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Ocean Literacy Opportunities in Urban Marine Ecosystems: Gorgonian Populations in Barcelona (Catalonia, Spain)

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Abstract

Urban marine ecology, an emerging field in marine research, presents new opportunities to promote ocean literacy and contribute to the UN Decade of Ocean Science for Sustainable Development (2021–2030). Seeking to advance these objectives, the Gorgonia Barcelona project, launched in 2021, adopted a collaborative and inclusive approach to foster collaboration among marine scientists, local scuba divers, fishers, policymakers, industry, academia, and citizens, co-producing knowledge concerning marine benthic ecosystems dominated by Gorgonians in Barcelona. This study presents the findings and methodology developed throughout four successful years of the project, offering insights that could inspire similar initiatives elsewhere. Additionally, a Q-sorting exercise was conducted to assess Barcelona divers' alignment with ocean literacy dimensions, providing a tool that can be applied in diverse contexts—an identified research priority in ocean literacy. Three main diver profiles emerged: optimistic, pessimistic, and neutral. Divers expressed concerns about the urban marine environment, demonstrating a strong desire for its improvement. The study also incorporates testimonials from visitors to the project's experimental aquatic zone, emphasising the role of older generations in fostering sustainable behaviours. Discussions with a representative of Barcelona's fishers highlight the valuable local ecological knowledge they provide, despite often feeling overlooked and left out of marine conservation and ocean literacy discussions. The findings help close knowledge gaps and highlight the need for stronger conservation efforts, as well as more sustainable and inclusive governance models in urban marine areas. They also demonstrate how coastal cities can serve as key players in advancing ocean literacy through responsible research and innovation-driven approaches that encourage sustainable actions.

Keywords
citizen engagement; fishers; Gorgonian; *Leptogorgia sarmentosa*; Mediterranean Sea; scuba diving; urban marine environment

1. Introduction

The UN declared 2021–2030 as the Decade of Ocean Science for Sustainable Development, aiming to enhance global efforts and stakeholder engagement under the motto "the science we need for the ocean we want." One of the main objectives of this initiative is to contribute to the global ocean literacy (OL) goals (IOC-UNESCO, 2018). OL emerged as a global effort to promote an understanding of the ocean's influence on humans and our influence on the ocean. This initiative arose from the need to integrate ocean knowledge into broader societal awareness and decision-making processes (Cavas et al., 2023). Moreover, OL is not only about being ocean-literate but also about having the capacity to apply marine knowledge to make informed and responsible decisions (Cava et al., 2005). In the Mediterranean, applying OL—particularly its adapted framework, Mediterranean Sea literacy—can contribute to responsible decision-making and governance, while also contributing to conservation, restoration, innovation, and sustainability goals (Mokos et al., 2020). Following several research efforts in OL that contributed to defining and mapping OL knowledge, the concept evolved to integrate and designate the current OL dimensions (McKinley et al., 2023). In a systematic review of OL research, Shellock et al. (2024) raised several concerns and priorities in advancing OL studies to achieve sustainable ocean futures. Notably, they emphasised the need to develop monitoring tools to analyse the interrelations among stakeholders, OL "emoceans" (i.e., emotional connections with the ocean), and, particularly, trust and transparency. Additionally, reporting OL findings from different regions and contexts worldwide is crucial for a more comprehensive understanding of "the OL big picture," as OL research remains scarce and is predominantly led by a few countries, mainly the US, followed by Canada and the UK (Shellock et al., 2024).

Meanwhile, the field of urban marine ecology has gained increasing research interest as coastal urbanisation continues to expand, creating complex intersections between economic development and marine conservation. Several studies have explored these interactions, highlighting key challenges, such as habitat loss, altered water quality, and biodiversity shifts (Burt, 2014; Firth et al., 2016; Piwowarczyk et al., 2013; Todd et al., 2019). Urban marine development is often linked to various ecological impacts, such as pollution and habitat alteration. Research has documented how these changes influence marine ecosystems, particularly in terms of water contamination and structural alterations to habitats (Bulleri et al., 2020; Dafforn et al., 2015; Firth et al., 2016). Among the most significant consequences of shoreline urbanisation are the construction of dykes and breakwaters, the dumping of urban and industrial waste, and the discharge of ballast water, all of which can severely impact marine ecosystems (Figure 1).

Todd et al. (2019) highlighted the need to address knowledge gaps in marine urban areas and adopt a broader approach to studying urban marine ecosystems to improve both ocean and human health. This requires integrating ecosystem drivers, analysing future trajectories and fostering collaboration with city governments, planners, and industry. As a result, innovative strategies are increasingly necessary to better understand and manage urban marine biodiversity.

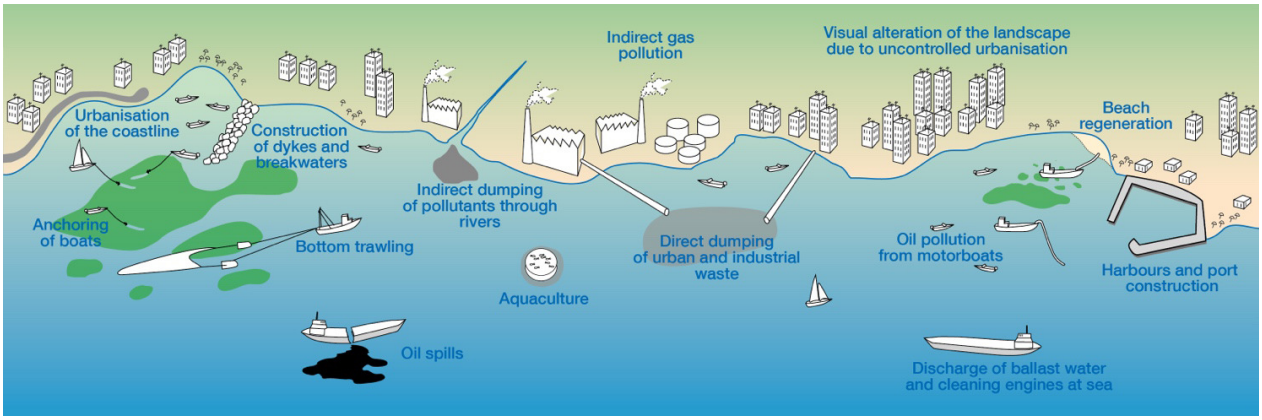


Figure 1. Some of the main anthropogenic pressures in urban marine areas. Notes: The authors were responsible for the translation of this figure; Illustration by Jordi Corbera. Source: Vendrell-Simón et al. (2022).

The coastal city of Barcelona (Catalonia, Spain), in the northwestern Mediterranean, has a deep maritime heritage and its cultural identity is closely tied to the sea. However, it was not until the 1990s, with the Olympic Games, that its once-marginalised seafront was transformed into a public space for recreation, aesthetics, and well-being. Over the past decade, efforts have intensified to strengthen the relationship between citizens and the coast, extending to the seabed, with the goal of reconnecting Barcelona's residents with the sea and its benefits. This vision is pursued through municipal programmes in collaboration with research centres, aiming to enhance urban liveability and resilience in the face of global change—an ongoing challenge for Mediterranean cities.

To support this effort, various OL initiatives have been launched to engage the public and promote a marine scientific culture that strengthens their connection to the sea, encouraging active participation in restoring urban marine ecosystems. In line with OL principles (Cava et al., 2005) and the goals of the UN Ocean Decade (IOC-UNESCO, 2018)—which envisions "an inspiring and engaging ocean where society understands and values the ocean in relation to human well-being and sustainable development" (IOC-UNESCO, 2021)—marine scientists and scuba divers have developed collaborative projects to improve OL among citizens.

