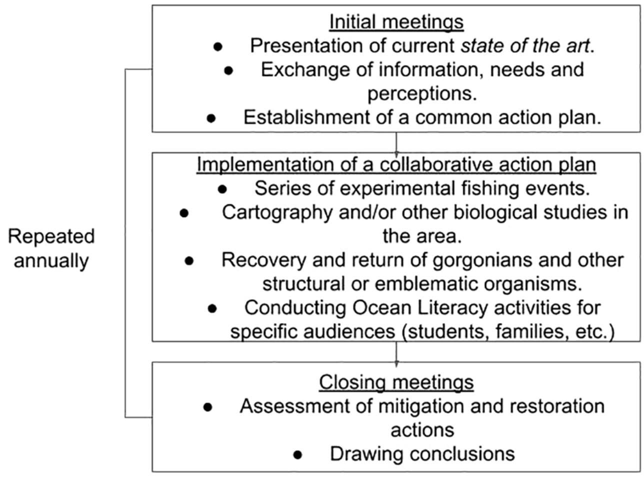


FIGURE 7
Participatory process conducted and repeated every year during the whole conduction of the RESCAP and MITICAP projects.

according to the size with the highest probability of success suitable for the restoration method used (see details in Montseny et al., 2020). Finally, the colonies were put in a stone of specific dimensions that allowed the gorgonian to fall and arrive to the seafloor in an upwards position, ensuring its survival (Figure 8). The restoration action was consolidated after the successful recovery and returned more than 4000 gorgonians and soft corals.

Annual OL activities aimed at exchanging and spreading marine scientific knowledge were conducted (Figure 9). Those activities included: in-person meetings, collaborative fishing events, common visualization of fishing grounds recorded by means of a ROV (remotely operated vehicle), visits to the experimental aquariums, OL workshops, formal and non-formal educational activities, the attendance to small-scale fishing

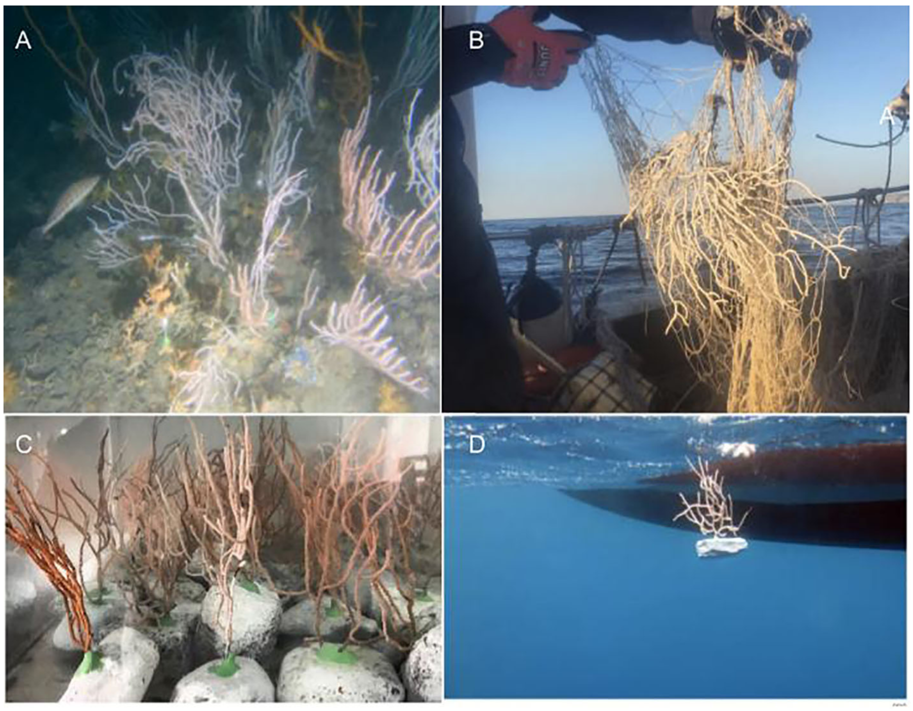


FIGURE 8
Photos of the restoration pilot project conducted in Cap de Creus MPA. **(A)** Gorgonians playing shelter and nursery role functions. **(B)** A gorgonian caught in a trammel net. **(C)** Gorgonians in the experimental aquarium attached to cobbles. **(D)** A gorgonian (attached to a cobble) is returned back to its natural environment.

FIGURE 9
Photos that show examples of the different kinds of OL activities planned towards exchanging marine knowledge, conducted during the projects. **(A)** Initial and final meetings between fishers and marine scientists. **(B)** Collaborative fishing events with fishers and marine scientists. **(C)** Common visualization of fishing grounds recorded by means of a ROV. **(D)** Visits of the general public to the fishing guilds, guided by marine scientists. **(E)** OL activities for families conducted by fishers and educators. **(F)** OL activities for educational communities conducted by fishers and educators. **(G)** Participation of fishers and marine scientists in Small-scale fishing conferences. **(H)** Social media posting and outreach through different media (TV, newspapers, websites, etc). **(I)** Explaining the projects in local social events.

conferences, social media posting and outreach in different media and outreach in other local social events.

