Marine Policy 160 (2024) 105981

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Engaging fishers in sea turtle conservation in the Mediterranean Sea

M. Virgili [a,*], A. Petetta [a], G. Barone [a], D. Li Veli [a], G. Bargione [a], A. Lucchetti [a,*]

[a] National Research Council (CNR), Institute for Biological Resources and Marine Biotechnologies (IRBIM), Ancona, Italy

ARTICLE INFO

Keywords:
Biodiversity conservation
Fishers' engagement
Sea turtles
Sustainable fishery
Mediterranean Sea

ABSTRACT

In the Mediterranean Sea, more than 121,000 sea turtles are incidentally caught each year by a variety of fishing gears, with more than 33,000 deaths and a mortality rate ranging from 10 to 50% depending on the type of fishing gear. Defining how to engage the fishers who are directly involved in incidental catches of turtles is critical to raise their interest, increase awareness and foster their collaboration with the scientific community and authorities. We developed a conceptual model to define the objectives of sea turtle conservation (Final Targets, FTs) at a management, technical, educational, and social level. The achievement of FTs was assessed through four Indicators (interest, scepticism, awareness, cooperation) based on the perception and behaviour of fishers. A 3-phase roadmap was set to engage fishers: 1) *Meeting*, it is the initial contact between the scientific community and the fishers to create baseline information on where, when, and how bycatch occurs; 2) *Deepening the knowledge*, it mainly consists on trainings to increase fishers' awareness of good practices and sustainable fisheries; 3) *In the field*, where scientists and fishers test innovative bycatch reduction devices (BRDs) aboard on commercial fishing vessel to comprehend the perspective of fishers in terms of the technical solutions proposed by scientists. Combining a theoretical and an empirical approach, this study provides successful indications (bycatch hot-spots, technological innovation of fishing gear, communication strategies, eco-labelling, improved sea turtle survivability) on how to achieve large-scale sea turtle conservation, which could be replicated in other areas.

1. Introduction

The conservation of sea turtles and other endangered marine species throughout the Mediterranean Sea is an environmental, technical, socio-economic, and political concern [1]. Fisheries heavily interact with the population dynamics, biology, and ecology of marine resources [2]. Mediterranean fisheries are characterized by multinational, multi-specific and multi-gear fisheries, mainly conducted by small and medium-sized vessels [3]. Over time, intense fishing pressure has led to the overexploitation of fish resources [4] and increasing deterioration of marine habitats [5]. Large vertebrates with life history characteristics that include long life span, late sexual maturity, large size at birth and low reproductive rates [6], are heavily impacted by commercial fisheries due to incidental bycatch. Sea turtles, elasmobranches, cetaceans, and sea birds fall into this category.

Three sea turtle species regularly inhabit Mediterranean waters: the loggerhead sea turtle (*Caretta caretta*), the green sea turtle (*Chelonia mydas*), and the leatherback sea turtle (*Dermochelys coriacea*). The loggerhead sea turtle is widespread throughout the basin, with nesting sites found in Greece, Libya, Turkey, and Cyprus. The green sea turtle is less common and mainly inhabits the easternmost part of the Mediterranean, with nesting sites in Turkey, Cyprus, and Syria. The leatherback sea turtle is rare and infrequently observed and it is unlikely that it nests in this basin [7–9]. The other species (*Lepidochelys olivacea*, *Lepidochelys kempii*, and *Eretmochelys imbricate*) are only occasionally sighted in the Mediterranean [7].

Studies based on genetics, tagging, and satellite tracking have demonstrated that the distribution of sea turtles is driven by the Mediterranean main circulation system [10]. Mediterranean fishing grounds overlap with the habitats and routes of these species [11], and fishing activities is a main source of anthropogenic mortality on sea turtle populations. In this basin, more than 121,000 sea turtles are incidentally caught by a variety of fishing gear each year, resulting in more than 33,000 deaths, with a mortality rate ranging from 10 to 50%, depending on the gear [9,12,13]. In this basin, due to their habits, behavioural ecology and migrations routes, the sea turtles interact with: bottom trawling (*demersal stage* in coastal habitats of continental shelf areas of the North Adriatic Sea, the Gulf of Gabés, Egypt, and Eastern Turkey [11,14,15]),

* Corresponding authors.
E-mail addresses: massimo.virgili@cnr.it (M. Virgili), alessandro.lucchetti@cnr.it (A. Lucchetti).

https://doi.org/10.1016/j.marpol.2023.105981
Received 6 April 2023; Received in revised form 7 December 2023; Accepted 11 December 2023
Available online 20 December 2023

set nets (*neritic stage* in coastal areas [16–18]) and longlines (*pelagic phase* with key areas in the waters of Spain, North Africa, Greece, and Southern Italy [19–22]), and rarely with other fishing gears [23–25].

C. caretta is a priority species in Appendix II/IV of the European Habitats Directive [26], the cornerstone of the EU nature conservation policy, which lists animals requiring protection. This species is also included in the Red List of the International Union for the Conservation of Nature and Natural Resources (IUCN, [27]). Although recent assessments have downgraded this species from the status “endangered” to “vulnerable” at a global scale, the adoption of conservation actions was stressed as crucial. Its conservation has become a focal issue in the Mediterranean since *C. caretta* has a role of a "cultural ecosystem service" species in addition to an important ecological role. The species is also a driver of potential socio-economic development for some coastal populations depending on tourism, i.e. through public activities of Marine Turtle Rescue Centers [28]).

In recent years, the General Fisheries Commission for the Mediterranean (GFCM) has established Fisheries Restricted Areas (FRAs) to protect essential habitats for Protected, Endangered, and Threatened species (PET) species [29]. However, modifications of traditional fishing gears to improve size and species selectivity were among the most intensively scientifically investigated approaches [30]. Experiments with Bycatch Reduction Devices (BRDs) aimed at making traditional gears more selective or less dangerous for sea turtles while limiting the loss of commercial species have mainly been used in drifting longlining and bottom trawling [31]. Technical modifications in longlines (e.g. hook shape and size, bait type and setting depth) to reduce both turtle bycatch and direct mortality have yielded inconsistent results [19,32,33], where those on Turtle Excluder Devices (TEDs) were rare and preliminary before the last decade [34,35]. Conversely, the development of BRDs for set nets has been lagging behind [36]. Recently, technological innovation for BRDs was developed in the context of the TartaLife Project (www.tartalife.eu). This initiative, described in the current paper, provided promising results in terms of turtle bycatch reduction without penalizing commercial catches, encouraging their rapid spread on a large commercial scale, through the engagement of fishers who did not know these devices, or had never tested them.

A comprehensive policy framework has been established for nature and biodiversity conservation in the European marine context. This framework includes, but is not limited to, the Natura 2000 network [37], the Common Fisheries Policy (CFP, [38]), the Marine Strategy Framework Directive (MSFD, [39]) and the EU Biodiversity Strategy for 2030 [40]. In particular, the reformed CFP promoted an Ecosystem-Based Approach, in which benefits from living aquatic resources are ensured “*while the direct and indirect impacts of fishing operations on marine ecosystems are low and not detrimental to the future functioning, diversity, and integrity of those ecosystems*” [41,42]. The reformed CFP afforded an opportunity to consider not only the achievement of environmental objectives, but also the establishment of economically and socially sustainable conditions for the sector [43] in line with the Sustainable Development Goals (SDGs) highlighted in 2015 by the United Nations General Assembly. In detail, the modern CFP includes targets at ecological, technical, management, and socio-economical level and indicators to monitor the environmental impacts of fishing. This policy framework inspired the TartaLife project, operating in sea turtle conservation within the Natura 2000 network, by assessing ecological indicators, testing management tools and technological solutions, and engaging with fishers.

Raising awareness amongst fishers and other stakeholders of the threats currently facing vulnerable populations throughout the Mediterranean, as well as their significance in the functioning of ecosystems and food webs is important to improve relations between fisheries and these species [12]. Vulnerable species, however, are not the only ones negatively impacted by the interaction with fishing activities. Fishers also risk economic losses as a result of incidental catches of sea turtles due to damage to their nets by entangled individuals or catch damages, or due to the depredatory behaviour of species that feed on bait meant to lure target species (i.e., longline). In addition to this, catches of charismatic species such of sea turtles may cause reputational damage to the fisheries.

Addressing the perspectives of stakeholders is essential to enable development of innovative management approaches, involving a shared accountability for outcomes. Stakeholder engagement have been supported by the development of roadmaps in the context of fisheries industry as well as in other sectors, including scientific development processes [44]. Roadmaps communicate vision, generate surveys, explore innovative pathways, and monitor progress, so serving as an inventory of potential solutions for a particular sector or issue. Roadmaps facilitate more interdisciplinary networking and collaborative research, and in an industry such as fisheries, they can support a development from traditional top-down management approaches towards collaborative governance approaches [45,46].

Frameworks for solving by-catch problems in fisheries with the use of a collaborative approach have been assessed in other seas [47,48]. One framework tested by researchers in Australia involved five key steps: (*i*) identification and (*ii*) quantification of bycatch, (*iii*) development of modification and technological innovation to minimize the mortality of PET species (*iv*) testing these mitigation devices in field experiments and (*v*) gaining acceptance of the new solutions throughout fisheries sector and other interested stakeholders. Logic and methods for completing this framework are common among many fisheries, and the use of fishers’ local ecological knowledge (LEK) has become increasingly common worldwide (same example are: Dutch demersal fisheries, [49]; Kenya small-scale fisheries, [50]; UK fishing industry, [51]; global review, [48,52].

In the past decade, an increasing number of interview-based studies have examined fishers’ perspectives on management issues [53,54]. A bottom-up approach and stakeholder involvement were recently used in biological and ecological studies in fisheries science to examine several environmental issues, such as benthic impact [55–57] and bycatch [58–61]. Taking inspiration from Australian researchers [48], the objective of this study is to identify a constructive path for fishers’ engagement in the reduction of incidental catches of sea turtle in the Mediterranean by defining a roadmap which includes the following elements: (*i*) to create baseline information on where, when, how, who, and why bycatch occurs, supported by fishers’ LEK; (*ii*) to raise fishers’ awareness on good practice and sustainable fisheries; (*iii*) to involve fishers in the development and testing of technical gear modifications for bycatch reduction (BRDs) and (*iv*) understand the perspective of fishers on scientifically proposed technical solutions. The degree of interest from fishers and their motivation to cooperate was monitored. Other topics such as research, technological innovation, information exchange, logistics, criticism, and social aspects were discussed to outline a purposeful process of interaction between fishers and the scientific community to promote conservation of sea turtles in the Mediterranean.

2. Methodological approach

2.1. Area of investigation and participating fishing fleet

The investigation focuses on the central Mediterranean Sea, which encompasses sea turtle migration routes (the Sicily channel and the Ionian Sea in autumn and winter, the Tyrrhenian Sea in spring [62]), foraging sites (the Adriatic Sea [63]), and a stable nesting rookery in the Ionian Sea [64,65].