Building on these factors, this study outlines the conceptualisation and framework of a marine research project: the Gorgonia Barcelona project. Throughout the process, multiple stakeholders were involved in following a responsible research and innovation (RRI) approach, which will be explained further. Information was gathered on different stakeholder groups, contributing to addressing research knowledge gaps and integrating them into the process in line with recommendations by Lucrezi et al. (2019) regarding divers and Salazar et al. (2024) regarding fishers. This project focuses on urban marine ecosystems, specifically marine benthic ecosystems dominated by the Gorgonian species *Leptogorgia sarmentosa* (Esper, 1791) in Barcelona.

Leptogorgia sarmentosa is a gonochoric Mediterranean Gorgonian species. Although it is known to survive in harsh urban conditions, it is more commonly found in non-harbour environments, usually as isolated colonies (Carpine, 1963; Gatti et al., 2012; Gori et al., 2011; Weinberg, 1976). Its bathymetric range extends from the surface (described by Betti et al., 2018) to depths of 300 metres (Carpine & Grasshoff, 1975). Gorgonians, which are found globally and across a wide range of depths, play a crucial role in marine ecosystems. Due

to their three-dimensional structure, they provide shelter (Ponti et al., 2016) and nursery habitats (Cau et al., 2020), supporting the survival of numerous species and contributing to increased marine biodiversity (Gili & Coma, 1998).

The Mediterranean Sea is often considered a biodiversity "hotspot." Despite representing only 0.32% of the ocean's total volume, it harbours 7%–10% of known marine species (Bianchi & Morri, 2000; Coll et al., 2010). However, there has been a proven rise in climate change impacts on marine benthic ecosystems in the Mediterranean Sea. In addition, some of its ecosystems have been poorly studied, and the associated socio-ecological dimensions are not well understood (Garrabou et al., 2022). On the other hand, marine citizen science has been shown to be an effective approach to fostering citizen engagement in marine research, playing a key role in enhancing conservation and management strategies for a sustainable future (Figuerola-Ferrando et al., 2024).

The study primarily aims: (1) to present the conceptualisation of the collaborative and inclusive initiative and lessons learned after a four-year-long successful implementation of the project—as a case study in Barcelona for citizen engagement in the monitoring of urban marine ecology, particularly focusing on marine benthic organisms dominated by Gorgonians; (2) to contribute to OL priority research areas by providing a Q-sorting tool aligned with OL dimensions to assess divers' perceptions based on their experience in urban marine ecosystems; (3) to shed light on Barcelona's divers' perspectives; (4) to provide insights into the role of fishers in the conservation of urban marine benthic ecosystems in Barcelona; (5) to present additional observations of other stakeholders' involvement in the study of urban marine ecosystems in Barcelona, especially highlighting the role of elderly people in achieving SDGs; and (6) to contribute to a more comprehensive understanding of urban marine ecosystems as well as the role of coastal cities and their governance in fostering inclusive approaches to better promote OL and achieve sustainability goals.

2. Methods

2.1. Study Area

The study area is located in the coastal city of Barcelona, in the northwestern Mediterranean. Specifically, scuba divers identified aggregations of *Leptogorgia sarmentosa* at the outer part of the harbour entrance (coordinates 41°22'N 2°11'E). Consequently, marine benthic ecosystems dominated by *Leptogorgia sarmentosa* in the Gorgonia Barcelona project were monitored at this site (Figure 2). The colonies were found at a depth of approximately 19 metres, growing on a submerged dyke.

The study area is located near Barceloneta, Barcelona's main artificial beach. Several piers have been built in the area to maintain the shoreline, and due to high erosion rates, there is a continuous influx of river sediments, resulting in a seabed composed of fine particles (Tomás-Cubells, 2013). Fishing is prohibited in this area, which minimises the presence of abandoned, lost, or otherwise discarded fishing gear. However, evidence of poaching, such as lost hooks and fragments of fishing lines, was found. Although scuba divers occasionally visited the area, interest in diving increased significantly after the project began in 2021, and the rediscovery of Gorgonians has been widely reported in newspapers and the media. High levels of heavy metals were found in the area in 1991 (Palanques & Diaz, 1994), but this situation has improved considerably thanks to the implementation of policies to improve the quality of Barcelona's seawater and

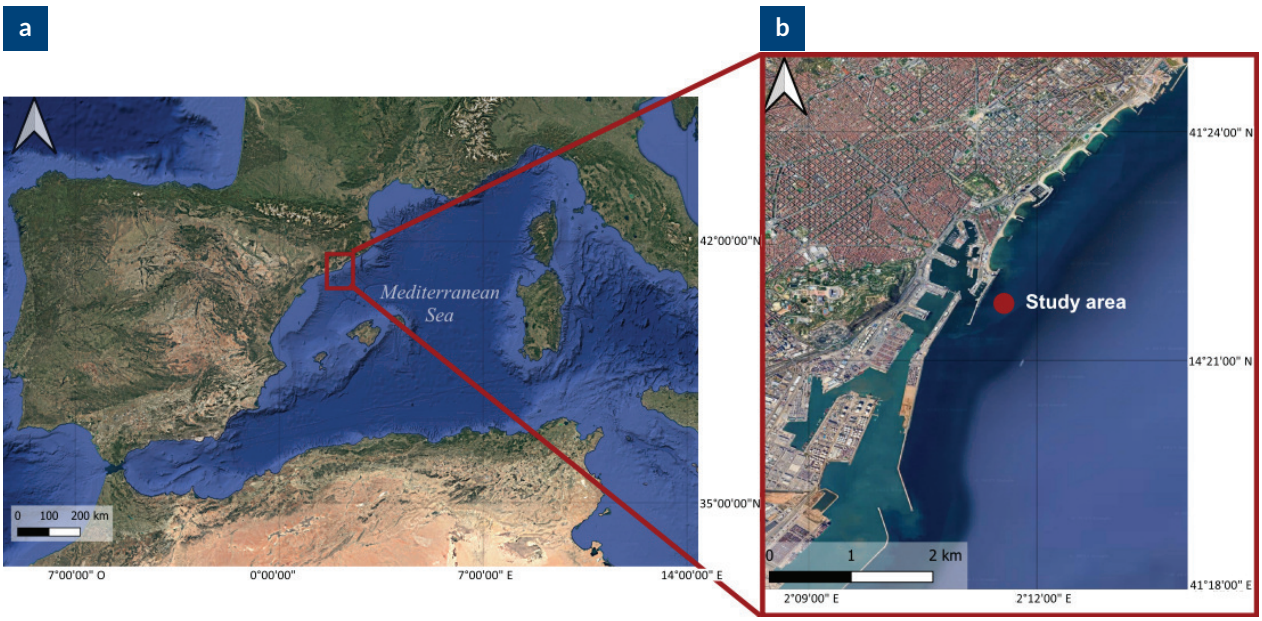


Figure 2. The study area is located in the northwestern Mediterranean, off the coast of Barcelona, where marine benthic ecosystems dominated by *Leptogorgia sarmentosa* are monitored in the framework of the Gorgonia Barcelona project: (a) A map showing the northwestern Mediterranean basin, where the city of Barcelona is located; (b) enlarged view of the study area for monitoring the Gorgonians of the Gorgonia Barcelona project, at the outer entrance of Barcelona's Olympic harbour.

sediments. Nevertheless, the area still received a "black flag" in the 2022 annual report from the Spanish grassroots environmental group Ecologistas en Acción, mainly due to hydrocarbons and heavy metals derived from the heavy maritime traffic associated with the nearby harbour of Barcelona—discharges from industrial and urban sources that are not adequately treated, microplastics from human activity, and atmospheric emissions from ship combustion and port machinery (Ecologistas en Acción, 2022).