Universities, and primary and secondary schools (including high schools) were also involved in the project as different parallel projects were conducted in the same framework, from school activities to PhD thesis.

2.3 Data collection: a survey for assessing ocean literacy and conducting a Personal Network Analysis and a Cultural Consensus Analysis

After the end of the framework projects, a survey was developed to conduct a Personal Network Analysis (PNA) and a Cultural Consensus Analysis (CCA) under the coordination of marine social scientists from the Autonomous University of Barcelona (UAB). The survey, intended for completion by the fishers participating in the projects, aimed to evaluate their marine scientific knowledge after the collaborative efforts in Cap de Creus MPA. It also aimed to identifypotential knowledge systems and assess their personal networks as potential disseminators of marine scientific knowledge. The survey was accompanied by a consent form stating that they accepted to be interviewed under the protection of the Spanish "Ley Orgánica" (decree-law) 3/2018 (BOE, 2018). The survey, which can be checked in Supplementary 2 was divided into two main parts:

The first part was designed for collecting personal information about each fisher (characterized as "ego") and to characterize the particular network of each fisher (their "alteri"). This was designed for collecting information about each "ego" with their "alteris", meaning people with whom each fisher had shared information about the projects. With this information, it was then possible to conduct a Personal Network Analysis (PNA) and analyze possible networks for communication and dissemination purposes. Taking into account that we all have a personal network built upon our life histories (McCarty et al., 2019), a PNA was used to explore the channels through which knowledge was transmitted. The personal network questionnaire applied consisted of four parts (based on McCarty et al., 2019): 1) "ego" characteristics (the respondent), 2) a name generator that allows the collection of "ego" "alteris" ("Mention people with whom you have spoken about the project"), 3) the attributes of the "alteris", and finally, 4) the ties between the mentioned "alteris".

The personal data gathering involved questions on the age of the fisher, details about their boat, target species (specifying why), fishing gears used, years of practicing fishing activities, preferred fishing grounds and years of experience there, months of fishing activity, months of peak activity and frequency of fishing. Also, questions about whether they combined fishing with other economic activities, regarding their self-perception as fishers by choosing certain adjectives, to value their impact and their willingness to participate again in collaborative projects with marine biologists. Then, they should specify if they have talked with other people about the projects and to which sectors these people belonged.inally, they provided 10 “alteris”, individuals with whom they have talked about the project. For each “alteri”, then they specified age, gender, city, or town of residence, years of acquaintance/relationship, closeness, frequency of encounters with “ego” and the places where “ego” and “alteri” usually met or whether there were usually more people around whenever they met a particular “alteri”.

The second part consisted of 54 questions to assess the marine scientific knowledge of each fisher. This part contained 21 multiple-choice questions with mostly only one right question. The questions were mainly about marine biodiversity in general (mostly gorgonians and *Posidonia oceanica*) and the links between fishing and marine ecosystems. Also, this part contained two open questions about Fisher’s previous experience with gorgonians. Finally, there were 31 Yes or No questions, too, addressing their perceptions about different aspects concerning trends in both local marine biodiversity and marine conservation with the possibility to add comments. Among the questions in the second part, a total of 41 questions were selected for conducting the CCA. These questions are indicated with an asterisk in Supplementary 2.

The data collected in the survey for conducting the PNA can be checked in Supplementary 3 and contains data for “ego”, e.g., from the 8 fishers involved during the whole project. Also, it contains information on the “alteri” provided by all fishers (except for one who didn’t want to participate in “alteri” part). All participating fishers signed an informed consent form.

2.4 Personal Network Analysis

After compiling all the data for the PNA, a data analysis was performed with “Egor” and “Igraph” packages in R version 3.5.0 (R Core Team, 2023) and included basic social network measures: size, density, components, diameter, clustering, betweenness centrality, and eigenvector centrality.

Size indicates the scope of the knowledge that has been acquired (the higher, the greater the reach of the diffusion). Density measures the level to which the same information is shared when it circulates between the “alteris” of the personal network. Components indicate if knowledge is spread efficiently among the actors. Diameter indicates how much compacted is the network and so how quickly or slowly the information can flow. Clustering provides the shape of the information communication. High clustering means that it is a closed personal network, and low refers to a tendency to be more open to the network. Betweenness centrality refers to the level to which actors are key in a personal network to transmit knowledge (high betweenness tells us that there are key actors for diffusion). Eigenvector centrality indicates nodes connected with key nodes with more accumulated ties (it shows if there are clusters in the personal network and if there are nodes that find out about things before the rest because of their connection with important nodes).

2.5 Cultural Consensus Analysis

To evaluate the level of shared and existing scientific knowledge at the end of the projects, CCA was used, which allows us to know whether there exist shared or cultural beliefs among a group, following Stone-Jovicich et al. (2011). Part of the knowledge questionnaire with binary and multiple-choice questions was taken to assess whether there was shared knowledge about the project. Those questions are indicated with (*) in Supplementary 2. Cultural consensus model operates on the basis of three assumptions: 1) common truth: there is only one correct answer; 2) conditional independence: the answers are independent of each other; and 3) homogeneity: the questions are on the same topic.