Meetings with fishers and field activities were scheduled for Geographical Sub-Areas (GSAs; [66]) and carried out in 129 major fishing harbours covering approximately 98% of the length of the Italian coast (Fig. 1). The sampling distribution of various engagement activities across geographic areas was generally in line with the distribution of the fishing fleet, although the consistency of data collection and

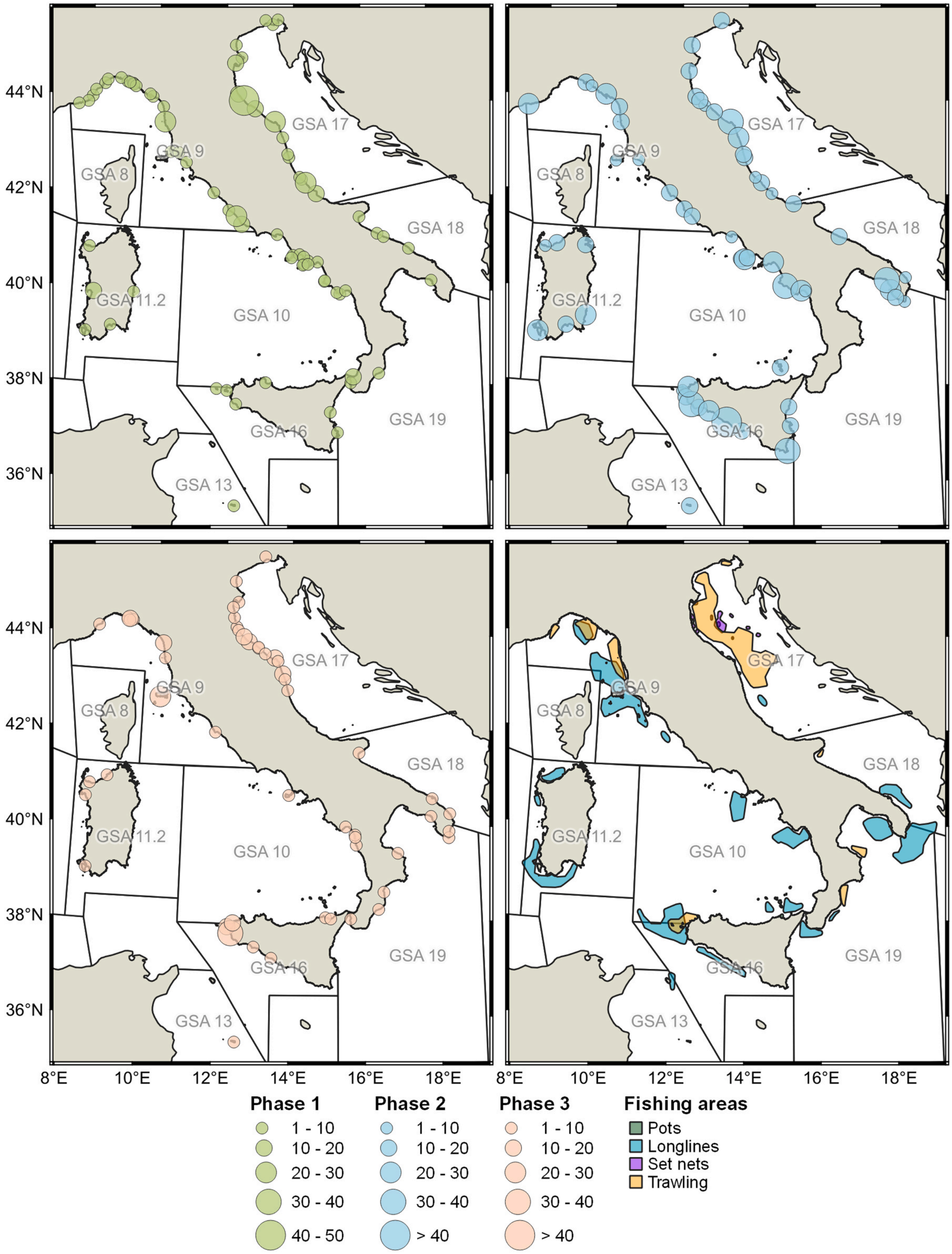

Fig. 1. Roadmapping. The bubbles represent the harbors, while the size of each bubble represents the number of fishers involved in each harbor. Phase 3 (at sea) is also represented.

reporting varied across GSAs and fishing methods.

This case study involves trawlers that target mainly demersal species, longliners that target swordfish and large pelagic species, and fishers who conduct coastal demersal fisheries using set nets (notably gill and trammel nets). The Italian fishing fleet including the abovementioned fishing metiers account for more than 90% of the impact of fishing on sea turtle populations in the study area [63]. These three fishing categories involve 9000 fishing vessels and 13,000 fishers [67], accounting for 57% of total national landings (around 100,000 tonnes) and over 500 million euros in revenue [29].

2.2. Fishers' engagement road map

This section describes the conceptual model used to outline a road map in fishers' engagement to arrive at viable solutions for the conservation of sea turtles, in line with the method used by other researchers in Australia [48].

The fishers (who engage with the turtles in the first place) and the scientists (who study solutions or opportunities) are recognized as the two main parties. A large-scale involvement of fishers was matched by a dense network of scientific personnel who reached out to fishers in the various harbours. More than 100 units of personnel were engaged, including interviewers, technicians and scientists from 9 institutions from different parts of Italy, including a research body, a regional authority, two non-profit organizations, two private organizations, and marine protected areas and a national park.

2.2.1. Targets and outcomes

The 2013 CFP aims to ensure that the activities of the fishing sectors are sustainable in the long term, through a management that provides for environmental, economic and social sustainability. For this purpose, we focused on the achievement of overarching targets (*Final targets*, FTs) to address sea turtle conservation in commercial fisheries in Mediterranean Sea. We identified four FTs relevant in CFP strategies:

- (FT1) *Management*: the involvement of fishers in the decision-making process regarding the conservation of Protected, Endangered, and Threatened species (PET) species;
- (FT2) *Technical*: implementing best practices and mitigation measures and devices for the reduction of bycatch and sea turtle mortality;
- (FT3) *Formative*: transfer of knowledge, experience, and know-how;
- (FT4) *Social*: promoting and disseminating the importance of responsible fishing and reducing disparities between the various stakeholders in the marine environment; empowering fishers in the species conservation strategies, e.g. by changing the type of communication (from turtle killer fishers to collaborative fishers in the conservation of the species); involving fishers in the initiatives proposed by the scientific community;

Key stakeholders were engaged in order to facilitate the achievement of certain outcome targets (OTs), which are measurable and achievable objectives or quantifiable intermediate results that enable the achievement of FTs through an organised planning process. The choice of the OTs followed the procedures adopted in the frameworks for results-based management (RBM) in fisheries [68]. Six OTs were defined a priori by authors and were grouped into three pairs serving the same purposes (Fig. 2). The OTs were intended to fill the knowledge gap in the interaction between sea turtles and fisheries (OT1.1 and OT1.2), to expand knowledge on the use of BRDs (OT2.1 and OT2.2) and to increase the fishers' awareness on sustainable fishing, ecosystem protection, and technological innovation (OT3.1 and OT3.2). A documentation path was established to ensure proper monitoring and achievement of OTs. For example, the production of bycatch hot spot maps for fishing metièrs and the assessment of interaction matrix and estimates were set as documentation for OT1. Similarly, the number of fishers trained on bycatch handling practices and BRDs was established to monitor OT2, while the effectiveness of multiple innovative and improved BRDs and their spreading on a commercial scale (i.e. number of vessels involved) focused on demonstrating the fishers' cooperation in responsible fisheries initiatives (OT3).

2.2.2. Roadmap outline

A three-phase roadmap was developed (Fig. 2). Each phase was preparatory for the next and comprised specific OTs, and stipulated the interaction between the involved actors, hereby creating the framework for achieving the FTs.

Phase 1 (*Meeting*) was the initial contact between fishers and researchers. At this point, project researchers asked fishers for information and data. This phase is divided into two consecutive sub-phases. The first sub-phase (first analysis of the problem) consisted of interviews performed by trained interviewers who seek out and interview fishers to: (*i*) understand (how, why, what is entailed, etc.); (*ii*) define (in which season, which areas, and which gear); and (*iii*) quantify (bycatch estimates and mortality) the problem of the interaction between commercial fishing and sea turtles (OT1.1). The second sub-phase (monitoring of the problem, OT1.2) consisted of the collection of reports on bycatch events provided by some trusted fishers. Phase 1 was linked to FT1 (potential implementation of management measures) and FT3 (increasing of scientific knowledge thanks to LEK of fishers).

Phase 2 (*Deepening Knowledge*) was the second stage in the engagement of fishers and progress in the exploration of a solution to problems with incidental catches of sea turtles. This phase represented an exchange of knowledge between researchers and fishers on the state of knowledge and practical experiences (OT2). As part of this, researchers updated and trained fishers on the good practices to follow on board in the event of incidental catch (OT2.1) and on available innovative mitigation devices to reduce bycatch (OT2.2). In turn, fishers provided their insight on practical aspects of fisheries operations in relation to bycatch measures. In addition to contributing to a shared knowledge base, the knowledge exchange served to increase the level of trust and cooperation between the two parties. Phase 2 was linked to FT2 (reduction of sea turtle mortality), FT3 (fishers trained), and FT4 (encourage fishers in responsible fisheries).

Phase 3 (*In the Field*) was the roadmap's final stage, where scientists and fishers test innovative mitigation devices (BRDs). In this interaction, there was a simultaneous, dynamic and balanced two-way exchange of knowledge (fishers' experience and scientists' research and development), with both parties equally bringing experience to be evaluated in the field through sea trials (during typical commercial activities). Two main OTs are to be attained: demonstrating the effectiveness of using more selective fishing gear (better fish catch and reduction in bycatch) (OT3.1) and stimulating them to pursue more sustainable fishing techniques that have a lower impact on marine ecosystems and marine protected species (OT3.2). Phase 3 was linked to all of the listed FTs (FT1, implementation of management tools; FT2, technological innovation; FT3, transfer of know how; FT4, fishers' involvement in scientific research).

2.2.3. Engagement methodologies

The initial steps of an engagement methodology consisted of identifying *who* we want to involve for achieving planned OTs. Successively, authors considerations focused on *when, where* and *how* to involve stakeholders. This concerns the identification of suitable locations for meetings between the fishers and the scientists, and for deciding when and for how long to organize and implement the chosen approaches, and whether and when to reiterate interactions.

Phase 1 targeted the vessel captains (given that it was the initial contact) and took place primarily in a location where the fishers felt comfortable, such as the headquarters of the association, the harbour, onboard the vessel or even a bar, especially during the days when fishers were not at sea. Phase 2 also primarily involved the captains. It took place after the indications emerged from the results of Phase 1 and lasted for several years. The scientist-fisher interactions took place at fishers' meeting places. Phase 3 assembled a wide array of fishing industry players, with the fishing vessel crew at the forefront. The scientific group comprised experts and technicians, and the meeting place was onboard the vessel.

The engagement methodology used was chosen with a view to engage a large number of fishers. Timing, logistics, homogeneity, effectiveness of sampling, and the reliability of results were all influenced by the methodology, which was closely associated with the OTs to be attained. The methodology differed from phase to phase and from the