2.2. The Gorgonia Barcelona Project Conceptualisation

When a scuba diver from the Catalan Federation of Subaquatic Activities (FECDAS) reported in 2020 the sighting of dense aggregations of *Leptogorgia sarmentosa* in Barcelona's waters, a research group at the Institut de Ciències del Mar from the Spanish National Research Council (ICM-CSIC), aware of the importance of the finding, decided to prospect the area. Thanks to the technical support provided by FECDAS, this prospecting was carried out. After confirming the high ecological importance of the finding, and thanks to the support and recommendations received by sociologists and marine researchers participating in the ResBios project (ResBios, 2022), the Gorgonia Barcelona project soon emerged.

The ICM-CSIC, the leader of this project, always with the technical support of FECDAS, was one of the partners participating in the European Horizon 2020 project ResBios. The project was part of the Science With and For Society programme and was based on the RRI framework. RRI seeks to manage research and innovation by engaging a wide range of stakeholders and the public from the outset of the process. This inclusive approach aims to foresee the positive impacts of research and innovation on society while minimising potential risks. The concept of RRI has been explored through several key dimensions, such as inclusion, anticipation, responsiveness, reflexivity, sustainability, and care (Burget et al., 2017).

Although it had some prior experience in this area, the ICM-CSIC participated in the project as an institution still in the early stages of integrating RRI practices. As such, it was accompanied by more experienced partners who had participated in the previous StarBios project (StarBios, n.d.), which followed a similar approach. During the project, the ICM-CSIC worked on different so-called "grounding actions" (specific actions conducted in less-experienced RRI institutions, with the final goal of integrating RRI into their daily procedures), with a special focus on three key aspects of RRI (gender equality, citizen engagement, and scientific education; Salazar et al., 2022a). The specific definitions of the key RRI concepts worked throughout the project are shown in Figure 3.

Since the conception of the Gorgonia Barcelona project and following the instructions of the sociologists involved in the ResBios project, the participation of citizens in the project was enhanced, and continued well after the project had finished, following the Manifesto for the Transformation of Science-Society Relations (Bijker et al., 2022). The name of the project (Gorgonia Barcelona) was voted on by more than 50 participants of an OL workshop organised at the ICM-CSIC as part of the Biennial of Barcelona. The project involved participants from the four sectors of the quadruple helix: academia, industry, government, and civil society (Roman et al., 2020). This concept (quadruple helix) soon evolved into the quintuple helix incorporating the natural environment and pursued the achievement of SDGs (UN, 2015), especially SDG 14 "life below water," SDG 11 "sustainable cities and communities," and SDG 17 "partnerships for the goals." Different indicators were also set for following up on the initiative (Schmidt,

Figure 3. The key aspects of RRI were addressed through grounding actions by research organisations in the ResBios project. Notes: The figure outlines the key aspects of RRI integrated into the ResBios project through concrete actions carried out by the research organisations; definitions for each concept are provided to ensure clarity and prevent potential misunderstandings. Source: ResBios (2022).

2023). The project was also developed under the umbrella of the local initiative Espai Mediterrani (Espai Mediterrani, 2020), where the ICM-CSIC participates together with other neighbourhood associations in pursuing the same goals of promoting OL, social justice, sustainability, and ocean health. The project followed a "local-to-global" approach and secured financial support from Barcelona City Hall and local businesses. The project was launched in 2021 in parallel with the global efforts of the UN Ocean Decade (IOC-UNESCO, 2018). Accordingly, it has been developed following the recommendations of the OL outcomes and challenges, as well as recommendations for climate action within the UN 2030 Agenda (Soergel et al., 2021). Soon after, it also followed an alignment with global OL efforts, such as the OL dimensions proposed by McKinley et al. (2023). The conceptualisation phase of the project included the following steps: stakeholder mapping and engagement, urban marine ecosystem assessment, OL framework integration, exchange of knowledge and perceptions with stakeholders involved, and communication and outreach strategy. The Gorgonia Barcelona project was structured in this way to contribute to knowledge gaps in urban marine ecology, promoting stakeholder-driven conservation efforts and serving as a model for inclusive marine research in urban environments.

2.3. Q-Sort Study, Divers, Fishers, and Other Stakeholders Involved

Given that the project emerged from an alliance between scuba divers and marine scientists, and considering the strong engagement of scuba diving volunteers, a study was conducted to explore divers' perceptions of Barcelona's urban marine ecosystems, based on OL dimensions (McKinley et al., 2023). The chosen methodology was the Q-method, following the recommendations of Webler et al. (2009). A Q-sorting method was designed, and 13 statements were produced, covering the main OL dimensions (McKinley et al., 2023), as shown in Table 1. For some of the OL dimensions, there was more than one statement (two for communication, one as a receiver, and another as a transmitter) and three for emotional connections (one positive, one negative, and another more neutral). Responses concerning different types of emotions were sought, to investigate if there was an emotional disconnection with the ocean when they perceived an impact. The first six statements concerned Barcelona's marine users in general, defined as individuals who perform activities regularly in Barcelona's marine and/or maritime areas or nearby. The last seven were related to the participants (divers) themselves, to better reflect their perceptions of the marine environment.

Following the recommendations of the ICM-CSIC Ethics Committee on ethical considerations and data protection (Ministerio de la Presidencia, Justicia Y Relaciones con las Cortes, 2018), an interview was conducted with the participants. The study was conducted with all the divers who participated in the project, including those who came only once and those who regularly participated in it. The interviews were conducted in person or virtually, depending on the availability of the volunteers. During the interviews, the scuba divers provided personal data and were invited to participate in the Q-test (Table 1 and Figure 4). Any doubts regarding the statements were addressed and clarifications were provided to ensure that all participants understood the questions in the same way. Qualitative data were also compiled to better contextualise the answers provided. The criterion to participate in this study was being a scuba diver who had participated in the field sampling of the Gorgonia Barcelona project. Volunteers were also asked to fill in some demographic information, as well as data about their use of marine ecosystems. Then, they were asked to fill in a pyramid with the 13 statements provided in Table 1. In this pyramid, there were gaps given on a scale from "strongly agree" to "strongly disagree," and they could only fill each gap with one statement (Figure 4).

Table 1. Statements of the Q-test conducted with divers of Barcelona about their perceptions and experiences as sea users in Barcelona and their related OL dimensions.

About your viewpoint on the users of the sea in Barcelona (including divers and other users)	
Statement	OL dimension covered
1. They have sufficient knowledge about Barcelona's marine ecosystems to act responsibly and make informed decisions	Knowledge
2. They are always kept informed by the authorities about risks or issues related to the marine environment that could negatively impact them, allowing them to decide how to act	Trust and transparency
3. They can meaningfully participate in decision-making processes that affect Barcelona's marine environment	Communication
4. They can easily empathise with other types of users because there are various tools available to explain and/or simulate these experiences	Access and experience
5. They generally share their observations of the marine environment—both positive and negative—within their personal networks	Communication
6. They have easy and sufficient access to scientific knowledge about Barcelona's marine environment and can contribute to generating more	Awareness
About your own experience as a user (diver) of the sea in Barcelona	
Statement	OL dimension covered
7. In general, Barcelona's marine ecosystems are not in good conservation status and do not have adequate protection measures	Attitude
8. I report or notify the relevant authorities when I detect a phenomenon that I consider abnormal, which could indicate an environmental alert or be of scientific interest	Behaviour
9. I consider myself a marine activist	Activism
10. My mood is not affected by the "health status" of the sea	Emotional connections
11. I understand the environmental changes associated with an urban ecosystem and adapt to them easily	Adaptive capacity
12. I feel positive emotions when I think about Barcelona's marine environment	Emotional connections
13. I feel negative emotions when I think about Barcelona's marine environment	Emotional connections