In this study, CCA was applied to assess scientific knowledge related to the projects that was shared among fishers. As an OL test was not conducted at the beginning of the collaboration, the presented analysis cannot distinguish among previous scientific knowledge or learnings acquired by fishers during the projects. In order to conduct the analysis, the package “AnthroTools” from R version 4.3.0 (R Core Team, 2023) was used following the approach of Purzycki and Jamieson-Lane (2017).

The CCA conducted provided three analytical elements, which are: 1) individual and group competence (value that ranges from 0 to 1: the closer to unity, the greater cultural competence), 2) key cultural responses (inductive reconstruction of the commonly shared responses (“cultural truth”), and finally, 3) Comrey ratio, which is the way to know if there is or there is not consensus in a social group [it tells us how much of the variance of the data can be explained only by one factor -the cultural truth-, following Caulkins (2004)]. If the Comrey ratio is >3:1, then there is cultural consensus.

3 Results

3.1 Personal Network Analysis

The results of the data collected for each fisher were used to characterize each “ego”. The 8 fishers involved during the whole project were all men and belonged to the Port de la Selva fishing guild except two who belonged to Cadaqués. With the exception of one, all fishers ranged from 46 to 60, and they had more than 15 years of experience in the fishing sector. The only exception was a fisher in the early 30s, who accumulated less experience. As small-scale fishers, the boats used in their daily fishing activity were less than 6 meters in length. Also, the boats ranged from 0,98 to 2,5 TRB of tonnage and from 9 to 42 W of power. The boats were made from wood or wood and fiber and were built more than 30 years ago, from the 70s to the 90s. The main fishing gears used by fishers were trammel nets, pots (traps), “bolitja” (local traditional fishing gear for fishing bonitoes) and solta (gillnets), palangrillo (longline), “bonitolera” (local traditional fishing gear for fishing bonitoes) and “potera” (local traditional jig-type hooks to catch squids).

A graphic with the main results obtained on all the “alteri” profiles can be checked in Figure 10. The “alteri” were mainly men (more than double of alteris provided) between 40-and 60 years old. “Ego” contacted the “alteri” with high frequency in general, mostly

