Mediterranean Marine Science

Vol 24, No 3 (2023)

VOL 24, No 3 (2023)

Social-ecological features of set nets small-scale fisheries in the context of Mediterranean marine protected areas

ANTONIO CALÒ, ANTONIO DI FRANCO, CHARALAMPOS DIMITRIADIS, LEA PIACENTINI, PATRICIA VENTURA, ALEXIS PEY, JOSÉ ANTONIO GARCÍA-CHARTON, ERIC CHARBONNEL, VICTOR DECUGIS, FRANCESCO DE FRANCO, IVONI FOURNARI-KONSTANTINIDOU, JOSIPA GRBIN, LUKA KASTELIC, LORENZO MEROTTO, ILARIA RINAUDO, MARIE-CATHERINE SANTONI, FRANCISCO SOBRADO-LLOMPART, MARIA TRUJILLO-ALARCON, FEDERICO QUATTROCCHI, MARCO MILAZZO, PAOLO GUIDETTI

doi: [10.12681/mms.33079](https://doi.org/10.12681/mms.33079)

Research Article

Mediterranean Marine Science
Indexed in WoS (Web of Science, ISI Thomson) and SCOPUS
The journal is available on line at http://www.medit-mar-sc.net
www.hcmr.gr
DOI: http://doi.org/10.12681/mms.33079

Social-ecological features of set nets small-scale fisheries in the context of Mediterranean marine protected areas

Antonio CALÒ[1,2], Antonio Di FRANCO[2,3], Charalampos DIMITRIADIS[4], Lea PIACENTINI[5], Patricia VENTURA[1,6], Alexis PEY[6], José Antonio GARCÍA-CHARTON[7], Eric CHARBONNEL[8], Victor DECUGIS[9], Francesco de FRANCO[10], Ivoni FOURNARI-KONSTANTINIDOU[4], Josipa GRBIN[11], Luka KASTELIC[12], Lorenzo MEROTTO[13], Ilaria RINAUDO[14], Marie-Catherine SANTONI[15], Francisco SOBRADO-LLOMPART[16], Maria TRUJILLO-ALARCON[7], Federico QUATTROCCHI[1,2], Marco MILAZZO[1,2] and Paolo GUIDETTI[2,17]

[1] Department of Earth and Marine Sciences (DiSTeM), University of Palermo, Via Archirafi 20-22, 90123 Palermo, Italy
[2] NBFC, National Biodiversity Future Center, Palermo 90133, Italy
[3] Stazione Zoologica Anton Dohrn, Department of Integrative Marine Ecology (EMI), Sicily Marine Center, Lungomare Cristoforo Colombo, 4521, 90149, Palermo, Italy
[4] National Marine Park of Zakynthos, El. Venizelou 1, 29100, Zakynthos, Greece
[5] Laboratoire Stella Mare, Université de Corse Pascal Paoli/CNRS, France
[6] Thalassa – Marine Research & Environmental Awareness, 17 Rue Gutenberg, 06000, Nice, France
[7] Department of Ecology and Hydrology, University of Murcia, Campus de Espinardo, 30100 Murcia, Spain
[8] Côte Bleue Marine Park. Observatoire PMCB, plage du Rouet, 31 Av. J. Bart. BP. 42. 13620 Carry-le-Rouet, France
[9] APAM (Association for Fisheries & Maritime Activities), 09 Avenue de la fontaine, 83700 Saint-Raphaël, France
[10] Consorzio di Gestione AMP Torre Guaceto, Via Sant'Anna 6, 72012, Carovigno, Italy
[11] Nature Park Telašćica, 23281, Sali, Croatia
[12] Strunjan Landscape Park, Strunjan, 152 6320 Portorož, Slovenia
[13] Portofino Marine Protected Area, 16038 Genova, Italy
[14] Egadi Islands Marine Protected Area, Piazza Europa 3, Favignana, Italy
[15] Bouches de Bonifacio Nature Reserve, Office de l'Environnement de la Corse, 20169 Bonifacio, Corsica
[16] WWF-Spain, Gran Vía de San Francisco 8, 28005, Madrid, Spain
[17] Stazione Zoologica Anton Dohrn, Department of Integrative Marine Ecology (EMI), Genoa Marine Centre, 16126 Genoa, Italy