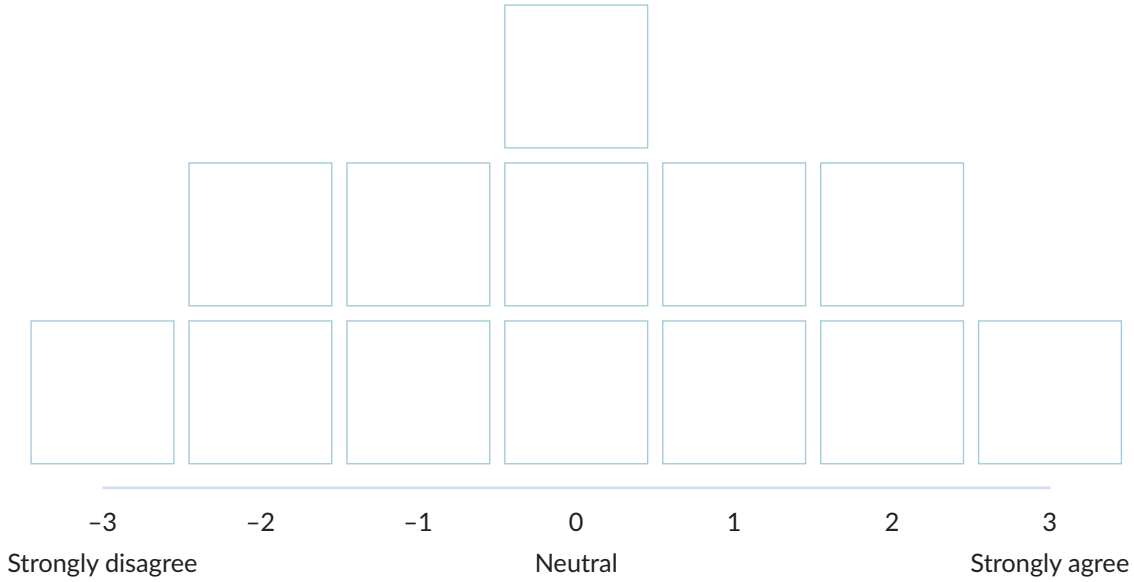


Figure 4. "Pyramid" used for the Q-sorting conducted with scuba divers. Note: Participants were instructed to place each of the 13 statements into one of the 13 available slots, ensuring that no more than one statement occupied the same slot.

2.4. Gathering Fisher's Perspectives in Barcelona's Urban Marine Ecosystems

Fishers are other relevant marine stakeholders that should be involved in managing marine ecosystems if we want to improve the management, preservation, and conservation of a certain area. The exploitation of living and non-living resources is one of the three primary drivers of marine urbanisation, as described by Todd et al. (2019; the other two are pollution and modification of natural habitats). Fishers play an important role in this regard. Previous studies have highlighted the crucial role of fishers in conservation efforts and the importance of exchanging perspectives while valuing their local ecological knowledge, as shown by Aswani et al. (2018), particularly in areas near Barcelona, such as the Cap de Creus marine protected area (Biel-Cabanelas et al., 2023; Salazar et al., 2024; Santín et al., 2022). Thanks to the contact with fishers through the Espai Mediterrani initiative, an initial meeting was conducted with a Barcelona fisher to exchange points of view and perceptions of Barcelona's urban marine ecosystems and to collect input and feedback for marine conservation goals.

2.5. Collecting Feedback From Citizen Engagement With the Project

In addition to the above-mentioned studies and the perspectives collected from different stakeholders involved in the Gorgonia Barcelona project, further insights into OL were collected from other groups that participated in related education and outreach activities. In the workshop held after the Spanish lockdown period due to the Covid-19 crisis, during which the name of the project was decided, a simple test for collecting impressions about OL promotion was also shared.

3. Results

3.1. The Gorgonia Barcelona Project

This project has been successfully conducted since its inception in 2021. Several stakeholders were involved in the project in various ways. It was designed to be inclusive, enabling broad participation. With this in mind, it included activities both within the urban marine ecosystems (Figure 5) and at the marine research institution, as well as at other locations. Participants also had the option to join these activities online or watch the recorded sessions offline later (Figure 6). Activities in the field were organised in coordination with FECDAS, who provided technical and logistical support and helped to recruit volunteers for each of the monthly samplings. In each of them, a briefing was provided promoting OL and explaining the protocols of the programmed activities for the sampling day. Additionally, the project made it possible to conduct pilot restoration actions both in the inside and outside areas of the harbour entrance and further monitoring of both areas (employing a remotely operated vehicle in the area inside the harbour). It is important to mention that scuba divers were extremely concerned about the wet wipes that were found suffocating Gorgonian polyps. Consequently, they produced awareness materials for social media and provided them to marine researchers for further dissemination and awareness purposes.

Different education and outreach initiatives were also promoted during the project. In each activity, including the FECDAS briefings, there was a dissemination of the importance of the conservation of urban marine ecosystems and benthic ecosystems dominated by Gorgonians. The crucial role of OL and the need to develop sustainable attitudes and behaviour were also stressed. The project raised the attention of different TV channels and social media, and it was also shared in different scientific conferences and meetings, being present in both local and global initiatives, such as the International Coral Reef Symposium (Salazar et al., 2022b).

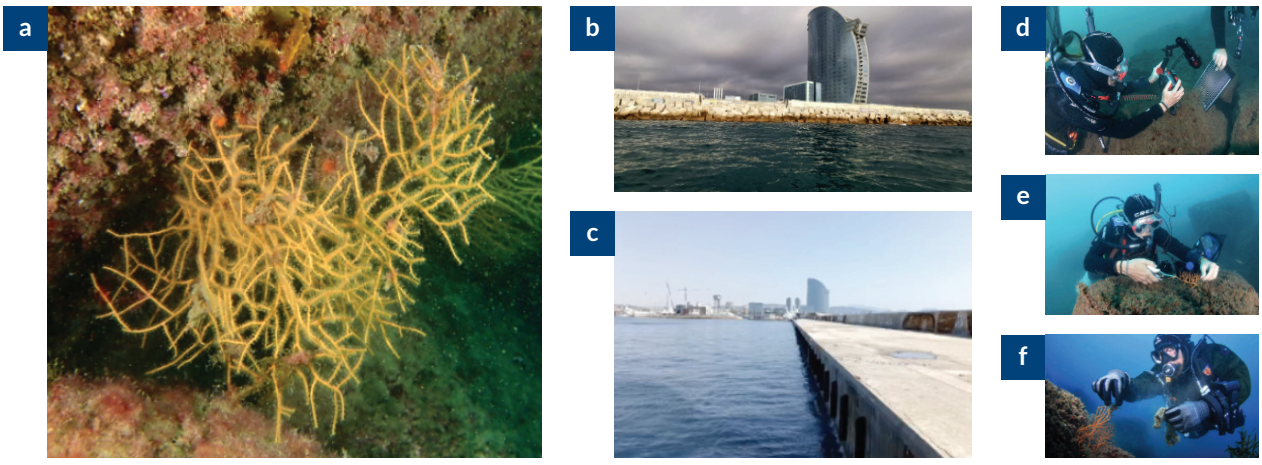


Figure 5. Overview of the actions conducted in the field: (a) The study species *Leptogorgia sarmentosa* in the study area (Photo by Susana Garrido); (b) and (c) Views of the exterior (study area) and interior sections of the harbour entrance, with the harbour visible, providing context for the surrounding environment of the study area; (c) the project also facilitated Gorgonian restoration pilot actions using technical diving and remotely operated vehicles in the interior section; monitoring activities such as photographing (d), collecting samples (e), and reporting and removing wet wipes (f).