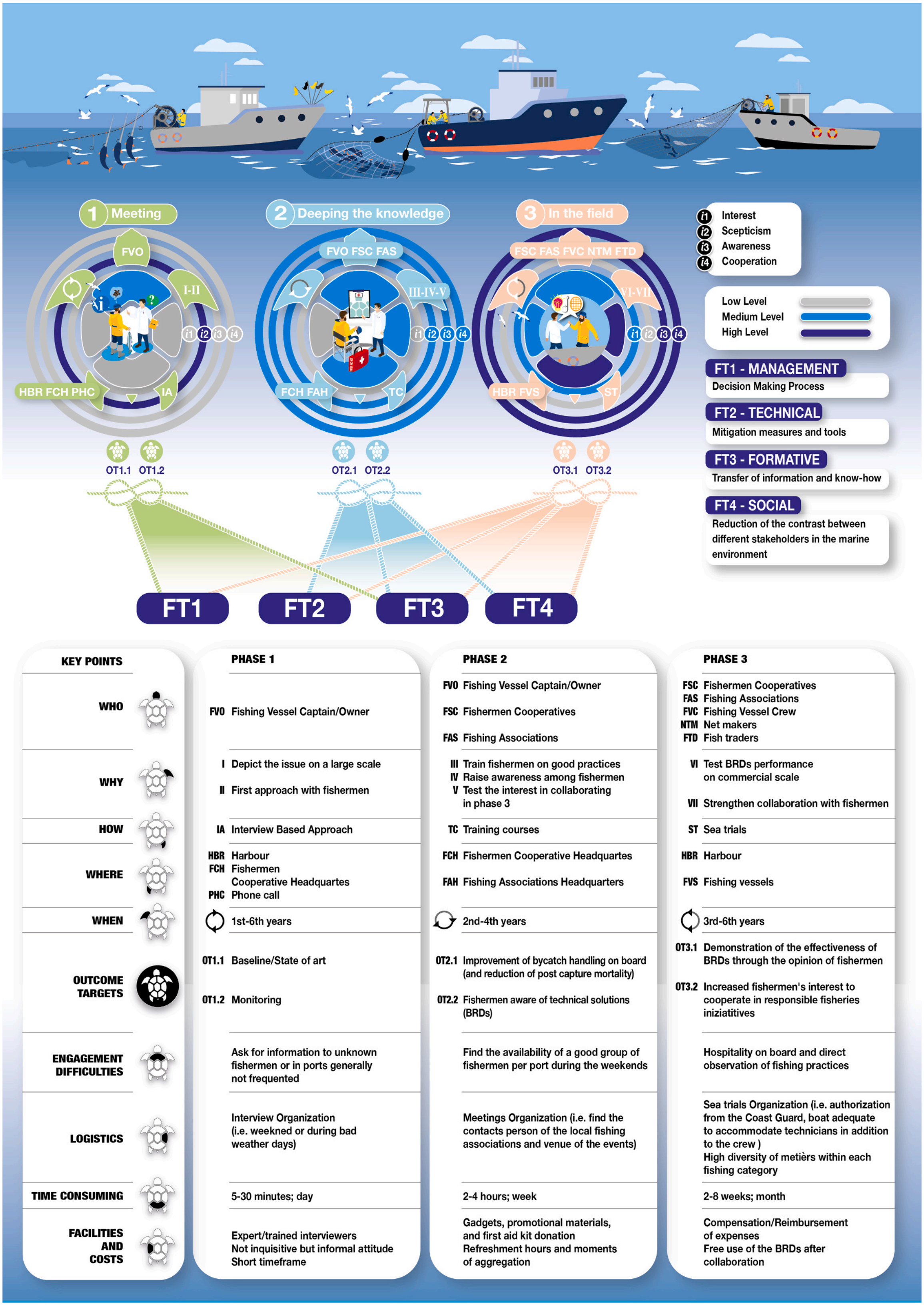

Fig. 2. Road map depicting the three phases and level of indicators and criticalities for each phase. Outcome target (OTs) linkages and final targets (FTs) are also represented. An explanation of all the acronyms used in the representation of the above phases is included below the figure.

Table 1
Methodologies applied in the different phases of the roadmap: methods, data collection, processing, and expected results.

Phase	Method	Description	Expected results
1	Interview-based approach (IBA) (on a large scale)	Face-to-face interviews (organized at the harbour during fishers' association meetings or by telephone) consisting of 5 sections (for detailed information, see Lucchetti et al. 2017): *Background information* – fishers' experience, fishing gear used, and fishing grounds; *Sea turtle interaction* – data on the number of sea turtles caught per season/year and information on the behaviour of fishers and post-capture handling; *Bycatch reduction* – suggestions, opinions, and knowledge on mitigation devices (i.e., Bycatch Reducer Devices, BRDs) and gear modifications to reduce the capture and post-capture mortality of turtles; *Interest and cooperation* – assessing the level of: interest in the in the topic and related solutions *(i1)* and cooperation in turtle conservation research projects *(i4)*. *Fishers' scepticism and/or awareness*– assessing the level of: fishers' willingness to pursue responsible fishing and turtle conservation *(i3)* and fishers' doubts and reservations (on BRDs, mitigation measures, etc.) *(i2)*. For detailed information, see Lucchetti et al. (2017). The last two section (related to indicators, i_s) were repeated at the end of each phase.	An estimate of sea turtle bycatch rates in Italian waters. Evaluation of the risk of bycatch for each type of fishing gear and identification of seasonal and spatial hotspots. Preliminary assessment of fishers' perception on sea turtle conservation and related solution by the use of indicators.
	Logbook (trusted fishers)	One-page paper logbook for fishers to record bycatch information on the date, coordinates, biometrics, weight, and health (i.e., alive, dead, or comatose) of turtles captured Self-reporting was entrusted to the captains of 8 fishing vessels operating in GSA 17 (3 OTB, 3 GNS, and 2 LLN).	Annual monitoring of sea turtle bycatch in different areas using different fishing gear.
2	Training (on a large scale)	Awareness campaign through infodays and seminars to communicate the project's objectives. Presentations and video-based training on the best practices to follow on board in the event of capture (i.e., resting position, protection from the sun and cold, unhooking procedure, release, tag presence, etc.). Demonstration on how to operate a BRD using a physical specimen; video and results of the set-up trials of each BRD proposed by scientists.	Growing awareness of sea turtle conservation efforts among fishers, fishing associations, and other stakeholders. Educating fishers on best practices for turtle handling to reduce post-capture mortality. In collaboration with scientists, a new assessment of fishers' perception in/bemusement over BRD testing (*i2*).
	Interview (on a large scale)	After 4 to 6 months, an easy questionnaire with closed-ended questions targeting the fishers who participated in the seminars and courses. The investigation focused on 3 categories: *General Questions* (GQ) on sea turtles; the use of the correct rescue methods and unhooking (*Operational Handling*, OH); and the release, transportation, and effective use of the kit received (*General Handling*, GH). Some questions in the OH and GH categories were similar to those reported in the Phase 1 Questionnaire to validate the training's effectiveness.	Appraisal of fishers' level of: interest in learning (i.e. rescue procedures) (*i1*), awareness (*i3*), and cooperation in best practice (*i4*).
3	Sea trials (planned distribution)	Sea trials were conducted on a commercial scale, with fishers hosting the researchers on their own vessels during routine fishing activities. The appropriate BRD was tested for each type of fishing métier. Scientists and expert technicians assisted in the rigging and gear modifications of BRDs. Sea trials were organized to compare fishing efficiency and bycatch reduction between traditional gear (*control*) versus modified or BRD-rigged gear (*test*). Depending on the fishing gear, alternate hauls deployed the test and control at different times (e.g., in a single trawl net) and paired hauls deployed the test and control simultaneously (e.g., in twin trawls). Catch and bycatch data (biometrics and weight of the different species) and gear performance data (TED inclination, LED illumination, baited hooks, etc.) were gathered for each haul by on-board observers. For detailed information, see Lucchetti et al., 2016; 2019; Vasapollo et al., 2019; Virgili, 2018; Petetta et al., 2020.	Development and selection of the optimal BRD configuration to minimize commercial loss and simultaneously reduce bycatch. Enhanced use of BRDs (additional modifications and technical measures) as a result of fishers' experience. Dissemination of BRD knowledge on a larger commercial scale and the gaining of a greater consensus among fishers as a result of the encouraging outcomes of sea trials. Implementation of effective BRDs and alternative fishing gear, particularly in identified turtle and commercial fishery interaction hotspots.
	Interview (planned distribution)	Face-to-face interviews were organized for each fishing vessel's crew at the end of the sea trials. The questionnaire consisted of 2 sections: *Background information*–experience of fishers, fishing gear, and prior knowledge of BRDs; *Socioeconomic impact of experimentation*–information on the difficulties encountered; changes to traditional fishing resulting from the use of BRDs (e.g., hauling time, logistics, safety measures, fuel consumption, etc.); perspective on catch quantity and quality, and on discard, debris, and bycatch reduction; general opinion on BRD implementation and associated effectiveness on sea turtle conservation and marine habitat protection.	Preliminary evaluation of the socioeconomic impact of the deployment of low impact fishing systems. Understanding the perspective of fishers on the technical solutions and mitigation devices proposed by scientists (feedback from indicators assessment). Evaluation of the potential BRD strengths and weaknesses, as well as a comparison between scientific results and fishers' opinions.

OT to be achieved. Interview-based approaches (IBA), workshops, and direct collaboration during field activities were utilized for engagement purposes on a wide spatial scale. Interaction with fishers took place at local harbours, public places, and to a lesser extent via telephone. Detailed information on the methodology and expected outcomes for each approach are outlined in Table 1. During the initial IBA approach (Phase 1), the interviewed fishers were engaged through a "snowball" approach, which is widely used in social science [69,70]. This involves recruiting future subjects from among the acquaintances of fishers already interviewed, thus overcoming the initial barriers to earning the fishers' trust. This method of sampling made it possible to conduct sufficient interviews. The need for this approach diminished after the initial engagement and, over time, our acquaintance with the fishers grew in every area and in each type of metier and some of them even became close collaborators, facilitating subsequent activities. Therefore, the initial phases (Phase 1 and 2) involved large-scale planning in order to target a large number of fishers, while field activities (Phase 3) were scheduled a priori in a more targeted manner due to the greater complexity of the engagement. The choice of ports in Phase 3 was addressed in those areas where the bycatch hotspot indices, related to season and fishing metier diversity and derived from Phase 1, were critical.

A stakeholder engagement event can include a single stakeholder (captain, fisher) as in the case of interviews in Phase 1, or more stakeholders as in the case of knowledge exchange and training (Phase 2) and field activity (Phase 3- local fishing fleet, vessel crew, etc.). A series of critical issues related to stakeholder interaction needs to be assessed: *engagement difficulties* (i.e., availability, attainability, and level of stakeholder trust), *logistics* (i.e., meeting and organization of activities), *time consumption* (amount of time spent on each individual engagement), and *facilities and costs* (measures and tools designed to facilitate and promote the outcome of the engagement, and/or compensate for the inconvenience caused to the stakeholder). Each criticality was assigned an intensity level (low, medium, or high) based on the degree of difficulty it entailed. At the end of each phase, the authors collected feedback from the scientific staff network dislocated in the investigated area, who assigned a criticality intensity score for each stakeholder interaction event taking into account time, effort, cost, constraints and barriers.

Finally, *Indicators* (i_s) to measure progress of fishers' engagement toward FTs during roadmap were defined. They were based on the perception and behaviour of fishers: (*i1*) interest level (in the topic and related solutions); (*i2*) scepticism (i.e., towards the feasibility of implementing technical solution and the legislative basis for this); (*i3*) awareness (responsible fisheries and the protection of sea turtles and marine habitats); and (*i4*) cooperation (with scientists and other stakeholders). The interviews with fishers made it possible to measure the level of engagement in the various proposed activities through standard questions that were repeated at the end of questionnaires in each phase. The questions concerned fishers' willingness to pursue responsible fishing (*i1,3*) and turtle conservation, and fishers' attitude to participate and cooperate in conservation research projects (*i2,4*). The responses were assigned a score to evaluate indicator developments phase by phase.

2.3. Data collection and data analysis

The majority of collected data was derived from the interviews, performed in compliance with the European Regulation (EU) 2016/679 guidelines on data privacy. Data on the perspective, awareness, and attitude of fishers toward sea turtle conservation were pooled together (from all the gear) and processed using a basic statistical method to examine the various feedbacks and determine the level of indicators (i_s) in each phase. Fig. 2 shows the intensity trend of the indicators by different degrees of colour; the i_s rates (based on the proportion of fishers' replies) are also reported in the text (Results section) and expressed in percentages. We considered a percentages below 65% as a low level, percentages between 66%– 75% were considered to be at a medium level, and percentages above 75% were assigned as a high level.

Other interview and technical data were archived in distinct datasets and processed in different ways according to the associated OT specifications.

Phase 01: In the first IBA, capture events reported by fishers were combined with fishing effort data obtained from the EU Data Collection Framework [71] to estimate bycatch. Using statistical analysis and the ZINB model (Zero-Inflated Negative Binomial Regression), an interaction matrix was created to identify hotspot regions and seasons of interaction between fishing gear and sea turtles for each gear. The detailed data analysis is discussed in Lucchetti et al. [72]. The association between bycatch data derived from the IBA and data reported by trusted fishers was then evaluated using the Generalised Linear Model (GLM) under the assumption that the data were Poisson distributed.

Phase 02: Info-days, seminars, and training courses were organized to increase fishers awareness about responsible fisheries initiatives. This approach targeted a large number of fishers. Following training courses on best practices for handling captured turtles on board and the presentation and explanation of how BRDs function, a sample of participants (chosen randomly in each harbour) was interviewed with general questions (rescue, handling, and transport on board) after a number of months. On the basis of the number of correct (COR), partially correct (DOU), and incorrect responses (UNC), basic statistics were computed to assess fishers' level of learning.

Phase 03: Activities in the field included the testing of BRDs on a commercial scale during typical fishing activities. The BRDs used were circle hooks in longlining, Turtle Excluder Devices (TEDs) in bottom trawling, visual deterrents (UV LEDs), and alternative fishing gear (collapsible pots) in set net fisheries. Annex 1 details BRD specifications, their rigging on fishing gear, and the reasons they reduce bycatch and/or post-capture mortality. Data on catch, bycatch, and gear performance (Table 1) were recorded by on-board observers to compare fishing efficiency and bycatch reduction between the traditional gear (control) and the modified or BRD-rigged gear (test). Principal data were stored in an ad hoc database, and the Generalized Linear Mixed Model (GLMM, [73] and references mentioned in Table 1) was used to analyse the BRD's catch efficiency relative to the control gear.