Corresponding author: Antonio Calò; antoniocalo.es@gmail.com
co-Corresponding author: Antonio Di Franco; antonio.difranco@szn.it

Contributing Editor: Stelios SOMARAKIS

Received: 19 January 2023; Accepted: 17 August 2023; Published online: 14 September 2023

Abstract

The small-scale fisheries (SSF) sector has attracted considerable attention over the last decade due to its major importance in sustaining the livelihoods of coastal communities worldwide, poverty alleviation, food security, social wealth and traditions. Despite this importance, quantitative and qualitative information on SSF is still largely lacking and when available, it tends to be scattered or very localized. SSF are also among the very few professional extractive activities generally allowed within Marine Protected Areas (MPAs), and are therefore expected to acquire further momentum in the near future in light of the projected increase of protected marine surface area due to international commitments. However, SSF associated with areas including MPAs may differ from those operating in unprotected contexts with regard to a range of socio-ecological aspects, thus potentially making management strategies currently in force unsuitable, and requiring the development of *ad hoc* local and regional policies. Here, we assessed the socio-ecological dimension of SSF operating within and around 11 Mediterranean MPAs, in six EU countries, with the aim of identifying relevant patterns that could inform policy and management relative to this fishing sector in view of the forthcoming increase of the marine surface area under protection. To do so, we have adopted a collaborative approach with fishers and combined a photo-sampling survey of 1,292 set net (mainly trammel-nets) fishing operations at landing with 149 semi-structured interviews with fishers, to gather information on features and catches of SSF fleets (e.g. vessel characteristics, gears, catch composition, catch and revenue per unit of effort). Overall, results highlighted: 1) multiple shared features emerging at regional level (i.e. among the 11 study areas), such as the predominant use of set nets, the major contribution of a limited number of species to the overall catch and revenue, the occurrence in the catch of threatened species and/or undersized individuals; 2) a variety of distinctive socio-ecological features differentiating local SSF communities such as the species mainly contributing to catch and revenue, species size distribution and fleet characteristics. In addition to presenting elements to inform common policies and strategies for SSF management in the context of MPAs, our study provides guidance for the development of a standard methodology for the full documentation of SSF in the Mediterranean Sea.

Keywords: catch composition; ex-vessel price; fishing gears; fleet characteristics; small-scale fisheries; Mediterranean; photo-sampling; fully documented fisheries.

Introduction

The United Nations General Assembly declared 2022 the International Year of Artisanal Fisheries and Aquaculture (IYAFA 2022), underlining the crucial contribution of small-scale fisheries (SSF) to human well-being, food security, and environment and biodiversity protection. SSF employ about 90% of the world's fishers, account for more than 25% of global catches, and play a key role in sustaining poverty alleviation, social wealth and the cultural heritage of coastal communities (Jentoft *et al.,* 2017). For this reason, the proper management of this sector is acknowledged as a major priority for marine scientists, practitioners and policy makers (Smith & Basurto 2019; Pauly & Zeller, 2016; Kittinger *et al.*, 2013; Chuenpagdee & Jentoft, 2016; Teh *et al.*, 2011).

The importance of SSF management acquires further relevance in the light of the projected increase in protected marine surface area to meet the international 30% target of protected oceans from the Convention of Biological Diversity by 2030 (i.e. 30×30), mainly through the establishment of new multiple-use marine protected areas (MPAs). In this perspective, SSF will likely play a key role, as they are among the very few extractive human uses allowed in MPAs owing to their ability to sustain the livelihoods and economy of local communities potentially without jeopardizing the ecological benefits provided by area-based conservation measures (Zupan *et al.*, 2018, Grorud-Colvert *et al.*, 2021). Achieving SSF socio-ecological sustainability, however, requires effective and evidence-based management that can be attained only through a deep and widespread knowledge of this sector under protected and unprotected conditions (Di Franco *et al.*, 2016). This is especially important considering the increasing competition for space and resources SSF are facing from other sources of extractive (e.g. recreational fisheries) and non-extractive (e.g. tourism) human activities (Lloret *et al.*, 2018, Gómez *et al.*, 2021), and that is contributing, among other factors, to the general decline of the small-scale sector (Gómez *et al.*, 2006; Lloret *et al.*, 2018).