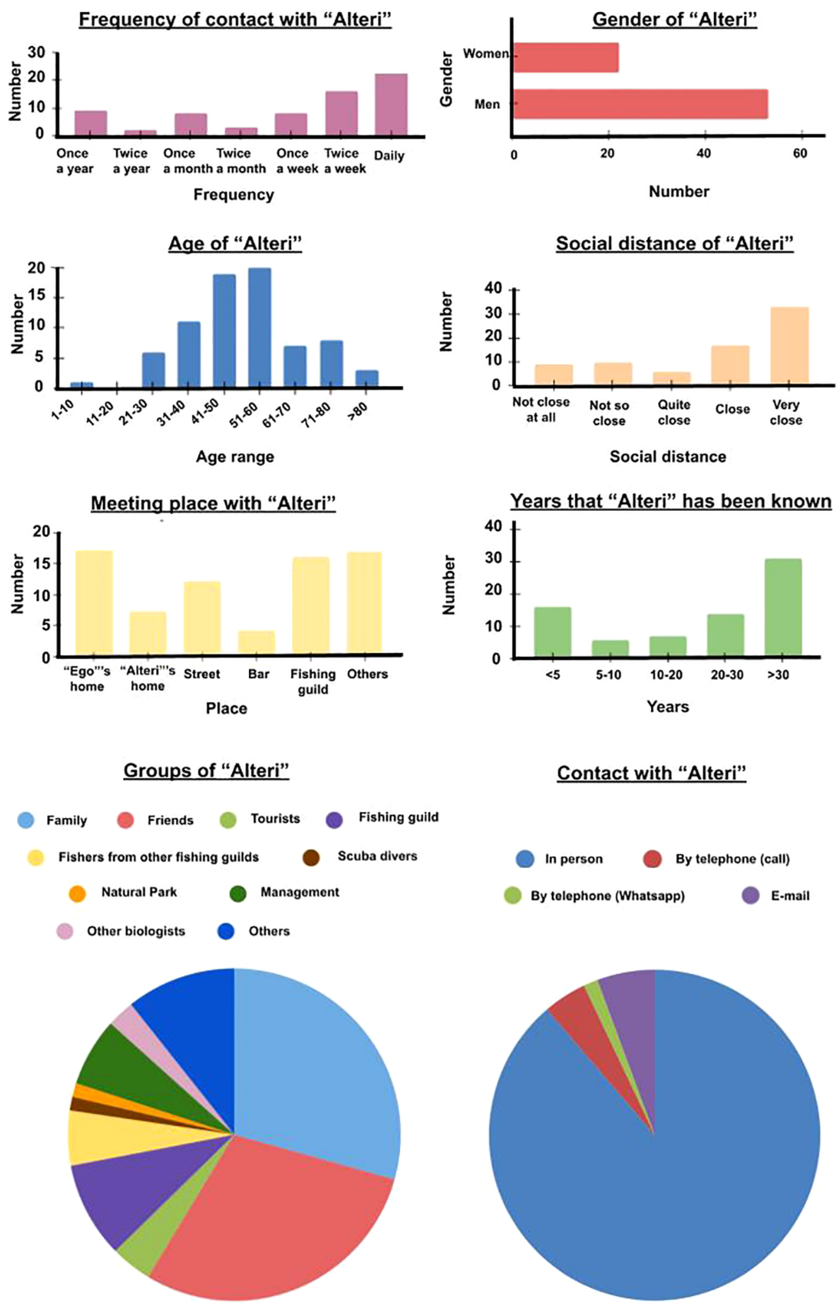


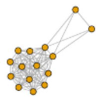
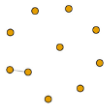
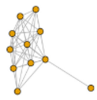
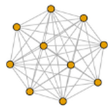
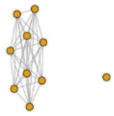
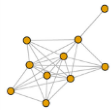
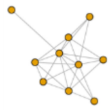
FIGURE 10
Characterization of the alteri provided by the fishers involved in the study. More details can be checked in Supplementary 2.

every day. The place to meet was varied, being home, the street, the fisher's guild, and other favorite sites. Among "others", it is important to highlight that the fishers mentioned fish markets, local commerce, schools, educational workshops, city halls, diving centers and other nearby cities or towns. The results also showed dissemination of the projects by fishers mainly in nearby Catalan towns or cities (Port de la Selva, Selva de Mar, La Vall, Llançà, Cadaqués, Roses, Colera, Albanyà, Palafrugell and Girona) but also in farther Catalan municipalities (Sant Cugat del Vallès, Lloret de Mar, Barcelona) and even other countries (Belgium, France and Italy).

Most of the "alteri" were considered as "very close" or "close" and the relationship among the fisher and the person provided started more than 30 years ago. Among the groups, "alteri" belonged mainly to family and friends but there were also tourists, other people from their own or other fisher's guilds, scuba divers, personnel from the Cap de Creus Natural Park, management personnel and other biologists. The most used communication channel was face to face but also telephone (calls over WhatsApp) and email.

The main results of the conducted PNA are summarized in Table 1. The networks obtained for each fisher involved in the

TABLE 1 Summary of the main results of the PNA for the fishers involved in the projects analyzed in this study, numbered from 1 to 8.

Fishers	1	2	3	4	5	6	7	8
PN								NA
Density	0,79	0,02	0,76	1	0,8	0,69	0,56	NA
Components	1	9	1	1	2	1	1	NA
Diameter	2	1	2	1	1	2	2	NA
Clustering	0,95	NaN	0,89	1	1	0,77	0,64	NA
Betweenness	0,11	0	0,21	0	0	0,15	0,31	NA
Eigenvector	0,15	1	0,19	0	0,13	0,28	0,4	NA
n (number of "alteri" provided)	15	10	11	10	10	10	10	NA

Note that fisher number 8 opposed to providing alteris and so the alteri's information for this fisher is indicated as "NA" (Not Available). "PN" refers to a Personal Network.

projects are provided, and the size, density, compounds, diameter, clustering, betweenness, and eigenvector of each network are shown. Overall, the networks were small (10-15 names), providing 10 "alteri", most of the fishers. Despite displaying small personal networks, results show that diverse actors are related to each other. In terms of density, most of the networks show a high cohesion except one (fisher 2). As for compounds, and except for Fisher 2, networks were not much fragmented, with 5 networks showing two distinct groups of "alteri" and one showing only one type of "alteri". The diameter of the networks was in general short with the exception, again, of Fisher 2 who presented disconnected groups of "alteri". High clustering dominated among the networks, with only fisher 2 presenting a loose network; networks belonging to fishers from the two fishing guilds present slight differences (the two networks from Cadaqués-Port Lligat show intermediate clustering and the ones from Port de la Selva are narrower). Finally, betweenness and eigenvectors show low values, meaning a high cohesion among "alteri".

3.2 Assessment of the fisher's ocean literacy and Cultural Consensus Analysis

The CCA results (see Table 2) are divided according to knowledge of gorgonians, *Posidonia oceanica* and general perception, separated by binary or multiple questions. The low Comrey's proportion obtained for all the analyses revealed a certain but very weak cultural consensus. There is no cultural consensus, although the results of the consensus on perceptions in the binary questions can be seen as the beginning of a process of knowledge creation.

All the data collected in the OL assessment can be checked in Supplementary 3. In general, the questions were correctly answered by most of the fishers. In Figure 11 correct answers for questions 1-13 are ordered by frequency. All fishers correctly marked *Posidonia* as a protector of littoral and an important habitat. Also, all of them identified gorgonians as important nursery habitats and shelters for many other species. The fishers saw a direct relation between the abundance of gorgonians and the abundance of fishing captures and

TABLE 2 Results of the CCA conducted with the fishers involved in the study.