A third round of interviews was conducted with a sample of fishers who participated in the sea trials. The majority of questions concerning the BRD experience were three-option multiple choice questions (i.e., improvement, no change, or drop in performance) for a quick comparison with conventional gear. Basic statistics were then computed to map the extent of the resulting changes (i.e., fishing time and performance, logistics, safety measures, fuel consumption, etc.) caused by the use of BRDs. The perspective on the BRDs' implementation was assessed by giving the opportunity to the fishers to assign a score (approval rating) to the various incentives (ecolabeling, financial, obligation of a law, more experience with BRDs, and other advantages such as the recovery of license points). The objective of processing was to determine which variable influenced fishers' opinions the most. The Boruta algorithm (R package; [74] was used to perform variable selection on a set of 5 variables (i.e., area, crew, fisher age, fisher experience, and gear), by searching for relevant variables and eliminating irrelevant ones. Following this, Likert graphs were produced to describe the perception of fishers and the influence of key variables.

2.4. SWOT analysis

In order to assess the effectiveness and sustainability of BRD implementation, the information from fishers gained during sea trials was compared with that of data gathered through Mediterranean-scale scientific research activities. To this end, a study of the available literature on BRDs (including that of the TartaLife Project) in minimizing sea turtle interaction with commercial fisheries was conducted in order to determine the *pros* and *cons* of the usage of these devices. A SWOT analysis [75,76] was undertaken to determine the Strengths and Weaknesses of the use of BRDs and the Opportunities and Threats associated with the employment of mitigation devices or modified gear instead of conventional gear.

The search for SWOT factors was implemented by assessing all references investigating the same BRDs mentioned in this article. A factor was deemed to be a key factor if it was investigated at least 10 times in the pool of references. Key factors for the analysis were evaluated based on the findings and recommendations obtained from the reviewed studies. Each key factor was assigned a 3-point score as follows: 0, no effect; 1, medium effect; and 2, strong effect. References discussing at least two key factors were included in the SWOT analysis. A final ranking of each key factor's mean scores was produced to outline the resulting scenario.

3. Results

3.1. Outcomes from fishers' engagement

Main outcomes and indicators performance varied from phase to phase (Fig. 2). In general, there were no particular critical issues in Phase 1, other than "getting to know" the fishers in order to gather their

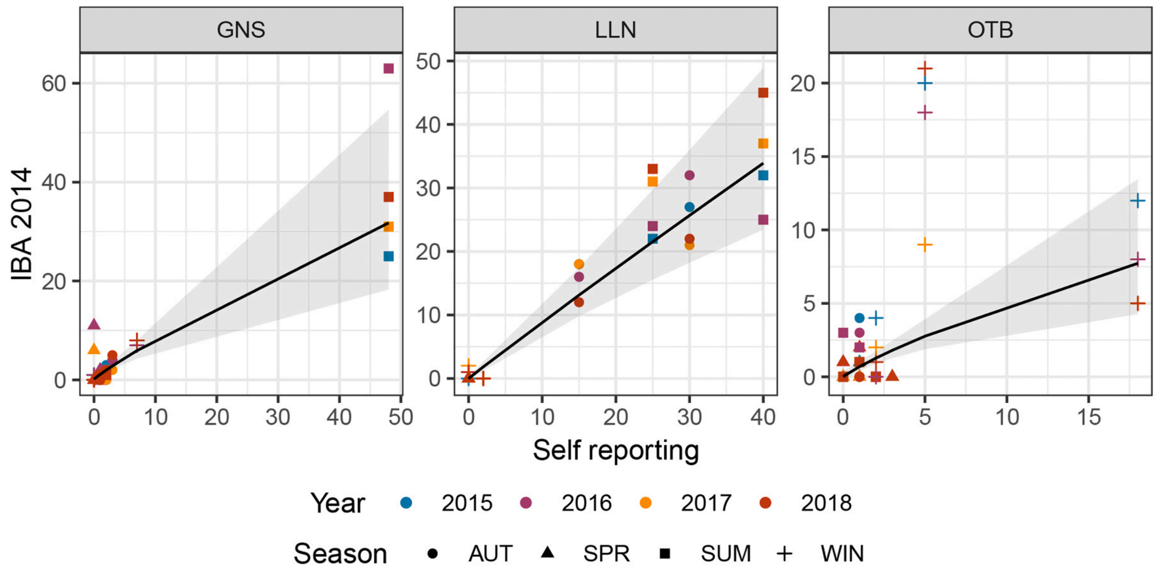

Fig. 3. Comparison between sea turtle catch data from IBA (2014) and self-reporting data (2015–2018) in Phase 1. Self-reporting was conducted by eight GSA 17 fishing vessels (3 OTB, otter trawl; 3 GNS, set net and 2 LLN, longline).

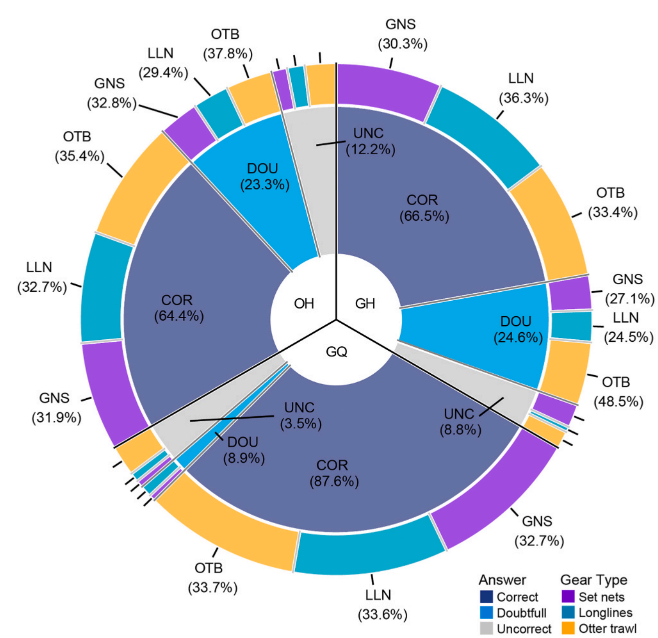

Fig. 4. Pie chart illustrating the results of the interview-based approach in Phase 2. The question categories are OH (Handling Operation), GH (General Handling), and GQ (General Questions). See Table 1 for more details.

feedback. Almost all the indicators were at low levels, with the exception of *i2,* which exhibited a high value during the first contact with fishers, reflecting the fishers' initial reticence and suspicion of this form of "passive" interaction with scientists.

In Phase 2, the issues relating to logistics, organization, and timing became increasingly critical. Gathering a substantial number of fishers in training courses, despite increasing difficulties, assured a step forward in breaking down the barriers of scepticism (*i2*) on the part of fishers and an infusion of trust in cooperation activities (*i4*). This phase was essential for ensuring that fishers were aware of the best practices to follow on board and how to handle a captured turtle, which were prerequisites for reducing post-capture mortality.

Phase 3 was the most critical phase, in which the scientists put their research and intuitions directly to the test while fishers pause their daily traditional work. It was the stage that facilitates the removal of obstacles in the form of the fishers' scepticism (*i2*), the advancement of collaboration (*i4*), and was a step closer to the concepts of sustainable fishing (*i3*). This does not suggest that fishers will focus their interest (*i1*) solely on fishing with more selective fishing methods following this phase, but they would certainly be more aware of how to improve their modus operandi and how to cooperate with others to improve fishing. The difficulties of engagement in this phase were diverse and multifaceted. From TartaLife experience, the lesson learnt was that certain perks such as payment for on-board hospitality and the free use of the BRDs once the collaboration is over may help mitigate obstacles to allow activities to progress.

3.2. Baseline and monitoring

Fig. 1 illustrates the mapping of Phase 1 undertaken through IBA. Seventy-six fishing harbours and 475 fishers were directly involved. The main IBA results are discussed in [60] and are briefly summarized below. Three-quarters of the fishers reported catching a turtle during the monitored year. Bycatch hotspots were defined in relation to the season and type of gear, with an estimate of more than 52,000 captures and 10, 000 deaths in the study region. The most harmful fishing gear were found to be trawl and set nets, with the highest likelihood of turtle bycatch (around 40,000 captures) in the Adriatic Sea, followed by longlines in the Ionian Sea and the Sicily Channel. The majority of incidental catches occurred in summer (> 15,000 events), followed by autumn and spring (about 13,600 and 13,000 respectively), with a lower number caught in winter (about 11,000). The majority of trawl net captures occurred in GSAs 17 and 18 (Adriatic Sea), where they seemed to be numerous throughout the year. Longline bycatch mainly occurred in GSAs 19 and 16 (Southern Italy), particularly during the summer and, to a lesser extent, autumn. Turtles appeared to interact with set nets in most GSAs, especially in the spring and summer, when fishing with this gear is most active due to favourable sea and weather conditions. The mortality rates derived from interviews with fishers enabled the estimation of about 10,000 turtle deaths, the majority of which were caused by set nets (5743) and trawl nets (3082).

The monitoring of bycatch conducted in GSA 17 in collaboration with fishers revealed the number of turtles captured annually between 2015 and 2018: GNS (*set net*), 5.02 ± 1.52 for, LLN (*longline*), 13.09

Box 1
Effectiveness of Bycatch Reduction Devices (BRDs) in reducing bycatch of sea turtles and other protected species (PET) and performance of BRDs in terms of commercial catch efficiency, obtained during Phase 3.

Bycatch reduction

A total of 51 sea turtles of the *C. caretta* species were captured during sea trials: 27 using longlining, 13 through bottom trawling, and 11 with set net fisheries. Fifteen sea turtles were caught with circle hooks (rate 0.06 ind/haul) and were released after being unhooked. There was no evidence of trauma or haemorrhage; the hooks were always placed in the outermost part of the mouthpiece, and their release by the fishers was easy to handle. Twelve sea turtles were caught with traditional hooks (rate 0.20 ind/haul): two of these had to have the hook surgically removed from the esophagus. Bycatch of elasmobranches with circle hooks was significantly reduced. The use of TEDs successfully reduced sea turtle bycatch. Ten of the 13 specimens captured during trawling sessions (rate 0.05 ind/haul) were captured in the northernmost GSA 17, indicating that this area is a bycatch hotspot during certain times of the year. In accordance with best practices, all specimens were released in good health after a rest period on-board. The bycatch of some species of larger elasmobranches, including stingrays (*Pteroplatytrygon violacea*) and rays (*Raja spp.*), was also avoided with the use of TEDs. Eleven turtles were caught with gillnets (rate 0.18 ind/haul) and all in the absence of visual deterrents. Two of these were dead; the remaining individuals were released in a good health. On the contrary, the capture of elasmobranches was not affected by the use of these deterrents. No turtles or other PET species were captured during pot fishing.

Catch efficiency and gear performance

A drop in the catch and quantity of individuals was recorded with the use of circle hooks. However, this loss was offset by a greater average size of the individuals caught than the J hooks (TL 113 ± 20.5 cm vs. 101 ± 22.1 cm). The specific curved shape of the circle hook ensures that the hook always remains attached to the outermost part of the mouth, regardless of the type of species caught (commercial or bycatch species). This wider hook is more selective than a standard J hook and, in fact, smaller swordfish do not remain hooked. Circle hooks secured the gear's durability and enhanced ease of baiting. The catch efficiency of bottom trawling varies widely by region, and the estimated catch loss in the presence of TEDs is 2% on average. Among the three fractions of the catch analyzed, statistically significant differences were only found in the discard and debris categories, while there were no significant differences in the commercial category. The Supershooter and FLEXGRID TEDs proved to be suitable and durable, while the soft TEDs provided improved handling, lightness, and impact resilience. During sea trials with visual deterrents, the catch efficiency of set net fisheries varied widely depending on the target species, but no significant differences were recorded in the presence of LEDs. LEDs were not damaged during hauling operations and had no effect on the operation of the fishing gear. Collapsible pots captured a wide spectrum of species (about 30 different species), the majority of which were of high commercial interest (sea bream, corb, octopus, and cuttlefish). The average number of fish caught with conventional and alternative gear is comparable. In some cases, the capture efficacy of pots exceeded that of traditional gillnets. The percentage of discards was near zero, and the few undesired or small species (e.g., crabs or small gobies) were immediately released into the water alive.