In this context, the FAO 'Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication', and their adoption by member states, represented international acknowledgment of the urgent need to overcome current issues related to SSF worldwide, by targeting key aspects for the sustainable development of the sector (FAO, 2015; Jentoft *et al.*, 2017; Chuenpagdee *et al.*, 2019). Despite SSF being generally acknowledged as potentially less impacting on coastal ecosystems and more socially equitable for fishery communities compared to large-scale fisheries, until very recently they have been relegated to a more marginal status and a lower priority on national and global fisheries agendas (Smith & Basurto, 2019; Jacquet & Pauly, 2008). One specific element stressed in the guidelines is the urgent need to fill the current information and data gap on the characteristics of SSF (Pauly & Charles, 2015; Pita *et al.*, 2019), that are crucial to inform sound policies and management strategies (Chuenpagdee & Jentoft, 2016). This data gap derives from factors both intrinsic and extrinsic to the SSF sector. On one hand, the inherent nature of SSF, which are extremely heterogeneous from an ecological and social-economic perspective and with communities often geographically isolated or socially difficult to access, hinders the development and application of long-term and spatially consistent monitoring approaches (Guyader *et al.,* 2013; Outeiro *et al.*, 2018; Pita *et al.*, 2019). On the other hand, the secondary role that SSF have played compared to large scale fisheries, both in scientific and policy agendas (Cohen *et al.*, 2019; Smith & Basurto 2019), along with the insufficient effort and scanty investments devoted to monitoring SSF, raise additional concerns (Pauly, 1997; Smith & Basurto, 2019; Teh *et al.*, 2011). Unsurprisingly, a commonly accepted definition of SSF is still lacking, often varying depending on the region or the country considered (Teh & Pauly, 2018; Halim *et al.*, 2019; Smith & Basurto, 2019). Although data collection on SSF has improved worldwide in recent years, e.g. by broadening data gathering to include social aspects (FAO, 2018; STECF, 2021) and by creating global research networks (e.g. Too Big To Ignore, 2017), a common effective framework that would allow the transition from local to regional or global assessments of SSF is still a long way from being developed, thus hindering effective SSF management (Chuenpagdee *et al.,* 2019; Gill *et al.*, 2019). Most of the time, accurate assessments of SSF are a prerogative of specific studies, generally sparse, sporadic or intermittent, and mostly referring to single local communities or small geographical areas (Maynou *et al.*, 2011; Battaglia *et al.*, 2010; Leleu *et al.*, 2014; Lloret *et al.*, 2018, Bousquet *et al.*, 2022). In the few cases in which common protocols for SSF monitoring do exist, such as the EU's Data Collection Framework (DCF) for fisheries, they are mostly based on declarative data from fishers (STECF, 2021). These statistics, usually self-reported through logbooks or self-declarations, have a degree of reliability that can vary widely depending on fishers' willingness to collaborate and support SSF monitoring and management (Basurto *et al.*, 2017; STECF, 2021). Assessment methodologies based on the direct collection of catch data by operators at landings have been generally limited to a few areas, based on a relatively small number of fishing days monitored and aggregating data at the scale of geographical sub-areas, due to the overall effort needed and to the usually limited engagement of fishers, often impeding the systematic and reliable characterization of the fisheries (Stoll *et al.*, 2023; STECF, 2021). From this perspective, there is an urgent need to develop and extensively implement accounting systems for SSF able to provide comprehensive, widespread and complete information on SSF catches, with the aim of fully documenting this fishery sector, as required for example by the reformed Common Fishery Policy (CFP) of the EU (Mangi *et al.,* 2015).

Furthermore, in the Mediterranean Sea, SSF have long been overlooked, despite their crucial role in relation to coastal social-ecological systems (Coll *et al.,* 2012; Tsikliras *et al.,* 2015). Only in recent years considerable attention has been focused on this sector thanks to a series of initiatives aimed at improving knowledge on SSF in order to achieve meaningful goals. For example, the 'Regional Plan of Action for SSF in the Mediterranean and the Black Sea' (RPOA-SSF), by the General Fishery Commission for the Mediterranean (GFCM), was designed to increase knowledge and understanding of SSF by improving and fostering data collection on a set of socio-ecological aspects. These recent efforts, however, have rarely, if ever, targeted the SSF associated with MPAs that may differ from those operating in unprotected contexts in terms of a wide range of socio-ecological aspects, thus requiring specific assessments capable of providing a basis for sound management and policy strategies in the forthcoming years.