Domain	Questions	Type	Comrey's Proportion	Interpretation (based in Caulkins, 2004)
Gorgonian	1,4-8,11-15,21	Multiple	2.19	Protoculture (weak agreement)
	41-43,47,50	Binary	2.41	Protoculture (weak agreement)
Posidonia	2,3	Multiple	2.22	Protoculture (weak agreement)
	24-26,40	Binary	2.34	Protoculture (weak agreement)
Perception	9,10	Multiple	2.13	Protoculture (weak agreement)
	27-39, 46,48-49	Binary	1.46	Subcultural (multi-centric)

100%	1. *Posidonia* protects the coastline, and it is a very important habitat. 7. When we say that gorgonians form communities, we mean that, among other things, they serve as nursery habitats important for various species of fish and invertebrates. 8. Conserving gorgonian marine forests often translates to increased catches in the long term and is beneficial for marine life. 11. Regarding the gorgonians returned to the sea with scientists: many of them survive. 12. Small-scale fishing harms gorgonian forests but this impact can be minimized with good practices. 13. Why is it so important to return gorgonians to the sea with a cobble? To facilitate their upward fall, promoting their survival.
88,89%	5. Why are gorgonians important in the sea? They create habitats in the sea and offer protection to other organisms.
77,78%	6. If you return gorgonians to the sea directly from the net, it is very unlikely that they will survive and thrive.
66,67%	9. In recent years, the populations of many commercially valuable fish species have significantly decreased.
55,56%	2. What is *Posidonia*? It is a marine plant. 10. In general, in recent years, the size of fish catches has significantly decreased.
44,44%	1. Gorgonian, posidonia and coral marine forests are very affected by anchoring and fishing nets, which is one of the reasons why there is a decline in fish populations. 4. What is a gorgonian? It's an animal.

FIGURE 11
Statements corresponding to the correct answers for questions 1-13, ordered from most to less well-answered. The percentage indicated on the left corresponds to the percentage of fishers who correctly answered each of the questions.

agreed with the fact that most of the gorgonians of the project had survived. Also, they recognized that small-scale fishing impacted marine benthic ecosystems but that this impact could be smoothed with good practices. Finally, they correctly identified that placing a cobble under recovered gorgonians can ensure their survival at sea.

Most of the fishers responded correctly to the main role of gorgonians in creating habitat and offering protection to other organisms, although one of the fishers answered incorrectly that most of the fish ate gorgonians. However, less than half of the fishers correctly identified gorgonians as animals, with 4 of the fishers identifying them as plants and one of them as a mineral structure. Other misconceptions included the thought that the gorgonians directly returned to the sea without a cobble or with a little piece of rock would also survive (each of these answers was chosen once). In general, fishers agreed with the fact that the abundance of several commercial species had decreased during recent years, but three of them stated that there was not much variation and even one stated that it had increased. Less than half of the fishers saw a direct relation between anchoring or lost fishing gear and the damage exerted on benthic ecosystems plus the consequent diminished fishing captures. Even more, 4 of them recognized damage in marine benthic ecosystems but with no consequences in fishing captures. Regarding the size of captures, there was no agreement, despite in general they thought fish sizes had decreased. Finally, almost half of the fishers thought that *Posidonia oceanica* was an alga.

Regarding fishers' perceptions (Figure 12), more than half of them identified collaboration in the conservation and restoration of the marine environment as the main gain of the projects, followed by the experience of working with biologists; one of them regarded the economic compensation earned during the projects as the main gain. Interestingly, all the fishers agreed with the fact that watching videos of the fishing grounds recorded by means of a ROV together with scientists was beneficial for better understanding fishing impacts on the marine benthic ecosystems. Surprisingly, when asked about possible measures to reduce impacts on marine benthic ecosystems dominated by gorgonians, most of them stated that there was no need to change anything because the impact was very low. Two of the fishers suggested reducing the size of the nets and the gear deployment time. One of them suggested changing the fishing gear.

The work of collecting and returning gorgonians from the fishing nets was mostly regarded as easier than previously thought, followed by "implying extra but well-employed work", and finally, two of them stated that it had caused a lot of extra work. None of the fishers regarded this task as having caused a lot of logistic problems during fishing events. Participating in the project was recognized as most beneficial in increasing the visibility of the sector followed by improving the relationship among fishers and empowering them. None of the fishers reported that it had caused conflicts among them.

Almost all of the involved fishers would recommend participation in the projects to other fishers and would like to participate in more similar projects in the future. Nevertheless, one of them indicated that conditions should be modified for him to recommend it or to participate again in the future in similar projects. When the fishers were asked about working alongside scientists, almost half of them indicated that it was a way of sharing knowledge. Four of them indicated that it was positive in general and only one of them indicated that it was positive in the short term but negative in the long term.

Finally, more than half of the fishers indicated that, in the future, they would try to catch fewer gorgonians, and the bycatch gorgonians would be returned to the sea if they had enough rocky substrates to attach them. This most voted answer was followed by the same answer but without the commitment of reducing the bycatch and two of them chose the answer that they would return gorgonians to the sea (without specifying that they should have enough rocky substrate, or a cobble attached).