± 1.86, and OTB (*otter trawl*), 2.64 ± 1.52. Data from self-reporting were consistent with IBA data (2014) regardless of year, season, or fishing gear (Fig. 3; $F_{6.122} = 118.7$, $p < 0.001$, $R^2 = 0.85$).

In Phase 1, fishers exhibited limited levels in some indicators (i_s). In detail, *i1* (interest) was low, confirmed by 38% of fishers rejecting the idea that there is a need about sea turtle conservation. Also, *i3* (awareness) was low: only 58% of respondents were aware that their actions adversely affect sea turtle populations and their preservation. Moreover, it resulted a lack of motivation in cooperating in projects/initiatives (*i4*) whose primary goal is to protect endangered species, and only a few fishers (less than 15%) seemed genuinely interested in learning something other than fishing itself (i.e. turtle rescue procedures). On the contrary, *i2* (scepticism) was high, evidenced by the majority of fishers expressing concern about adapting/modifying their traditional gear (i.e. fear of performance loss). Fishers were extremely concerned about the mandatory usage of BRDs or other comparable alternatives. In any case, the majority of respondents (60%) believed that applying mitigation devices (BRDs) to traditional fishing gear (under specific conditions, i.e. financial incentives) would be more effective at reducing turtle bycatch rates than relocating to a different fishing zone.

3.3. Good practice

Fig. 1 depicts the mapping of Phase 2 training courses. Fifty-nine fishing harbours and 1069 fishers were actively involved in the meetings, and 211 of these fishers were subsequently interviewed to determine their level of learning following the courses and their interest in the new BRDs to reduce bycatch. In general, regardless of the category of questions asked, most respondents answered correctly (64%, OH,

Table 2
BRDs performance in terms of fishing efficiency (commercial catch) and reduction in sea turtle and other species bycatch (OTH). CRTL: Control gear without BRDs rigging. OTH includes: PET species in longline fishing (LLN), PET species, discards and debris in trawling (OTB), PET species and discards in set nets (GNS), and POT fisheries. Average (AVG) and standard error (SE) of Catch and OTH are stated as follows: kg/1000 hooks for LLN, kg/h for OTB, kg/km* 12 h for GNS, and kg/day for POT. Turtle bycatch is indicated as the number of individuals caught. Statistically significant differences obtained with the t-test are reported in bold.

		Catch			OTH			Turtles		
		AVG	SE	*p-value*	AVG	SE	*p-value*	AVG	SE	*p-value*
LLN	J hook	65.24	9.83	**0.005**	10.4	1.44	**< 0.001**	0.2	0.057	**0.02**
	C hook	35.72	2.78		2.72	0.32		0.06	0.015	
OTB	CRTL	18.35	0.68	0.24	60.43	3.69	**0.002**	0.05	0.02	**0.015**
	TED	17.21	0.69		45.33	3.18		0	0	
GNS	CRTL	12.49	2.33	0.42	2.47	0.7	0.13	0.18	0.064	**0.007**
	LED	16.33	4.14		1.2	0.44		0	0	
GNS	CRTL	4.37	0.44	**0.027**	0.95	0.23	**0.011**	0	0	
	POT	6.33	0.76		0.06	0.03		0	0	

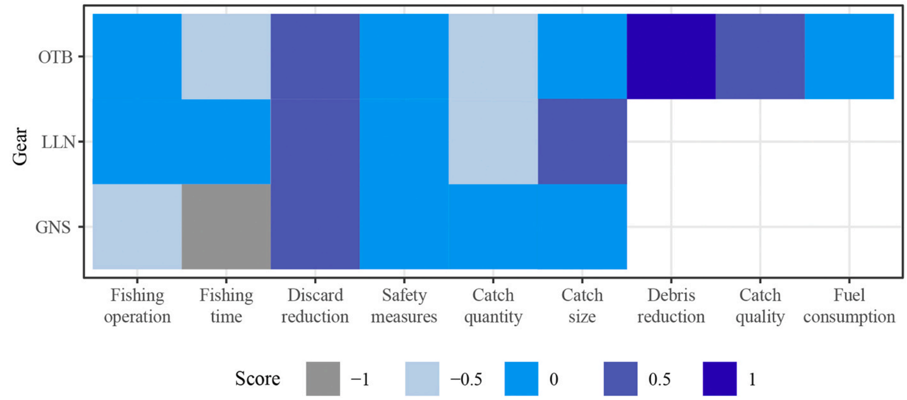

Fig. 5. Heat map of the relevant parameters assessed in Phase 3, which were based on the perception of fishers. BRD performance is scored as follows: 0.5 to 1 is the improvement index; 0 is no change; and < 0, is a drop in performance.

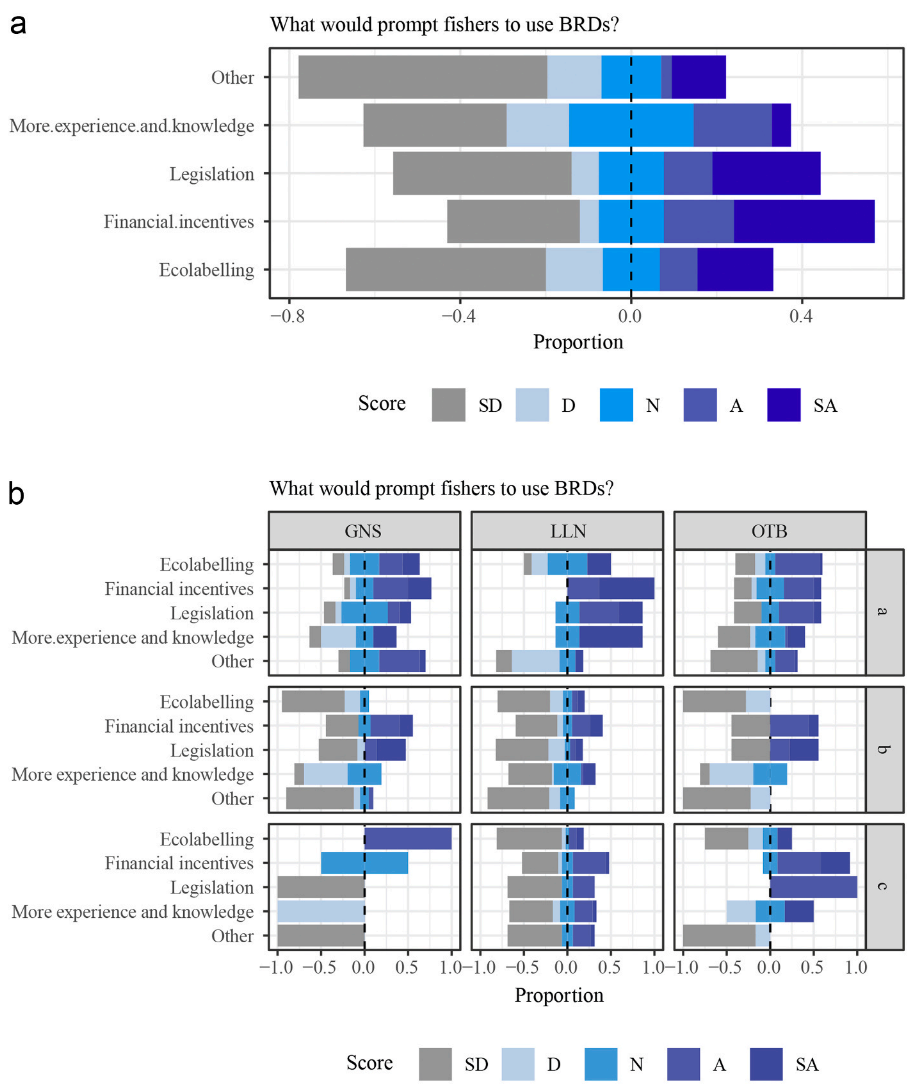

Fig. 6. Likert graphs. A) Variation of fishers' interest in relation to various types of incentives, taking into account the total number of respondents. B) Likert scales derived from the Boruta algorithm assessment. Score: SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, and SA = Strongly Agree. a. Adriatic Sea (GSA17–18); b. Southern Seas (GSA16–19); c. Tyrrhenian Sea (GSA 9, 10, 11).

Handling Operation; 87%, GQ, *General Handling*; 66%, GH, *General Questions*) and were partially correct to a lesser extent (Fig. 4). The proportion of incorrect answers was consistently very low, irrespective of the metier (< 12%).

What stands out most in Phase 2 is that, after the course, more fishers provided answers in response to questions about handling practices and release that were in accordance with good practice (OH-GH) (52% in Phase 1 vs. 65% in Phase 2). Furthermore, the fishers appeared to be less

Table 3
SWOT Analysis: factors and average scores.

STRENGTHS	S	WEAKNESSES	S
Reduction in sea turtle bycatch	**1.54**	Changes in fishing operations	**1.09**
Fishing performance (catch)	**1.21**	Loss of time during fishing operations	0.86
Catch quality	**1.86**	Rigging difficulties and measures by metier	**1.30**
		Costs	**1.25**
		Further Experimentation	**1.55**
OPPORTUNITIES	**S**	**THREATS**	**S**
Reduction in debris	**1.85**	Loss of commercial catch	**1.00**
Reduction in discards	**1.63**	Gear performance	0.83
Reduction in bycatch of other species	**1.23**	BRD robustness/structure	**1.46**

wary and concerned about the handling of an accidental catch on board and its delivery (in the case of an individual in a comatose state) to the Rescue Center or local Coast Guard. In Phase 1, we anticipated that some fishers would exhibit scepticism (*i*2) towards the use of BRDs. During this phase, fishers' doubts and reservations (*i*2) about using BRDs decreased by about 15%, following the demonstration of BRDs in sea trials. On the contrary, *i*1, *i*3 and *i*4, showed an increase of 18%, 12% and 52% respectively.

3.4. BRD implementation

Fig. 1 illustrates the mapping of Phase 3 activities (harbours and sea coverage). Fifty-three fishing harbours and 387 fishers were directly involved in the sea trials. The time span covered 569 fishing days in total: 310 days for longlines, 136 (452 hauls) for otter trawling, 61 for gill nets, and 62 days for pots. An area of 60,426 km^2 was covered at sea, or 9.7% of the total area of the seven GSAs included. Results from the sea trials are available in the references listed in Table 1 and are described and summarised in Box 1 (including Table 2).

3.4.1. Fishers' perception of BRDs

About half of the fishers interviewed after the sea trials claimed they were familiar with BRDs, but just a minority (14%) had tested them. Almost all (87%) confirmed that utilizing BRDs was easy or not difficult at all. The minor obstacles encountered involved modifying the traditional gear and evaluating any technical measures to ensure a successful fishing and catch. Fig. 5 depicts the impact of BRDs on the logistics and fishing performance for each fishing metier. In general, safety measures, catch size, and fuel consumption remained the same; discard (and debris reduction in OTB) and catch quality improved. Generally speaking, slight shifts in fishing operations, time, and catch performance (i.e. quantity) were seen in all the three fishing metiers. The fisher's overall perception of the use of BRDs was favourable, by accepting some compromises.

The incentives that would encourage fishers to install BRDs are mostly pecuniary in nature (e.g., total or partial financing of BRDs, Fig. 6a). The Boruta algorithm confirmed that place of origin, the fishing gear used and the dimension of crew were more important factors for motivation than age and level of experience (see Annex II). In the Adriatic Sea (GSA 17–18), fishers have shown to be receptive to almost all types of incentives, irrespective of the metier. The response of fishers in the southern seas (GSA 16–19) was different: not only were they generally unenthusiastic, but they have almost entirely subscribed to economic incentives or abided by regulatory obligations. The case of the Tyrrhenian Sea was different (GSA 9,10, and 11), where the response was primarily influenced by the type of gear used, with the highest interest recorded in Ecolabeling in GNS, Financial Incentives in LLN, and Legislation in OTB (Fig. 6b).