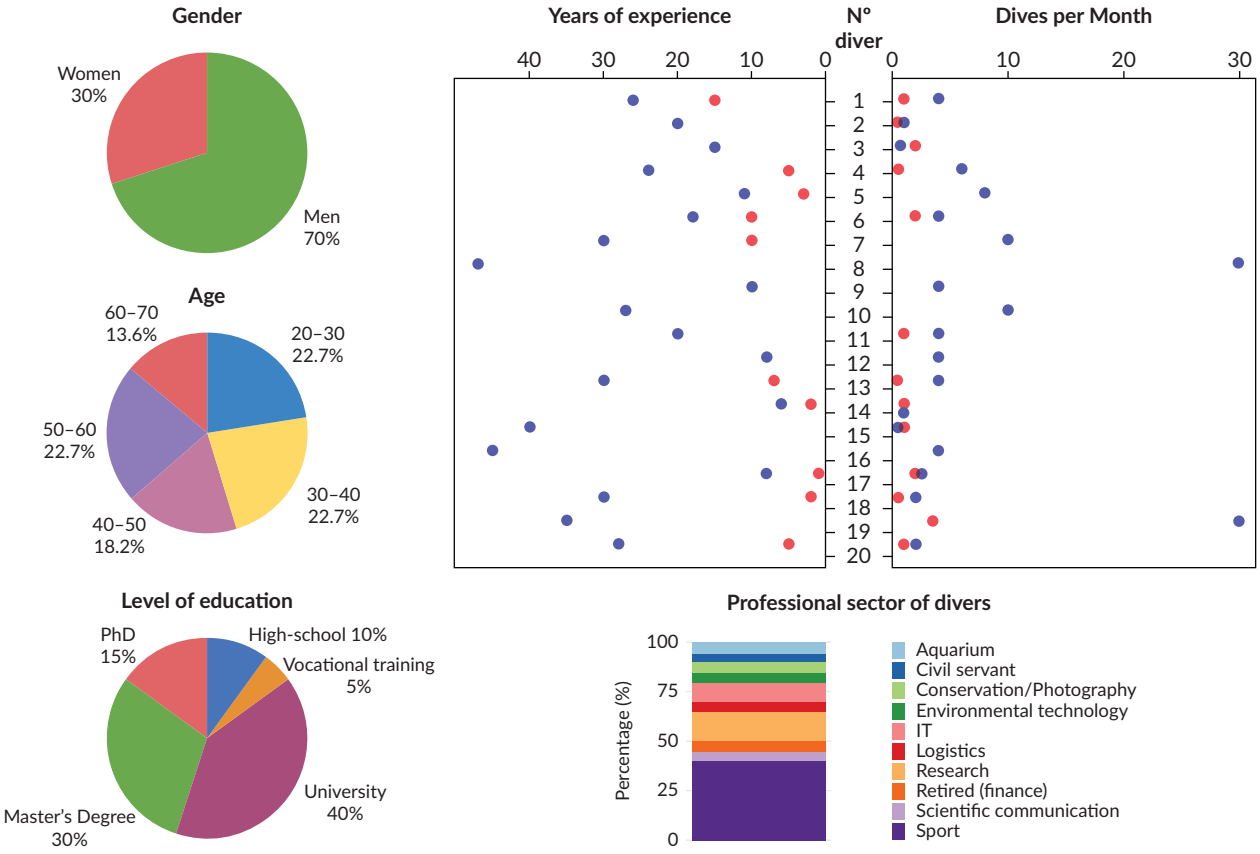
Figure 6. Some of the engagement activities developed in the framework of the Gorgonia Barcelona project included: visits to learn about Gorgonians (a), which included feeding them (e), development of final master's degree research works in collaboration with universities (b), secondary school scientific projects (c), and meetings and workshops involving citizens of diverse ages, social backgrounds, and sectors (d).

The case study of Barcelona is very similar to the one reported by Betti et al. (2018) in Genoa (Italy). Consequently, the science conducted in the project involved collaboration with other local research groups from Barcelona, as well as international collaborations with research institutions from Italy, France, and the US to provide data spanning from the local to the global context. Within the framework of the project, it has been possible to conduct scientific studies on Gorgonian reproduction, metabolism, resistance to thermal stress, microbiome, and transcriptome. These studies are still ongoing.

3.2. Divers' Perceptions

In total, 20 scuba divers who participated in the project sampling answered the test. The summary of the results is shown in Figure 7.

The participants included 6 women and 14 men. Their ages were as follows: five between 20 and 30 years, five between 30 and 40, four between 40 and 50, five between 50 and 60, and three between 60 and 70. Two had studied until secondary school, one had undergone vocational training, eight had undergraduate degrees, six held a master's degree, and three held a PhD. Regarding their professions, eight were related to sports, three to research, development, and innovation, one to logistics, two to IT, one worked in the administration, another was retired but had worked in the financial sector, one worked in an environmental agency, one was a photographer, another in scientific communication, and another in an aquarium. All of them had more than six years of diving experience, which ranged from 6 to 45 years (specifically in Barcelona, this experience ranged from 1 to 45 years). Their frequency of practising snorkel or scuba diving ranged from daily to five times per year in general, and from one day per week until one day per year. Seventeen of them lived or had lived in Barcelona, while three had not. Sixteen currently lived in a coastal city or village, whilst four did not. When asked about where they acquired marine knowledge, sources varied



Mostly agree with: 7. In general, Barcelona's marine ecosystems are not in good conservation status and do not have adequate protection measures.
Mostly disagree with: 1. Barcelona marine users have sufficient knowledge about Barcelona's marine ecosystems to act responsibly and make informed decisions.
Ranking and total marks given (in parenthesis) to each of the statements
9. I consider myself a marine activist (25).
5. Barcelona marine users generally share their observations of the marine environment—both positive and negative—within their personal networks (23).
7. In general, Barcelona's marine ecosystems are not in a good conservation status and do not have adequate protection measures (14).
11. I understand the environmental changes associated with an urban ecosystem and adapt to them easily (14).
12. I feel positive emotions when I think about Barcelona's marine environment (13).
8. I report or notify the relevant authorities when I detect a phenomenon that I consider abnormal, which could indicate an environmental alert or be of scientific interest (11).
6. Barcelona marine users have easy and sufficient access to scientific knowledge about Barcelona's marine environment and can contribute to generating more (7).
13. I feel negative emotions when I think about Barcelona's marine environment (–3).
10. My mood is not affected by the "health status" of the sea (–7).
4. Barcelona marine users can easily empathize with other type of users because there are various tools available to explain and/or simulate these experiences (–9).
2. Barcelona marine users are always kept informed by the authorities about risks or issues related to the marine environment that could negatively impact them, allowing them to decide how to act (–17).
3. Barcelona marine users can meaningfully participate in decision-making processes that affect Barcelona's marine environment (–25).
1. Barcelona marine users have sufficient knowledge about Barcelona's marine ecosystems to act responsibly and make informed decisions (–32).

Figure 7. Summary of answers given by scuba divers who participated in the project and the study. Note: In the scatterplot, blue dots represent "in general," and when the answer is different for Barcelona, it is represented by red dots.

from personal experiences to books, guides, documentaries, talks with fishers, talks with marine scientists, talks with other scuba divers, involvement in citizen science initiatives or scientific courses, university studies, social media, scuba diving courses, and underwater photography competitions. When asked about their perception of their marine scientific knowledge, all of them voted at least 6 out of 10, with most of the

results 7 or 8 (in this item, 5 was considered as sufficient knowledge). Surprisingly, respondents who had higher studies in marine-related fields were not necessarily those who gave themselves higher marks.