4 Discussion

4.1 Collaborative work among marine scientists and fishers

RESCAP and MITICAP projects can be considered successful projects for several reasons. First of all, they counted on the continuous support from both local and national policymakers to conduct them. Marine researchers and fishers worked hand by hand for common purposes, putting differences aside. Both collectives focused on common goals and exchanged knowledge and perceptions continuously, thereby creating an atmosphere of

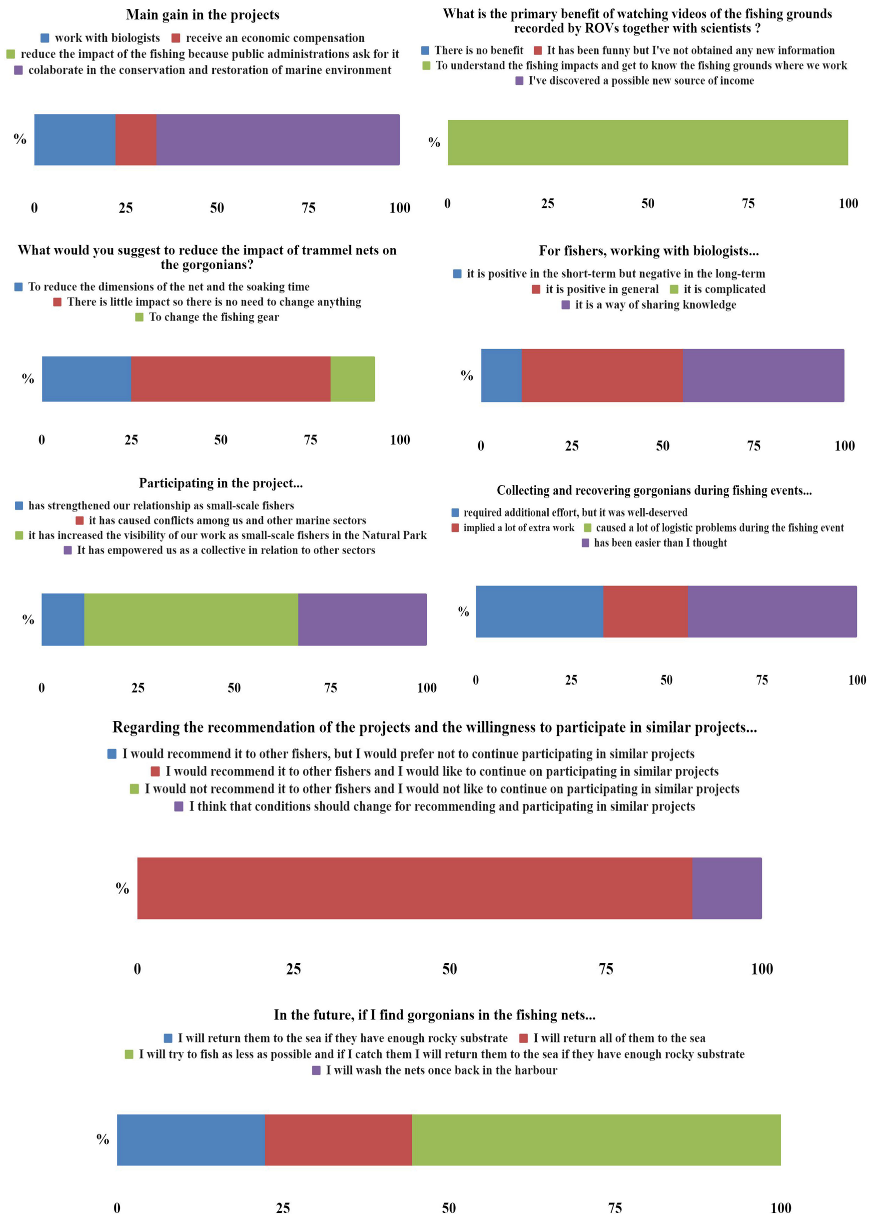


FIGURE 12
Perceptions of fishers who participated in this study.

trust. It is important that small-scale fishers feel heard and part of the MPA's management and conservation strategies to avoid negative consequences. In Sicily, for example, the fishers were not considered in management plans and they saw marine protection as a failure (Himes, 2003). Despite these kind of collaborations are not new and have been previously highlighted in other MPAs (e.g. Lucrezi et al., 2019) projects such as the ones presented offered new opportunities. In fact, the active restoration of cold-water corals entangled in trammel nets was only made possible through constant cooperation efforts of marine scientists, fishers and policymakers as well as involving other important sectors of society (universities, citizenship, media, private sector, among others) during the process.

The approach followed also served to detect possible issues of high ecological importance, like spotting possible outbreaks of *Astrospartus mediterraneus* (Risso, 1826) in the Mediterranean Sea as reported in Biel-Cabanelas et al., 2023. In 2022, Liconti et al. already highlighted the importance of considering and integrating under-utilized observations for decision-making in marine conservation.

Despite the relevant results and achievements after 5 years of collaboration for conservation and restoration purposes in the Cap de Creus MPA, in order to ensure long-term success it remains crucial to stress the need of developing a sustainable plan. This plan should not only rely on bottom-up approaches but should also include and integrate top-down approaches following an ongoing cycle of change-reflection-learning-change (Bijker et al., 2022).