In this phase, *i3* and *i4* showed the high level. Almost all fishers (89%) were satisfied with the experience gained and aware of the importance of responsible fisheries (*i3*), and 76% of them were willing to participate again in future initiatives of the same type (*i4*). The majority of respondents were convinced that the implementation of BRDs could reduce the negative impact of fishing, particularly on PET species, reducing *i2* at low level (22%).

3.4.2. SWOT analysis: key factors

Scientific data gathered during the implementation of BRDs on a commercial scale are described in the references listed in Table 1. These references have been combined with others investigating BRDs in the Mediterranean, bringing the total number of references gathered to 31 (resulting in 48 records; see Annex III and IV).

Three of the fourteen identified key factors were Strengths, five were Weaknesses, three were Opportunities, and three were Threats (Table 3 and Annex IV). All Strengths and Opportunities received a score of > 1, as did four Weaknesses and two Threats. The scenario outlined by the analysis confirmed that BRDs are a beneficial alternative to traditional gear for minimizing sea turtle bycatch in the Mediterranean Sea, at least for some metiers.

The Strengths of BRDs include the fact that they effectively reduce bycatch while maintaining good fishing performance and delivering a higher quality catch. Opportunities include a reduction in discards, debris, and other PET species (i.e., cetaceans and elasmobranchs). However, the Weaknesses (i.e., changes in fishing operations, rigging difficulties in some metiers, costs, and the need for further experimentation) and Threats (i.e., loss of catch of some commercial species and the choice of a suitable BRD, considering needs for strength and structural safety) are negative factors that should be addressed to also improve sustainability at the socioeconomic level.

In conclusion, the fishers' perceptions of BRD-equipped gear compared to traditional gear were consistent with the scientific data gathered in Phase 3 and other Mediterranean studies (Annex III). Minor negative changes in catch performance and fishing time have been identified. However, in some cases, the quality and selectivity of the catch has increased, offering some form of compensation (Fig. 5).

4. Discussion

Modern fisheries management systems increasingly focus on responsible fisheries and the Ecosystem Approach to Fisheries (EAF). The targets contained therein can create 'tension' between society, policy and science when environmental sustainability concerns appear in conflict with maintaining fishers' livelihoods. The main aim of this study was to contribute to resolve such tensions by engaging fishers in collaborative approach for sea turtle conservation, as organized into a road map [77].

Stakeholders in the fisheries sector are varied. They are not only represented by individuals who embark and work at sea, but also by those who oversee all operations on land, such as representatives of fishing associations (who handle administrative and representational duties), fish retailers (who sell and trade fish), and net manufacturers (who produce and repair the gear). Obviously, the first-hand experience of fishers cannot be ignored in the study of the interaction between commercial fishing activities and the conservation of protected marine species. The crew of a Mediterranean fishing enterprise has a culture that is strongly rooted in family ties and close relationships, making family members the direct protagonists of commercial activities. Fishers include the captains (who are often the owners of the fishing vessels) and the other crew members and are the key stakeholders that have direct experience with fishing activities.

The drafting of a detailed and consolidated roadmap for the engagement of fishers to mitigate the interaction between commercial fisheries and marine protected species calls for a multi-phase space-time planning involving different approaches of cooperation and communication between the fisheries sector and the scientific community. A three-phase roadmap was drafted and the study area was adequately covered by all operations, according with the level of bycatch per gear and area. More than 1500 fishers or 11.6% of the target fishing fleet were engaged through this process. Main insights and findings coming from roadmap are presented in Insight 1–3.

The convergence of a range of multipurpose approaches (theoretical and practical) had the potential to obtain promising findings to reduce fishing-induced mortality. Our first step was to identify the knowledge gaps about the problem of the interaction between sea turtles and fisheries, followed by an evaluation of potential solutions. It was only at the end that a decision was made on how fishers should be involved and in what capacity (FTs). The information flows in regard to FTs differ according to the phases: FT1, FT2 and FT3 mainly involved a one-way flow of information from researchers to fishers in Phase 1 and 2, while Phase 3 involved a more balanced two-way exchange. In turn, the FT4 involved a close interaction between the two parties, oriented towards the achievement of the various OTs though practical solutions.

Phases 1 and 2 involved collaboration between the two actors, but through addressed information flow. At first, the scientists asked for fishers information, subsequently they offered knowledge in the form of training. Phase 3 represented the transition from a collaborative approach [77,78] to a scenario of shared participation (participatory approach, [79,80]), where the experiences and knowledge of the two parties met and intertwined. TartaLife roadmap can be analysed in terms of the Ladder of Citizen Participation by Arnstein [79], in which the author described a continuum from non-participation of citizen to full citizen control. Arnstein divided this continuum into different levels, depicted as rungs on a ladder. Our roadmap started with scientist that informed fisher on the importance of his collaboration in sustainable fisheries initiatives (*Informing*- first step toward legitimate citizen participation). Phase 1 is the “rung” of *Consultation*, in which fishers have been reached by traditional methods used for consulting people such as surveys, meetings, and public events. When scientists restrict the input of stakeholders’ collaboration solely to this level, participation remains just a window-dressing ritual. Fishers are primarily perceived as statistical abstractions, and participation is measured by how many answer a questionnaire. What fishers achieve in all this activity is that they have ‘participated in participation’. This “rung” is not yet stable as it offers no guarantee that fishers’ concerns/information and suggestions will be taken into account or in which way. Phase 2 is the “rung” of *Placation*. It occurs when fishers are granted a limited degree of influence in a process (as in fisher’s training and updating), but their participation was still tokenistic (“fishers are merely involved only to demonstrate that they were involved”). Phase 3 represented the upgrade of the roadmap that sounds like the “rung” of *Partnership*. Participation as partnership occurs when public institutions, or in our case scientific community, allow fishers to negotiate ideas and strategies, share funding, or collaboration in technological innovation. In fact, the two parties begin to share planning and responsibilities through such structures such as joint policy boards, planning committees, and panels for resolving criticisms. In our case, where, when and how to implement mitigation tools and measures, and how to incentive and spread this strategies.

Each phase had its logistical complexities, timing, distinctiveness, and OTs, all of which were monitored by the level of four indicators (i_s). The level of the various indicators clearly highlighted the progress in engagement made in each phase, monitoring the “connection” between the two counterparts. As scepticism gradually diminished the willingness to cooperate in responsible fisheries initiatives and awareness of the importance of safeguarding PET species and their habitats highly increased. This demonstrated that educating fishers on their behaviour is crucial for reducing both bycatch and post-catch mortality.

This study set out to go further to some initiatives performed in Australia [47,48], detailing each component of the theoretical approach and combining it with strong empirical support on large spatio-temporal scale. Therefore, a gradual and multi-step involvement is required, simultaneously resulting in ever-increasing affinity. Overcoming the mistrust of fishers is a gradual and gradational process that is not to be rushed. Fishers need to reason, evaluate, and verify before proceeding, since they must have the utmost confidence that their actions will not have a detrimental impact on their future endeavors (restrictions, new rules, etc.). The involvement of fishers in scientific cooperation cannot ignore these factors, nor can one ignore that many fishers, anything else equal, can have a preference for carrying on with established practices [15].

The development of projects and initiatives in nature conservation and species protection are direct response to the degradation of numerous habitats and the decline of biodiversity. Bycatch, boat strikes, intentional killing, and entanglement in marine debris, including ghost gear, are identified as the main threats in the Mediterranean Sea [7,13,81]. There is a large body of literature in marine conservation biology that is accessible and devoted to documenting this issue at the population, ecosystem, and global levels, frequently recommending amelioration strategies [82]. However, few of these studies are focused on disseminating and testing technical or management solutions on a commercial scale and establishing priority cooperation with the fishing industry. This study demonstrates that effective stakeholder engagement in data collection, training on best practices, and implementation of mitigation solutions can potentially be replicated in other areas or projects to provide elements for the formulation of national and regional strategies for the conservation of vulnerable species and the sustainability of fisheries.

Collaboration with fishers is crucial for monitoring and reducing incidental catch through information exchange and BRD technology installation. Therefore, improved procedures for data collection should be established to better understand the many factors that influence bycatch, and new technology that can reduce bycatch should continue to be developed, updated, and disseminated. To fill the knowledge gaps on where, when and what bycatch occurs, it is necessary to optimize and standardize the monitoring effort [83] throughout the entire basin. The baseline of this information is not scarce, and it has undergone several updates in recent decades [84,85]. However, monitoring is actually not homogeneous in terms of sampling effort and data collection structure and is mainly based on IBA. The use of new technologies, in collaboration with fishers, never used so far in the Mediterranean (e.g. Remote Electronic Monitoring, REM) or used only for purely scientific purposes (e.g. Passive Acoustic Monitoring for dolphins, PAM), to improve data collection in terms of quantity and quality, can contribute to a breakthrough in data collection, with the intention to update the EU protocols actually in force (DCF and Marine Strategy data calls).

Cooperation with fishers is also fundamental for boosting sea turtles’ post-capture chances of survival through the use and application of the correct procedures to be adopted on-board in the event of incidental catch. The applicability and efficacy of BRDs should be evaluated against baseline data and over a period of time, and replicated as appropriate. The production of standards and application manuals that can be easily consulted by fishers (to make them independent in the BRDs rigging) could stimulate a wider dissemination about and use of BRDs. The next step concerns filling the gap of BRDs that have not shown promising results or have failed, with new, more advanced technologies (as in the case of dolphin deterrents [86,87]).

The combination of education, awareness-raising programs, and cross-border knowledge transfer offers a participatory paradigm for bycatch evaluation and, ultimately, bycatch mitigation [80,88]. This dynamic and stepwise approach provides for a partnership between the fishing industry, management bodies, and research institutions [46,78]. The new research initiatives funded by the European Union (e.g. Horizon Europe calls) aim at a more holistic vision [89] in the conservation of PET species, favouring a more comprehensive approach in terms of species to protect (sea turtles, elasmobranches, cetaceans and sea birds), actors to involve (stakeholders, researches, NGOs and commercial enterprises) and policy targets to achieve (social involvement, environmental education, dissemination and technological innovation such as artificial intelligence). This ambition should be conducted with a participatory model, and Tartalife has set the basis for developing an increasingly complex model of cooperation with fishers in the Mediterranean context, where there is less tradition for this sort of cooperation compared to other Northern European countries.

Tartalife was also preparatory for other research funding for the protection of PET species in the Mediterranean, for the establishment of ad hoc funds for fishers (incentives to use BRDs) and for raising public awareness through environmental education programmes and ecolabelled fish product.

Declaration of Competing Interest

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

Data Availability

Data will be made available on request.

Acknowledgments

This research was supported by the LIFE Financial Instrument of the European Community, TartaLife Project of sea turtle mortality in professional fishing (LIFE12NAT/IT/000937). The authors would like to thank the project partners, the NGOs, and other research institutions that collaborated in the TartaLife interviews and field activities. Special thanks go: to the colleague Kåre Nolde Nielsen of the University of Tromsø (Norway), for helping us in the elaboration and revision of the methodological approach addressed in the paper, and the anonymous reviewer who contributed in a fundamental way to the presentation of the article. The deepest appreciation goes to all the fishers and crews of fishing vessels who volunteered their time to collaborate with us. We are indebted to the staff of CNR-IRBIM (Ancona, Italy), who provided considerable assistance throughout the project, and the Italian Coast Guard of each maritime district for authorizing all activities at sea. We are grateful to Monia Bonfili (Bonfili Design; www.bonfilidesign.it) for the illustration in Fig. 1, and to Eurostreet for the linguistic editing. The support received from all the aforementioned contributors has led to the TartaLife Project's success in winning the Life Award 2021.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2023.105981.