Volunteers assigned the highest value (+3) to statements 1–2 and 5–12. Four people assigned the highest value to statement 7, three to statement 9, three to statement 5, two to statement 11, two to statement 12, two to statement 8, and one for each of the following statements: 1, 2, 6, and 10. Despite differing opinions, scuba divers as individuals agreed more with the fact that marine ecosystems in Barcelona were not in a good health status and/or had inadequate protection. They also agreed to consider themselves marine activists and promoters of OL through their own experiences. They reported interesting sightings during their activities and had positive emotions when thinking about the marine ecosystems in Barcelona. Also, they understood the associated changes to urban marine ecosystems like Barcelona's (in uses, modification of the coastline, etc.)

Volunteers assigned the lowest value (−3) to statements: 1–3, 6–8, and 10–12. Five people assigned the lowest value to statement 1, three to statement 13, three to statement 3, two to statement 10, two to statement 2, and one for each of the following statements: 6–8, 11, and 12. Despite differing opinions, scuba divers as individuals disagreed more with the fact that Barcelona's marine users have enough knowledge to be able to act in a responsible and sustainable way. In addition, three strongly disagreed with having negative emotions when thinking about Barcelona's marine ecosystems and three strongly disagreed with having enough opportunities to participate significantly in decision-making processes with repercussions for Barcelona's marine ecosystems. Furthermore, they strongly disagree with being always informed by authorities about the risks or problems associated with Barcelona's marine environments. Finally, one strongly disagreed with the fact that his mood was not related to the ocean health status of Barcelona's marine ecosystems.

When looking at the total marks given, the most voted statement was "I consider myself a marine activist," with 25 points given, followed by 23 points given to statement 5 (they consider themselves as promoters of OL). The statement related to adaptive capacity received 14 points, followed by having positive emotions when thinking about Barcelona's marine ecosystems (13 points), then 11 points given to statement 8 (reporting special sightings while diving), and seven to statement 6 (they have enough access to marine scientific knowledge). Statements 13 (negative emotions, −3), 10 (mood not altered by Barcelona's marine ecosystems ocean health, −7), 4 (can empathise with other Barcelona marine users, −9), 2 (are always informed by the authorities about risks associated with marine ecosystems, −17), 3 (they have the opportunity to participate in decision-making related to Barcelona's marine ecosystems, −25), and 1 (Barcelona's marine users have enough knowledge to behave sustainably, −32) gained negative overall marks, reflecting a strong disagreement with these statements.

A parallel analysis conducted using R software (R Core Team, 2023) did not identify any significant factors in the data per se. However, an exploratory factor analysis extracting three factors with a maximum variation rotation "varimax," yielded a mean item complexity of 1.5 and revealed that three factors were sufficient to account for the observed variance. A factorial loading matrix was used to show how and to what extent each observed variable (in this case, each statement) was associated with each latent factor. It provided three main types of respondents (Figure 8). The first type of scuba divers believe that authorities do not adequately inform Barcelona's marine users, that Barcelona's marine ecosystems are in bad health and not sufficiently protected, and they do not express strong positive emotions towards Barcelona's ecosystems compared with

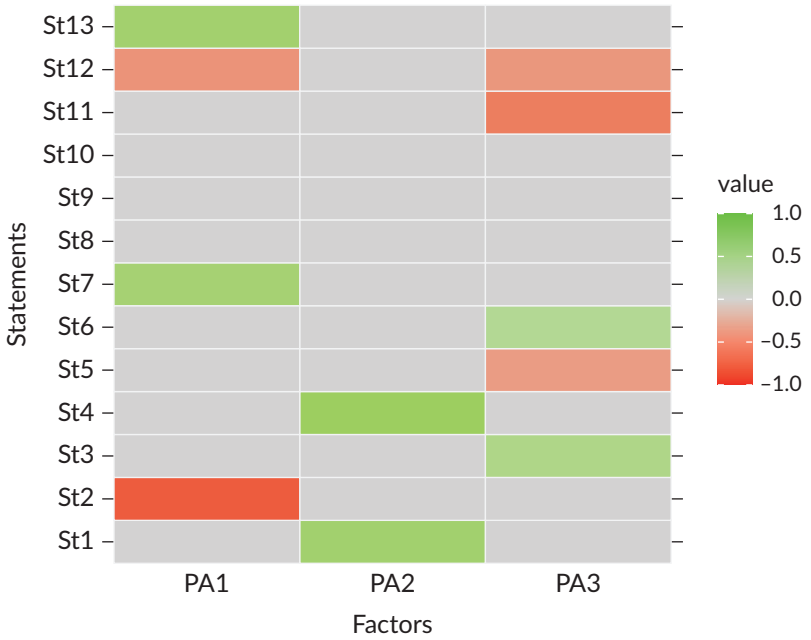


Figure 8. Factorial loading heatmap from the Q-test conducted with scuba divers in Barcelona. Notes: The colour scale represents the strength and direction of the values: green for positive values, red for negative values, and light grey for near-zero loadings; PA1 (first principal axis factor), PA2 (second principal axis factor), and PA3 (third principal axis factor) refer to each of the three main factors identified; note that there is only one statement (statement 12) that is common to factors 1 and 3, the other statements are unique for each of the factors.

the others (in fact, they show negative emotions). The second group of respondents exhibits a more positive outlook: they believe that users of Barcelona's marine areas have enough knowledge and can behave in a more sustainable way. They can also empathise with other users. The third group believes that they can participate in decision-making, that they contribute little to promoting OL, and that although they have enough access to marine knowledge, they have difficulties in understanding changes in Barcelona's marine areas, and they do not show positive emotions towards Barcelona's marine ecosystems.

In general, the first factor (which can be referred to as "negative") accounts for 17.8% of the variance in responses, the second factor (which could be referred to as "positive") explains 12% of the total variance, while the third factor (labelled "neutral") explains 11.5% of the total variance. Altogether, 41.3% of the total variance could be explained by the three factors extracted. Regarding clarity criteria, 10 statements were related to these factors (St1–St7, St11, St12, and St13) and three did not have an associated factor (St8–St10).

3.3. Fishers' Perspectives

The main inputs provided by the fishers were as follows:

1. Barcelona's fishers felt demonised by several stakeholders. They recognised that their fishing activities have an impact on marine ecosystems and were aware of these impacts. However, they argued that it is unfair to single out their sector as the sole contributor to marine environmental issues. They also believed that the term "overfishing" was overused.

2. In the same vein, fishers advocated for identifying other significant environmental impacts, such as the source of the large quantities of wet wipes and other debris frequently caught in their nets—debris that they believe has a severe negative impact on marine ecosystems.
3. Fishers expressed a desire for a more horizontal and reciprocal exchange of information. They emphasised that they were not resistant to change and had already implemented all the adjustments recommended by the administration. However, they pointed out that in past collaborations with biologists, there was often no feedback or follow-up after they provided data, which left them feeling overlooked and disrespected. This lack of recognition has contributed to their reluctance to participate in similar initiatives.
4. Fishers highlighted their extensive local ecological knowledge, citing, for instance, specific rocky areas where bottom trawling is not conducted and which they believe are well preserved, but, according to them, remain unstudied by scientists. Additionally, based on their daily fishing activities, they observed changes in marine ecosystems and expressed concern over the impact of pesticides and dissolved pollutants, which they felt had not been sufficiently addressed.
5. Fishers felt unheard and insufficiently integrated into decision-making processes. Fishers argued that they are often excluded from decisions that directly affect their sector and called for greater transparency, trust and compensation when more sustainable measures are implemented or when they participate in sustainability projects that impact their work. They emphasised that their cooperation should not be taken for granted or exploited, particularly when these initiatives further strain an already demanding profession.