In this study, we assessed the socio-ecological features of SSF operating in the context of 11 Mediterranean MPAs (i.e. operating within and around the MPAs), in 6 EU countries, in order to identify patterns that could inform sustainable management and policy for this sector in view of the upcoming implementation of new spatial conservation measures (mainly MPAs) in European waters. Specifically, by adopting an interdisciplinary approach, combining photo-sampling of catches at landings with questionnaires administered to fishers, we aimed to a) identify common aspects emerging at regional level (i.e. over the spatial domain considered), and b) reveal local heterogeneities (i.e. among areas) in relation to a set of social-ecological features of SSF fleets and communities (e.g. vessel characteristics, types of gear employed, catch composition, catch per unit of effort, revenue per unit of effort). Besides presenting novel elements related to SSF in the Mediterranean Sea, our study provides useful insights for the development of a standard methodology for the full documentation of Mediterranean SSF.

Materials and Methods

Study area

The study was carried out between June 2017 and October 2018 and encompassed 11 areas, distributed in the Mediterranean waters of 6 EU countries, partially including or in proximity to 11 Marine Protected Areas (MPAs, *sensu lato*, including areas established under different designations), and where one or multiple SSF communities operate: South Corsica, Cap Roux, Côte Bleue (France), Portofino promontory, Egadi Archipelago and southern Trapani coast, northern Brindisi coast (Italy), Straits of Ibiza and Formentera, Cabo de Palos and adjacent Murcia coast (Spain), Dugi-Otok island (Croatia), Strunjan (Slovenia) and Zakynthos island (Greece) (Fig. 1). The sampling process was embedded within the framework of a larger collaborative project where small-scale fishers, MPA management bodies and researchers agreed to collaborate with the goal of improving SSF management in the context of Mediterranean MPAs (see Di Franco *et al.*, 2020, for further details). Fishers interested in taking part in SSF monitoring were instructed on the specifics of the data to be collected and the monitoring protocols, with the aim of ensuring the reliability of the sampling process. In addition, *in situ* MPA management bodies were appointed as local data collection centers (i.e. staff members from each MPA were in charge of administering the questionnaires and collecting the photo-samples of the fishing operations, see below, that were then transferred to researchers for the analyses), benefiting from their widespread coverage of the territory and their long-standing relationship with local SSF communities. This allowed a capillary and continuous sampling effort over the study period in all areas.

Fishing fleet and gear characterization

Here we refer to SSF as fishing operated by relatively small vessels, <12 meters total length, (''length overall'', LOA), and not using towed gear, as formally defined by the European Maritime and Fisheries Fund (EU 2014). Typically, most SSF operate within the first three nautical miles (ca. 5.5 km) from the coast (Coppola, 2006; Guyader *et al.*, 2013) and within a limited distance of operation from their home harbor, using low-power engines and operated by a single fisher (usually the owner) or a few fishers (frequently family members) (Di Franco *et al.*, 2014). SSF communities in each area were characterized using a questionnaire administered to fishers by trained operators in summer 2017. The questionnaire was designed to gather information on the features of SSF fleets operating in each area, specifically focusing on: the number of boats owned by fishers, their LOA and engine power. Fishers were also asked about the gears used, distinguishing the following categories: set nets (i.e. trammel nets and gillnets), bottom longlines, pelagic longlines, multi-species traps, traps for lobsters, traps for cephalopods and 'other gears'. Additional complementary information was obtained in 2018 by asking fishers to provide an estimate of their overall fishing effort over the year, indicating the approximate number of annual fishing days. Regarding this aspect, fishers from South Corsica elected not to respond to this specific question, as they were involved in too many projects and suffering from interviewer fa-