References

[1] A. Mazaris, G. Schofield, C. Gkazinou, C. Almpanidou, C.G. Hays, Global sea turtle conservation successes, Sci. Adv. 3 (2017), e1600730, https://doi.org/10.1126/sciadv.1600730.
[2] R. Froese, A. Proelß, Rebuilding fish stocks no later than 2015: will Europe meet the deadline? Fish Fish. 11 (2010) 194–202, https://doi.org/10.1111/j.1467-2979.2009.00349.x.
[3] J. Lleonart, F. Maynou, Fish stock assessments in the Mediterranean: state of the art, Sci. Mar. 67 (2003) 37–49, https://doi.org/10.3989/scimar.2003.67s137.
[4] F. Colloca, G. Scarcella, S. Libralato, Recent trends and impacts of fisheries exploitation on Mediterranean stocks and ecosystems. Front. Mar. Sci. 4 (2017) 244.
[5] H.K. Lotze, M. Coll, J.A. Dunne, Historical changes in marine resources, food-web structure and ecosystem functioning in the Adriatic Sea, Mediterranean, Ecosystems 14 (2011) 198–222, https://doi.org/10.1007/s10021-010-9404-8.
[6] J.A. Musick, Life in the slow lane: ecology and conservation of long-lived marine, Anim., Am. Fish. Soc. Symp. 23 (1999) 1–10.
[7] P. Casale, Sea turtle by-catch in the Mediterranean, Fish Fish 12 (2011) 299–316, https://doi.org/10.1111/j.1467-2979.2010.00394.x.
[8] A. Lucchetti, A. Sala, An overview of loggerhead sea turtle (Caretta caretta) bycatch and technical mitigation measures in the Mediterranean Sea, Rev. Fish. Biol. Fish. 20 (2010) 141–161, https://doi.org/10.1007/s11160-009-9126-1.
[9] D. Margaritoulis, R. Argano, I. Baran, F. Bentivegna, M. Bradai, J. Caminas, P. Casale, G. De Metrio, A. Demetropoulos, G. Gerosa, B. Goley, D. Haddaoud, J. Houghton, L. Laurent, B. Lazar, Loggerhead Turtles in the Mediterranean Sea: present knwoledge and conservation perspectives, in: A. Bolten, B. Witherington (Eds.), Loggerhead Sea Turtles, Smithsonian Insititution Press, Washington DC, USA, 2003, pp. 175–198.
[10] P. Casale, A. Broderick, J. Camiñas, L. Cardona, C. Carreras, A. Demetropoulos, W. Fuller, B. Godley, S. Hochscheid, Y. Kaska, B. Lazar, D. Margaritoulis, A. Panagopoulou, A. Rees, J. Tomás, O. Türkozan, Mediterranean sea turtles: current knowledge and priorities for conservation and research, Endanger. Species Res. 36 (2018) 229–267.
[11] A. Lucchetti, E. Punzo, M. Virgili, Flexible Turtle Excluder Device (TED): an effective tool for Mediterranean coastal multispecies bottom trawl fisheries, Aquat. Living Resour. 29 (2016) 1–12.
[12] A. Lucchetti, Sea turtles, in: P. Carpentieri, A. Nastasi, M. Sessa, A. Srour (Eds.), Incidental Catch Vulnerable Species Mediterr. Black Sea Fish. – A Rev., Studies and Reviews No. 101 (General Fisheries Commission for the Mediterranean), FAO, Rome, 2021.
[13] J. Tomás, P. Gozalbes, J. Raga, J. Godley, Bycatch of loggerhead sea turtles: insights from 14 years of stranding data, Endanger. Species Res. 5 (2008) 161–169, https://www.int-res.com/abstracts/esr/v5/n2-3/p161-169/.
[14] P. Casale, L. Cattarino, D. Freggi, M. Rocco, R. Argano, Incidental catch of marine turtles by Italian trawlers and longliners in the Central Mediterranean, Aquat. Conserv. Mar. Freshw. Ecosyst. 17 (2007) 686–701, https://doi.org/10.1002/aqc.
[15] A. Lucchetti, G. Bargione, A. Petetta, C. Vasapollo, M. Virgili, Reducing sea turtle bycatch in the Mediterranean mixed demersal fisheries, Front. Mar. Sci. 6 (2019), 387, https://doi.org/10.3389/fmars.2019.00387.
[16] P. Casale, D. Freggi, R. Basso, R. Argano, Interaction of the static net fishery with loggerhead sea turtles in the Mediterranean: insights from mark-recapture data, Herpetol. J. 15 (2005) 201–203.
[17] K. Echwikhi, I. Jribi, M.N. Bradai, A. Bouain, Gillnet fishery loggerhead turtle interactions in the Gulf of Gabes, Tunisia, Herpetol. J. 20 (2010) 25–30.
[18] A. Lucchetti, C. Vasapollo, M. Virgili, Sea turtles bycatch in the Adriatic Sea set net fisheries and possible hot - spot identification, Aquat. Conserv. Mar. Freshw. Ecosyst. (2017) 1–10, https://doi.org/10.1002/aqc.2787.
[19] I. Jribi, K. Echwikhi, N. Bradai, A. Bouain, Incidental capture of sea turtles by longlines in the Gulf of Gabès (South Tunisia): a comparative study between bottom and surface longlines, Sci. Mar. 72 (2008) 337–342, https://doi.org/10.3989/scimar.2008.72n2337.
[20] S. Piovano, G. Basciano, Y. Swimmer, C. Giacoma, Evaluation of a bycatch reduction technology by fishermen: a case study from Sicily, Mar. Policy 36 (2012) 272–277, https://doi.org/10.1016/j.marpol.2011.06.004.
[21] S. Piovano, A. Celona, A. Basciano, S. Di Marco, C. Giacoma, At-sea evaluation of artificial bait impact on longline target and bycatch species, Proc. Second Mediterr. Conf. Mar. Turt. (2005) 48.
[22] S. Piovano, Y. Swimmer, C. Giacoma, Are circle hooks effective in reducing incidental captures of loggerhead sea turtles in a Mediterranean longline fishery? Aquat. Conserv. Mar. Freshw. Ecosyst. 19 (2009) 779–785, https://doi.org/10.1002/aqc.
[23] S. Bonanomi, F. Moro, A. Colombelli, J. Pulcinella, C.M. Fortuna, A 14-year time series of marine megafauna bycatch in the Italian midwater pair trawl fishery, Sci. Data 9 (2022), 51, https://doi.org/10.1038/s41597-022-01155-2.
[24] A. Lucchetti, V. Angelini, G. Furii, S. Pari, C. Vasapollo, M. Virgili, Evidence of loggerhead sea turtle (Caretta caretta, linnaeus, 1758) injuries caused by rapido (beam) trawling in the mediterranean, Herpetol. J. 28 (2018) 134–136.
[25] J. Pulcinella, S. Bonanomi, A. Colombelli, C.M. Fortuna, F. Moro, A. Lucchetti, A. Sala, Bycatch of Loggerhead Turtle (Caretta caretta) in the Italian Adriatic Midwater Pair Trawl Fishery, Front. Mar. Sci. 6 (2019) https://www.frontiersin.org/article/10.3389/fmars.2019.00365.
[26] Council of the European Communities, (CEC), Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, . J. Eur. Union 206 (1992) 7–50.
[27] P. Casale, A. Tucker, Caretta caretta (amended version of 2015 assessment), IUCN Red List Threat, Species e. T3897A11 (2017), https://doi.org/10.2305/IUCN.UK.2017-2.RLTS.T3897A119333622.en.
[28] A. Lucchetti, E. Punzo, C. Vasapollo, M. Virgili, Tartarughe marine e servizi ecosistemici: l'esperienza del progetto Tartalife, Biol. Mar. Mediterr. 24 (2017) 61–62.
[29] FAO, The State of Mediterranean and Black Sea Fisheries 2020, General Fisheries Commission for the Mediterranean, Rome, 2020, https://doi.org/10.4060/cb2429en.