In this regard, the importance of establishing common goals was highlighted, with both biologists and fishers agreeing on the need for compensated fishing ban periods and the implementation of mitigation measures that could yield benefits for both marine conservation and the fishing industry.

3.4. Learnings From Other Stakeholders Involved

Fifty-six participants rated their marine scientific knowledge at 2.71/5, and there was a consensus on the desire for more education and outreach opportunities to increase OL levels. The most expressed preference for the frequency of such events was once a month. When asked about their perception of ocean health in Barcelona, participants always gave less than 3/5, sometimes giving a 2 or a 1. In terms of biodiversity, they usually gave 3/5, although some of them gave 2/5 and 4/5. In general, teachers and educators knew that Gorgonians were animals, but the public and children did not usually know this.

One of the education and outreach experiences conducted within the framework of the project was a request from an intergenerational service-learning initiative led by a vocational training programme. The project aimed to connect elderly people in the Barceloneta neighbourhood with vocational training students to explore challenges related to the climate emergency. The students expressed interest in visiting the ICM-CSIC, where one of the projects presented to them during the visit was the Gorgonia Barcelona Project. One of the main conclusions from this exchange was that young people felt a strong sense of responsibility but lacked the necessary tools to counteract climate trends. Meanwhile, although elderly participants often felt excluded from the conversation and believed they lacked sufficient knowledge, it was collectively concluded that they could play a crucial role in addressing the climate crisis. By sharing their experiences of a simpler and humbler lifestyle from their childhood, adolescence and youth, they could help promote more sustainable behaviours.

Regarding the exchange of perspectives with policymakers and administration, it is important to highlight that the project was very well received and supported. Policymakers and administrators valued having interlocutors to discuss marine benthic ecosystems and recognised the project as an inspiration for achieving climate mitigation goals.

Additionally, the private sector expressed interest in financially supporting the project and becoming directly involved, for example, through activities such as diving, visiting aquaria, and feeding Gorgonians.

4. Discussion

4.1. Collaborative and Inclusive Citizen Engagement Initiatives in Coastal Cities

Coastal environments in urbanised areas are often degraded due to pollution and other negative impacts from human activities (Islam & Tanaka, 2004). This fact contrasts with the observations made by divers in the harbour area of Barcelona, with a high diversity and a surprising population of Gorgonians. It is known that urban infrastructures, such as docks or harbours, have a positive effect on the creation of habitats and the increase in biodiversity (Chapman & Underwood, 2011). But what was observed in Barcelona was unexpected and this promoted the inception of the Gorgonia Barcelona project. The project has been developed by posing a series of ecological questions that have always been shared with the participating social groups. In this way, the volunteers who participated were aware that they were taking part in a scientifically compelling project, which made it easier for them to connect with it emotionally. Thus, communication and OL between scientists and citizens were facilitated. Another important aspect of the project was the fact that it was developed in an urban setting, particularly in a large city like Barcelona. This fact makes it easier for many groups or citizens who wish to get involved in marine research projects to do so due to the proximity to their area of residence. Not everyone can travel to locations far from their city, regardless of how interesting the research projects may be. Therefore, projects conducted in urban areas hold great potential for reaching a wider range of social groups and increasing OL.

As this was the first initiative of its kind—making it both the initial monitoring of Barcelona's Gorgonians and the launch on this context of a new project guided by RRI—its main objective was to serve as a pilot. The goal was to explore the feasibility of conducting regular samplings with scuba diving volunteers in Barcelona's urban marine ecosystems, assess how the public and various city stakeholders would respond, and test a new model for citizen engagement in coastal cities. Despite the project already aligning with most of the 10 principles of citizen science, it could still be better aligned with them (Robinson et al., 2018), especially with those related to generating new open-access data. These aspects will be further explored in the future.

4.2. Gathering Divers' Alignment With OL Dimensions

The sex ratio of divers involved in the study in Barcelona (Catalonia, Spain) corresponds to similar data reported by Lucrezi et al. (2019) in Portofino (Italy) and differs from the data reported by divers from Mozambique, where there was a more equal representation of men and women (Lucrezi & Saayman, 2017). This reflects the general predominance of males in diving in Barcelona. It is important to mention that this issue was already identified by FECDAS, which participates in several programmes to reverse these trends and promote diving activities among women. As highlighted by Cerrano et al. (2017), it is very important to characterise diverse

communities because they often incorporate different perspectives and opinions that could not be considered universal. Surprisingly, respondents who had higher studies in marine-related fields were not necessarily those who gave themselves higher marks. This is likely because people who work directly in marine science are also aware of the wide range of knowledge encompassed within the field and so are more aware of their knowledge gaps. Other factors that were not extracted, or complementary studies, could help to better interpret the answers given. However, with the current analysis, we can already gain insight into the varied perceptions of each scuba diver. The divers from Barcelona were not an exception in that regard, and the result of the study conducted reflects diverse opinions among them, aligned with findings by Lucrezi et al. (2019) when analysing divers from Italy and Mozambique. Nevertheless, as most of the results can be explained with the three identified factors, the Q-sorting tool presented here could be a new tool that provides a solution to address these assessments, while also contributing to building further knowledge about the relationship of divers with the OL dimensions.

4.3. Adding Barcelona Fishers' Perspectives in OL Conversation

Addressing the needs of the involved stakeholders and setting OL strategies for decision-making, based on scientific marine knowledge, is crucial for managing urban marine ecosystems, particularly regarding the fishing sector. This approach aligns with findings from other, less impacted areas (Salazar et al., 2024). When this study was conducted, fishers were not involved in the Gorgonia Barcelona project, but thanks to further conversations, they will participate by providing Gorgonians caught in their nets, following previous similar approaches reported by Montseny et al. (2021) that ensure sustainable and feasible ways of conducting restoration actions. Additionally, responding to their concerns about wet wipes and local ecological knowledge not collected, researchers involved in the project will move on to provide answers to these concerns, following successful results, considering that this practice of responding to fishers' needs contributes to generating trust and transparency to build a strong and collaborative relationship among scientists and fishers, as reported by Biel-Cabanelas et al. (2023).

4.4. Final Remarks and Recommendations for the Governance of Urban Marine Ecosystems

As mentioned in Section 4.1, marine research projects conducted in urban areas following inclusive and collaborative approaches hold great potential for reaching a wider range of social groups and increasing OL. This is especially important to be considered for governance purposes in urban marine areas, as several groups have highlighted that they often feel excluded from the conversation. For coastal cities to have citizens committed to sustainable and climate action, they must be empowered and appreciated as stewards of their urban marine ecosystems. Important efforts have already been made in "green areas" (Magrinya et al., 2023) that could be extended to "blue areas."