It is important to consider other disciplines and dimensions that could affect the strategy plan developed or create unequal conditions. Absence or gap disciplines and dimensions that could compromise the chosen strategy and the applied conservation efforts. This study not only presents a proven model of collaborative work in MPAs but also the importance of integrating and re-adapting the conservation strategies to new social contexts and different dimensions (ranging from local to global contexts).

4.2 Personal Network Analysis

The PNA revealed opportunities for spreading marine scientific knowledge and promoting sustainable fishing behavior. These opportunities have a high potential in the context of social and community intervention (Maya-Jariego and Holgado, 2015). It is important to note that fishers were asked to provide at least 10 “alteri” but they have probably spread knowledge about the projects with more people. On the results obtained, despite most of the networks being very close in space, some “alteri” were identified farther, even at an international level (France, Belgium, and Italy), which once again highlights the importance of not underestimating the potential of collaborative initiatives in MPAs. In order to detect groups of fishers with more or less prominence and social leadership, it would be very interesting to compare the results of more PNA conducted in the area (Maya-Jariego et al., 2018). It would also be very interesting to amplify this effort and extend this PNA to other persons involved in the project, such as policymakers, families or students. This approach would detect the missing relationships between stakeholders of the Cap de Creus MPA, which could be beneficial to improve its management. This need was already detected in the Mediterranean MPA of Portofino, Italy, by Markantonatou et al. in 2016.

Moreover, one aspect not considered in the analysis was the content of what was spread from “ego” to “alteri”. A more in-depth analysis would be desirable to detect potential non-formal educators. Also, considering the possibility of spreading misconceptions, it would be desirable to design a complete OL strategy including PNA in MPAs management. Also, it would be very interesting to compare the results of more PNA conducted in the area, with other near small-scale fishers that could serve as detectors of groups of fishers with more or less social prominence (Maya-Jariego et al., 2018). Another important aspect to highlight is the age of the fishers involved in the project, which is directly related to the communication habits and channels mostly used by them. This information may be very interesting in order to develop communication strategies, mapping the audiences already reached, and developing particular strategies to reach missed audiences (Maya-Jariego and Holgado, 2015). For example, the results of the present study show that the fisheries world, but also their networks, continue to be a male domain, and therefore, considering that most of the networks were dominated by men it would be also interesting to put special emphasis on reaching audiences of women, too.

4.3 Ocean Literacy assessment and Cultural Consensus Analysis

The OL questions, mainly focused on marine scientific knowledge, were filled by fishers only just after the projects were completed. Therefore, it is difficult to draw conclusions on whether this knowledge was already previously learned. Even if this was not the case, it would be difficult to identify the sources of knowledge: whether it was acquired directly from biologists, through social media posts, news, or from other external sources. However, to reduce the noise for drawing conclusions, some of the questions were specifically formulated with a focus on the project’s learnings.

Among knowledge related to the conservation of marine benthic ecosystems, misconceptions concerning gorgonians were previously reported in different sectors of society (including not only fishers but also students and policymakers) (Salazar et al., 2019). The present study shows that after 5 years of collaborative projects between fishers and marine biologists, some misunderstandings or mistakes were still detected. For example, the fishers believe that fishing impact on marine benthic ecosystems are not related to the observed lower fish abundance. Perhaps one of the aspects that can explain this response is the lack of knowledge on fish life cycle that goes from egg, to larva, juvenile, and adult. During the early life stages of fish, the first three phases depend on bottom habitat complexity to increase survival rates of these vulnerable early stages. These areas serve as nurseries and shelter (Cau et al., 2020). This is a topic to be better explained in future co-fishing projects. This reinforces the importance of developing ambitious OL strategies in MPA management.

For future OL tests, it would be very interesting to conduct the same test with other small-scale fishers in the area but not directly involved in the projects, as well as with other kinds of fishers (bottom trawlers, for example) and other areas. Also, it would be necessary to conduct the test before and after the action or during different phases of the project in order to try to detect which specific activities enhanced the acquisition of marine scientific knowledge. Additionally, it would be very interesting to conduct an OL test some years after the end of a project to detect the possible consolidation of scientific knowledge on time. Moreover, this assessment after some time could serve for detecting best OL practices not only for acquiring marine scientific knowledge but also to retain the concepts in the long-term. It would also be desirable to extend these OL tests to other related sectors.

The CCA revealed what we have called “protoculture” for practical purposes in the sense of an incipient culture integrating scientific knowledge in ego knowledge that is being established in different domains. This implies that it is possible to reach a certain consensus in the short or middle term if more efforts are dedicated to developing marine scientific knowledge. Nevertheless, the level of "protoculture" highlights at the same time that if not enough efforts are put into strengthening OL strategies, the already existing domains could still be weaker in the future.

The implications of these results are broader because the loss of knowledge critically threatens marine local ecosystems, especially in community-based conservation efforts (Aswani et al., 2018).

Our findings reinforce the idea that for MPA management purposes it is vital to consider the already existing TEK and LEK in the Cap de Creus area, too, which is revealed to be accumulated for at least 10-15 years of fishing experience by small-scale fishers in the area. This accumulated knowledge was very useful for marine science purposes such as characterizing a possible outbreak of *A.mediterraneus* (Biel-Cabanelas et al., 2023).