[30] A. Petetta, M. Virgili, S. Guicciardi, A. Lucchetti, Pots as alternative and sustainable fishing gears in the Mediterranean Sea: an overview, Rev. Fish. Biol. Fish. 31 (2021) 773–795, https://doi.org/10.1007/s11160-021-09676-6.
[31] A. Lucchetti, A. Sala, An overview of loggerhead sea turtle (Caretta caretta) bycatch and technical mitigation measures in the Mediterranean Sea, Rev. Fish. Biol. Fish. 20 (2010) 141–161.
[32] K. Echwikhi, I. Jribi, M.N. Bradai, A. Bouain, Effect of type of bait on pelagic longline fishery-loggerhead turtle interactions in the gulf of gabes (Tunisia), Aquat. Conserv. Mar. Freshw. Ecosyst. 20 (2010) 525–530, https://doi.org/10.1002/aqc.1120.
[33] S. Piovano, S. Clò, C. Giacoma, Reducing longline bycatch: the larger the hook, the fewer the stingrays, Biol. Conserv. 143 (2010) 261–264, https://doi.org/10.1016/j.biocon.2009.10.001.
[34] A. Sala, A. Lucchetti, M. Affronte, Effects of Turtle Excluder Devices on bycatch and discard reduction in the demersal fisheries of Mediterranean Sea, Aquat. Living Resour. 24 (2011) 183–192, https://doi.org/10.1051/alr/2011109.
[35] S. Atabey, E. Taskavak, A preliminary study on the prawn trawls excluding sea turtles, J. Fish. Aquat. Sci. 18 (2001) 71–79.
[36] M. Virgili, C. Vasapollo, A. Lucchetti, Can ultraviolet illumination reduce sea turtle bycatch in Mediterranean set net fisheries? Fish. Res. 199 (2018) 1–7, https://doi.org/10.1016/j.fishres.2017.11.012.
[37] H.O. Fock, Natura 2000 and the European Common Fisheries Policy, Mar. Policy 35 (2011) 181–188, https://doi.org/10.1016/j.marpol.2010.09.003.
[38] European Regulation (EU) 1380/2013, Regulation on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC, Jour Eur. Union, L 354 (2013) 22–61.
[39] European Regulation (EU) 2008/56, Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive), . J. Eur. Communities. L 164 (2008) 136–157.
[40] European Commission, EU Biodiversity Strategy for 2030. Bringing nature back into our lives., (2020) 20.5.2020 COM(2020) 380.
[41] R. Prellezo, R. Curtin, Confronting the implementation of marine ecosystem-based management within the Common Fisheries Policy reform, Ocean Coast. Manag. 117 (2015) 43–51, https://doi.org/10.1016/j.ocecoaman.2015.03.005.
[42] D. Gascuel, M. Coll, C. Fox, S. Guénette, J. Guitton, A. Kenny, L. Knittweis, J. R. Nielsen, G. Piet, T. Raid, M. Travers-Trolet, S. Shephard, Fishing impact and environmental status in European seas: a diagnosis from stock assessments and ecosystem indicators, Fish Fish. 17 (2016) 31–55, https://doi.org/10.1111/faf.12090.
[43] G. Gallizioli, in: J. Urquhart, T.G. Acott, D. Symes, M. Zhao (Eds.), The Social Dimensions of the Common Fisheries Policy: A Review Of Current Measures BT - Social Issues in Sustainable Fisheries Management, Springer Netherlands, Dordrecht, 2014, pp. 65–78, https://doi.org/10.1007/978-94-007-7911-2_4.
[44] R. Galvin, Science Roadmaps, Science 280 (80) (1998) 803, https://doi.org/10.1126/science.280.5365.803a.
[45] H. Döscher, T. Reiss, Graphene Roadmap Briefs (No. 1): innovation interfaces of the Graphene Flagship, 2D Mater. 8 (2021) 22004, https://doi.org/10.1088/2053-1583/abddcc.
[46] K.N. Nielsen, M.M. Aschan, S. Agnarsson, M. Ballesteros, A. Baudron, M.D. F. Borges, A. Campos, R. Chapela, A.K. Daníelsdóttir, K. Erzini, Ó. Gregersen, P. Holm, A. Lucchetti, S. Margeirsson, H.V. Mendes, P. Olsen, M. Rangel, A. Sala, J. L. Santiago, S. Sigurðardóttir, C. Silva, D. Sykes, J.R. Viðarsson, M. Virgili, L. Wise, P.G. Fernandes, A framework for results-based management in fisheries, Fish Fish 19 (2018), https://doi.org/10.1111/faf.12257.
[47] S.J. Kennelly, The issue of bycatch in Australia's demersal trawl fisheries, Rev. Fish. Biol. Fish. 5 (1995) 213–234, https://doi.org/10.1007/BF00179757.
[48] S.J. Kennelly, M.K. Broadhurst, By-catch begone: changes in the philosophy of fishing technology, Fish Fish 3 (2002) 340–355, https://doi.org/10.1046/j.1467-2979.2002.00090.x.
[49] N.A. Steins, M.L. Kraan, K.J. van der Reijden, F.J. Quirijns, W. van Broekhoven, J. J. Poos, Integrating collaborative research in marine science: Recommendations from an evaluation of evolving science-industry partnerships in Dutch demersal fisheries, Fish Fish 21 (2020) 146–161, https://doi.org/10.1111/faf.12423.
[50] N. Wambiji, N.I. Kadagi, B.I. Everett, A.J. Temple, J.J. Kiszka, E. Kimani, P. Berggren, Integrating long-term citizen science data and contemporary artisanal fishery survey data to investigate recreational and small-scale shark fisheries in Kenya, Aquat. Conserv. Mar. Freshw. Ecosyst. 32 (2022) 1306–1322, https://doi.org/10.1002/aqc.3829.
[51] M.J. Armstrong, A.I.L. Payne, B. Deas, T.L. Catchpole, Involving stakeholders in the commissioning and implementation of fishery science projects: experiences from the U.K. Fisheries Science Partnershipa, J. Fish. Biol. 83 (2013) 974–996, https://doi.org/10.1111/jfb.12178.
[52] A.T.M. van Helmond, L.O. Mortensen, K.S. Plet-Hansen, C. Ulrich, C.L. Needle, D. Oesterwind, L. Kindt-Larsen, T. Catchpole, S. Mangi, C. Zimmermann, H. J. Olesen, N. Bailey, H. Bergsson, J. Dalskov, J. Elson, M. Hosken, L. Peterson, H. McElderry, J. Ruiz, J.P. Pierre, C. Dykstra, J.J. Poos, Electronic monitoring in fisheries: Lessons from global experiences and future opportunities, Fish Fish 21 (2020) 162–189, https://doi.org/10.1111/faf.12425.
[53] A. Lucchetti, C. Piccinetti, U. Meconi, C. Frittelloni, M. Marchesan, S. Palladino, M. Virgili, Transferable Fishing Concessions (TFC): A pilot study on the applicability in the Mediterranean Sea, Mar. Policy 44 (2014), https://doi.org/10.1016/j.marpol.2013.10.009.
[54] J.L. Santiago, M.A. Ballesteros, R. Chapela, C. Silva, K.N. Nielsen, M. Rangel, K. Erzini, L. Wise, A. Campos, M.F. Borges, A. Sala, M. Virgili, J.R. Vidarsson, A. Baudron, P.G. Fernandes, Is Europe ready for a results-based approach to fisheries management? The voice of stakeholders, Mar. Policy 56 (2015), https://doi.org/10.1016/j.marpol.2015.02.006.
[55] X. Basurto, S. Gelcich, E. Ostrom, The social–ecological system framework as a knowledge classificatory system for benthic small-scale fisheries, Glob. Environ. Chang. 23 (2013) 1366–1380, https://doi.org/10.1016/j.gloenvcha.2013.08.001.
[56] A. Muntadas, M. Lample, M. Demestre, J. Ballé-Béganton, S. de Juan, F. Maynou, D. Bailly, A knowledge platform to inform on the effects of trawling on benthic communities, Estuar. Coast. Shelf Sci. 201 (2018) 223–233, https://doi.org/10.1016/j.ecss.2017.01.001.
[57] K. Soma, J.R. Nielsen, N. Papadopoulou, H. Polet, M. Zengin, C.J. Smith, O. R. Eigaard, A. Sala, S. Bonanomi, S.W.K. van den Burg, G.J. Piet, E. Buisman, A. Gümüş, Stakeholder perceptions in fisheries management - sectors with benthic impacts, Mar. Policy 92 (2018) 73–85, https://doi.org/10.1016/j.marpol.2018.02.019.
[58] J.J. Kiszka, Bycatch assessment of vulnerable megafauna in coastal artisanal fisheries in the southwest Indian, Ocean, Final Rep. South West Indian Ocean Fish. Proj. (2012) 113, http://www.swiofp.net/publications/component-5-rapid-bycatch-assessment.pdf.
[59] R. Lewison, B. Wallace, J. Alfaro-Shigueto, J.C. Mangel, S.M. Maxwell, E.L. Hazen, Fisheries bycatch of marine turtles: lessons learned from decades of research and conservation, in: J. Wyneken, K.J. Lohmann, J.A. Musick (Eds.), Biol. Sea Turtles, Vol. 3, CRC Press, Boca Raton, FL, 2013, pp. 329–351.
[60] A. Lucchetti, C. Vasapollo, M. Virgili, An interview-based approach to assess sea turtle bycatch in Italian waters, PeerJ 2017 (2017), https://doi.org/10.7717/peerj.3151.
[61] V. Nguyen, S. Larocque, L. Stoot, N. Cairns, G. Blouin-Demers, S. Cooke, Perspectives of fishers on turtle bycatch and conservation strategies in a small-scale inland commercial fyke net fishery, Endanger. Species Res. 22 (2013) 11–22, https://www.int-res.com/abstracts/esr/v22/n1/p11-22/.
[62] F. Bentivegna, P. Breber, S. Hochscheid, Cold Stunned Loggerhead Turtles in the South Adriatic Sea, Mar. Turt. Newsl. 97 (2002) 1–3.
[63] P. Casale, M. Affronte, D. Scaravelli, B. Lazar, C. Vallini, P. Luschi, Foraging grounds, movement patterns and habitat connectivity of juvenile loggerhead turtles (Caretta caretta) tracked from the Adriatic Sea, Mar. Biol. 159 (2012) 1527–1535, https://doi.org/10.1007/s00227-012-1937-2.
[64] T. Mingozzi, G. Masciari, G. Paolillo, B. Pisani, M. Russo, A. Massolo, Discovery of a regular nesting area of loggerhead turtle Caretta caretta in southern Italy: a new perspective for national conservation, Biodivers. Conserv. 16 (2007) 3519–3541, https://doi.org/10.1007/s10531-006-9098-6.
[65] L. Garofalo, T. Mingozzi, A. Micò, A. Novelletto, Loggerhead turtle (Caretta caretta) matrilines in the Mediterranean: further evidence of genetic diversity and connectivity, Mar. Biol. 156 (2009) 2085–2095, https://doi.org/10.1007/s00227-009-1239-5.
[66] (GFCM) General Fisheries Commission for the Mediterranean, Establishment of Geographical Sub-Areas in the GFCM area amending the resolution GFCM/31/2007/2, (2009) RES-GFCM/33/2009/2.
[67] STECF, The 2021 Annual Economic Report on the EU Fishing Fleet (STECF 21–08), EUR 28359 EN, 2021. doi:10.2760/60996.
[68] N. Nielsen, P. Holm, M. Aschan, Results based management in fisheries: Delegating responsibility to resource users, Mar. Policy 51 (2015) 442–451, https://doi.org/10.1016/j.marpol.2014.10.007.
[69] J. Faugier, M. Sargeant, Sampling hard to reach populations, J. Adv. Nurs. 26 (1997) 790–797, https://doi.org/10.1046/j.1365-2648.1997.00371.x.
[70] K. Browne, Snowball sampling: using social networks to research non-heterosexual women, Int. J. Soc. Res. Methodol. 8 (2005) 47–60, https://doi.org/10.1080/1364557032000081663.
[71] European Regulation (EU) 2017/1004, Regulation (EU) 2017/1004 of the European Parliament and of the Council of 17 May 2017 on the establishment of a Union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common, . J. Eur. Communities. L 157 (2017) 1–21, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32017R1004.
[72] A. Lucchetti, C. Vasapollo, M. Virgili, An interview-based approach to assess sea turtle bycatch in Italian waters, PeerJ 5 (2017), e3151.
[73] R. Holst, A. Revill, A simple statistical method for catch comparison studies, Fish. Res. 95 (2009) 254–259, https://doi.org/10.1016/j.fishres.2008.09.027.
[74] M.B. Kursa, W.R. Rudnicki, Feature selection with the boruta package, J. Stat. Softw. 36 (2010) 1–13, https://doi.org/10.18637/jss.v036.i11.
[75] R.G. Dyson, Strategic development and SWOT analysis at the University of Warwick, Eur. J. Oper. Res. 152 (2004) 631–640.
[76] B.G. Dana, SWOT analysis to improve quality management production, Procedia-Soc. Behav. Sci. 62 (2012) 319–324.
[77] S. Holm, P. Hadjimichael, M. Linke, S, Mackinson, Collaborative research in fisheries: co-creating knowledge for fisheries governance in. Europe, Springer,, 2020.
[78] M. Dedual, O. Sague Pla, R. Arlinghaus, A. Clarke, K. Ferter, P. Geertz Hansen, D. Gerdeaux, F. Hames, S.J. Kennelly, A.R. Kleiven, A. Meraner, B. Ueberschär, Communication between scientists, fishery managers and recreational fishers: Lessons learned from a comparative analysis of international case studies, Fish. Manag. Ecol. 20 (2013) 234–246, https://doi.org/10.1111/fme.12001.
[79] S.R. Arnstein, A Ladder Of Citizen Participation, J. Am. Inst. Plan. 35 (1969) 216–224, https://doi.org/10.1080/01944366908977225.
[80] C.D. Maravelias, P. Vasilakopoulos, S. Kalogirou, Participatory management in a high value small-scale fishery in the mediterranean sea, ICES J. Mar. Sci. 75 (2018) 2097–2106, https://doi.org/10.1093/icesjms/fsy119.

[81] P. Casale, D. Margaritoulis, Sea turtles in the Mediterranean: distribution, threats and conservation priorities, IUCN/SSC, Gland, Switz. (2010).
[82] J. Ullmann, M. Stachowitsch, A critical review of the Mediterranean sea turtle rescue network: a web looking for a weaver, Nat. Conserv. 10 (2016) 45–69, https://doi.org/10.3897/natureconservation.10.4890.
[83] E.M. Finkbeiner, B.P. Wallace, J.E. Moore, R.L. Lewison, L.B. Crowder, A.J. Read, Cumulative estimates of sea turtle bycatch and mortality in USA fisheries between 1990 and 2007, Biol. Conserv. 144 (2011) 2719–2727, https://doi.org/10.1016/j.biocon.2011.07.033.
[84] P. Casale, Sea turtle by-catch in the Mediterranean, Fish Fish. (2011) 299–316, https://doi.org/10.1111/j.1467-2979.2010.00394.x.
[85] J. Sacchi, Overview of mitigation measures to reduce the incidental catch of vulnerable species in fisheries. Studies an, FAO,, Rome, 2021, https://doi.org/10.4060/cb5049en.
[86] D.V. Popov, G.D. Meshkova, P.D. Hristova, G.Z. Gradev, D.Z. Rusev, M. D. Panayotova, H.A. Dimitrov, Pingers as cetacean bycatch mitigation measure in bulgarian turbot fishery, Acta Zool. Bulg. (2020) 235–242.
[87] G. Buscaino, M. Ceraulo, G. Alonge, D.S. Pace, R. Grammauta, V. Maccarrone, A. Bonanno, S. Mazzola, E. Papale, Artisanal fishing, dolphins, and interactive pinger: A study from a passive acoustic perspective, Aquat. Conserv. Mar. Freshw. Ecosyst. 31 (2021) 2241–2256, https://doi.org/10.1002/aqc.3588.
[88] M. Hall, E. Gilman, H. Minami, T. Mituhasi, E. Carruthers, Mitigating bycatch in tuna fisheries, Rev. Fish. Biol. Fish. 27 (2017) 881–908, https://doi.org/10.1007/s11160-017-9478-x.
[89] E. Lindkvist, K.E. Pellowe, S.M. Alexander, E. Drury O′Neill, E.M. Finkbeiner, A. Girón-Nava, B. González-Mon, A.F. Johnson, J. Pittman, C. Schill, N. Wijermans, Ö. Bodin, S. Gelcich, M. Glaser, Untangling social–ecological interactions: a methods portfolio approach to tackling contemporary sustainability challenges in fisheries, Fish Fish. 23 (2022) 1202–1220, https://doi.org/10.1111/faf.12678.