5. Conclusions

This study highlighted several key aspects regarding the involvement of various stakeholders in Barcelona's urban marine ecosystems, particularly in the context of the study of marine benthic ecosystems dominated by Gorgonians. The insights gained offer a model for other marine conservation efforts focused on flagship species in different regions and can contribute to understanding how to engage different stakeholders in achieving conservation and OL objectives. The study emphasises the importance of participatory and

collaborative models to align efforts and goals across diverse sectors, contributing to OL global efforts and fostering more sustainable behaviour, closer relationships, and the stewardship of urban marine ecosystems. Combining both top-down and bottom-up approaches has been proven to be an effective strategy for marine protected area planning worldwide (Gaymer et al., 2014). These recommendations should also be applied to often-overlooked marine areas such as urban marine ecosystems. This study aimed to shed light on this issue and, as a suggested improvement, when applied in other areas, it should be recommended to better align with the 10 citizen engagement principles (Robinson et al., 2018). From the study, the following final key conclusions can be drawn:

- Divers: The Q-test conducted with Barcelona's divers reveals diverse profiles within the group, each offering unique insights into the city's urban marine ecosystems. Their direct interaction with underwater environments provides valuable perspectives that can enhance and complement scientific research, helping to fill knowledge gaps in data collection and monitoring. By involving divers as citizen scientists, their observations and expertise become a vital resource for advancing urban conservation efforts. The results of the Q-test suggest that, overall, scuba divers in Barcelona play a key role in promoting OL, a finding consistent with previous studies by Chung et al. (2013) and Lucrezi et al. (2018). Furthermore, the Q-sort emerges as a proven tool that addresses one of the priorities highlighted by Shellock et al. (2024), the need to develop appropriate methods and measures to address OL dimensions, especially emoceans, trust, and transparency. This tool could be used with other groups of divers in Barcelona or other nearby or distant locations, to conduct comparative studies that help to better understand the potential role of divers. The tool could be further explored and potentially adapted for studies with other stakeholders involved in OL promotion.
- Fishers: Fishers are another crucial group in urban marine ecosystems, and their involvement must be prioritised. Consistent with previous research by Salazar et al. (2024) and Montseny et al. (2021), it is evident from the perceptions of Barcelona's fishers that greater efforts are needed to actively engage them in conservation initiatives. This would promote bilateral exchange of information and emphasise the importance of local ecological knowledge, as reported by Johannes et al. (2000). By fostering open communication and integrating the knowledge of both scientists and fishers, we can build stronger partnerships and reduce potential reluctance or conflicts. Sustainable measures implemented by fishers, particularly those in artisanal fisheries, should receive greater recognition and be more actively integrated into management processes, as highlighted by Gómez et al. (2006) and Gómez and Lloret (2017).
- Citizenship: The study underscores the importance of reviving and valuing the knowledge and practices of older generations. Their traditions, often rooted in sustainable practices and a deeper respect for nature, can serve as a foundation for shaping modern conservation strategies. By integrating these perspectives into educational and community initiatives, we can foster a sense of cultural continuity while addressing contemporary ecological challenges.
- Policymakers: Collaboration between scientists, policymakers, and other stakeholders should be based on trust, transparency, and a clear focus on shared goals. Policymakers play a central role in creating the regulatory frameworks and funding opportunities necessary to support participatory models and ensure long-term ecological sustainability.
- Industry: The private sector and industry could provide financial support and actively participate in urban marine ecology studies. Their involvement would help promote more sustainable practices within their companies and contribute to increasing OL.

In conclusion, the study underscores the need for collaborative and inclusive approaches to urban marine conservation, in line with findings from Sauer et al. (2021). The RRI approach, involving participants from the sectors of the innovation quintuple helix, has proven effective in enhancing OL opportunities in marine ecology studies, consistent with previous findings by Lundquist and Granek (2005) and Magoni et al. (2018). Figure 9 presents an adapted innovation model based on the innovation quintuple helix, incorporating key considerations for achieving conservation goals in urban marine ecosystems.

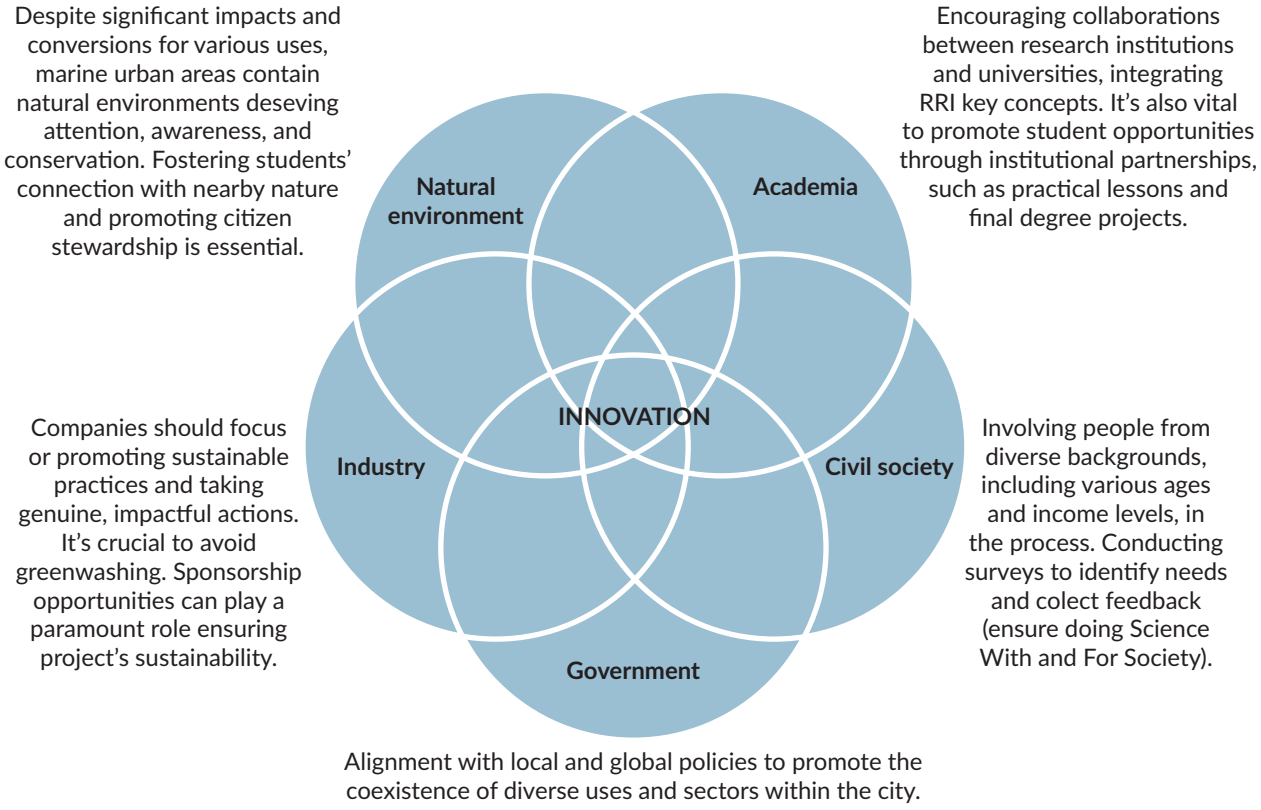


Figure 9. The quintuple helix model adapted to the context of urban marine ecosystems, highlighting key findings and factors that enhance citizen engagement and promote sustainable behaviour in collaborative urban marine conservation initiatives.

Expanding participatory models and advancing OL in coastal cities worldwide will be essential for ensuring the long-term health and sustainability of these vital ecosystems. This study contributes to filling some of the knowledge gaps raised by Shellock et al. (2024) regarding OL research in achieving sustainable ocean futures. The conclusions align with findings about governance approaches that embrace the multidisciplinary and intersectoral nature of OL. The conclusions of this study will serve as a step forward, especially for researchers, practitioners, and decision-makers in Barcelona for promoting OL, but also could be an example for OL multidisciplinary studies and models of governance in other locations. Following these approaches can lead to sustainable and equitable governance and conservation of marine urban ecosystems, supporting broader goals of sustainable development.

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Conflict of Interests

The authors declare no conflict of interests.

Data Availability

All data collected have been presented throughout the study; for any related enquiries, please contact the corresponding author.

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