5 Conclusions

As mentioned above, the RESCAP and MITICAP projects have been developed in the MPA of Cap de Creus where the involved fishers are users and should change their fishing strategies and reduce their impact. The results of these projects have important value as pilot evidence of how fishers can adapt to incorporate new sustainable fishing habits. To directly know their opinion, what they have learned, and whether this will be useful to achieve the objectives of changing habits, is essential to develop a management plan agreed upon between users and administrations. Due to the exceptionality of a 5 year-long collaborative work among small-scale fishers and marine scientists in the Cap de Creus MPA, this study would like to provide a final list of 5 conclusions and remarks, hoping that this experience may not only inspire the implementation of other similar projects but also help to avoid some mistakes and thus help to deliver successful collaborative projects.

1) Developing ambitious OL strategies in Marine Protected Areas is urgently needed. These strategies are essential for making well-informed decisions and for promoting sustainable behavior not only within MPAs but also beyond.

In order to improve OL, both studies and action plans are urgently needed as a basic dimension to address marine-related conservation actions in MPAs. OL tests conducted with small-scale fishers in Cap de Creus MPA after 5 years of collaboration with marine scientists still revealed some misconceptions about marine biology and the consequences/impact of fishing activities on marine benthic ecosystems. This could affect the effectiveness of conservation efforts and, specifically, to attain a more responsible fishing activity. This could also be applied in other similar projects and biological studies conducted in other MPAs. Those strategies could be extended to other sectors and agents of change involved in MPA management. They could also include several OL tests for assessing the acquisition of marine scientific knowledge through time and serve as possible detectors of the most efficient strategies to be applied. An approach based on assessment, development of OL activities, re-assessment, and drawing of conclusions accompanied by interviews to listen to fishers' opinions to be contrasted with the results obtained would be very much recommended.

It would be crucial, prior to any conservation action, to consider and characterize the already existing knowledge and monitor knowledge transfer as well as the knowledge acquired among the stakeholders involved in particular action plans. Nevertheless, if this strategy is not possible, it would be highly recommended to include at least one OL study in the strategy and report the results to the OL community.

2) Incorporating sociological dimensions into conservation efforts by conducting studies on OL, Cultural Consensus Analysis and Personal Network Analysis can provide new perspectives that are often overlooked. These perspectives have the potential to significantly enhance the management of MPAs.

As culture and local marine biodiversity are interconnected, the sociological dimensions, OL studies, and CCA are vital in conservation efforts. Despite the PNA revealing limited and local dissemination, the power of some fishers involved in reaching a wider audience -reaching even international contexts- should not be underestimated. Conducting OL studies, CCA, and PNA in other MPAs and increasing local stakeholders' participation is strongly recommended.

3) Conducting CCA in MPAs can be crucial for characterizing and safeguarding highly threatened knowledge systems.

Small-scale fishers in Cap de Creus MPA share a "protoculture": this weak consensus in certain domains should be considered in future conservation actions in the area. If this "protoculture" is strengthened, then OL strategies could benefit from the already existing consensus among local fishers. On the other hand, if this "protoculture" is ignored, there exists a real risk of diminishing the consensus over time, which may make the development of OL strategies and the promotion of marine scientific knowledge more difficult.

4) Underestimating stakeholders' personal networks and not conducting PNA could imply lower impact, loss of opportunities, and even unwanted effects in MPA management.

Although the PNA conducted was mostly limited to 10 "alteri", PNA in Cap de Creus MPA revealed several opportunities to reach local and seasonal stakeholders but also international audiences. Underestimating the opportunities to reach key stakeholders could severely affect conservation goals and opportunities for promoting marine scientific knowledge and enhancing sustainable behavior.

5) Multidisciplinary and multidimensional projects with effective action plans are crucial to achieving conservation goals in MPAs.

Including social dimensions in biological studies at the same time that considering both disciplines organically as inextricable provides new insights and may improve management decisions and planning for conservation purposes. Marine biologists and social scientists, policymakers, and local fishers should be involved in setting common goals and working hand in hand with MPAs. It is also important to include other social sectors such as universities or at community level families during the process. It turns out to be relevant to remember that punctual efforts, studies, and actions addressed towards conservation efforts are repeatedly proven not to be enough and that only common agreements on conservation regulations and associated responsible behavior of citizens in not only local but also global contexts are needed.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval was not required for the studies involving humans because people involved in the study agreed to participate in the study on a voluntary basis for research purposes and private data is not shared. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. The manuscript presents research on animals that do not require ethical approval for their study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

JS: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. SG: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. BV-S: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. MP: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. NV: Investigation, Methodology, Writing – review & editing. SA: Investigation, Methodology, Writing – review & editing. PB: Investigation, Methodology, Writing – review & editing. AS: Investigation, Methodology, Writing – review & editing. MM: Investigation, Methodology, Writing – review & editing. MB-C: Investigation, Methodology, Writing – review & editing. J-MG: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2024.1320515/full#supplementary-material

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