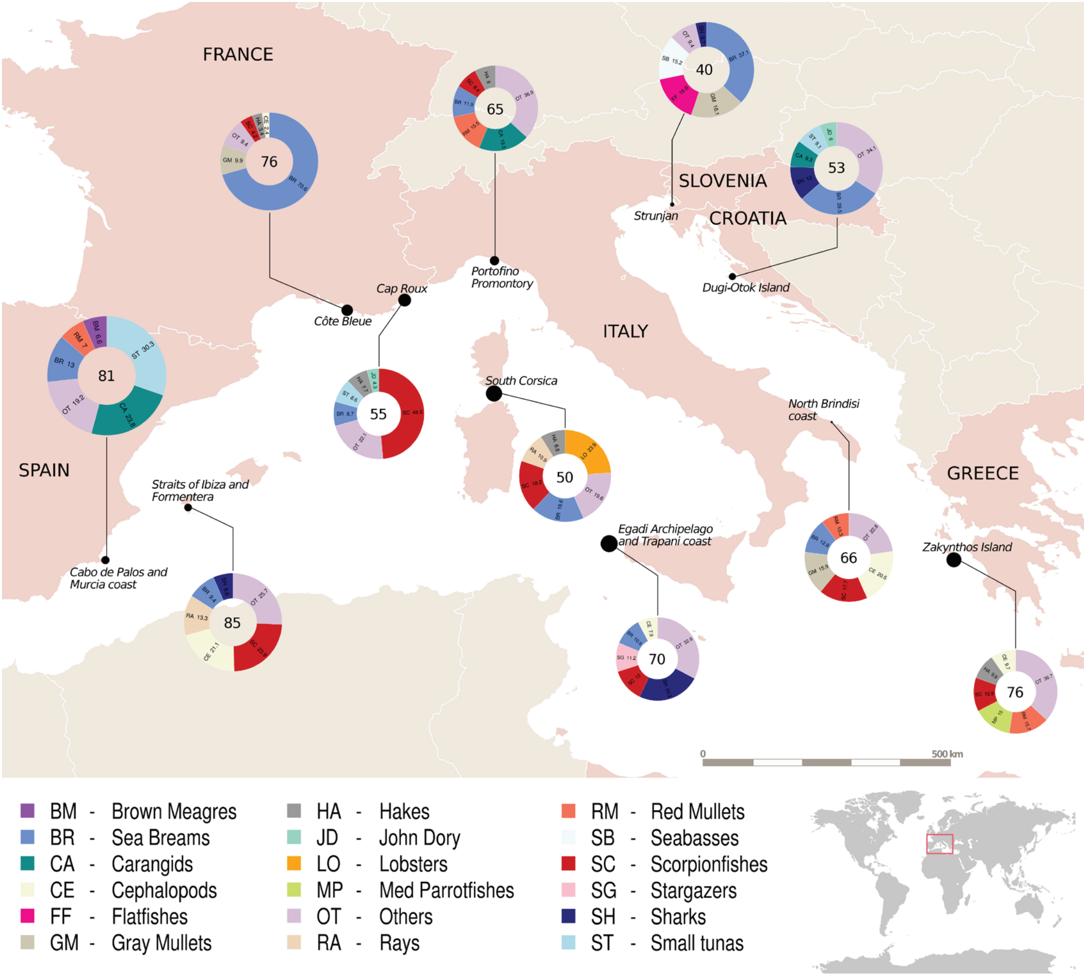

Fig. 1: Study areas. Donut-plots represent, for each area, the proportion of mean catch per unit of effort (CPUE) of the 5 most fished groups (all other groups are included in 'Others', refer to Table S2), the radius of each plot is proportional to the mean total CPUE recorded for that area. The total number of species recorded in each area is indicated within each donut plot. The size of the black dots, indicating the position of the study areas, is proportional to the total number of small-scale fishers operating in each area.

tigue. Therefore, in this area, the Environmental Office of Corsica directly provided the information on the average number of fishing days recorded in the context of another project (DACOR project). Since the total number of fishers is variable among areas (Table S1, Supplementary Material), we aimed at sampling a minimum of 30% of fishers in each area and increased the percent sampled as the size of the SSF community decreased. Finally, we were able to interview between 5 and 21 fishers in each area, with a percentage of interviewees relative to the total number of fishers in the community ranging from 34% (South Corsica) to 100% (North Brindisi coast). The total sample (considering all SSF communities together) accounted for about 60% of all fishers operating in the study areas. Respondents were mostly targeted through purposive, opportunistic and snowball sampling (Bryman, 2012).

Catch composition

The assessment of fishing operations was done on a subsample of the fishers interviewed in each area. In order to obtain the most comprehensive dataset possible, and considering that different fishers may have different fishing habits, we monitored fishing operations from all fishers willing to take part in the assessment (ranging from 5 for North Brindisi coast to 12 for South Corsica). In a few cases, the relatively small size of the SSF communities and prolonged adverse meteorological conditions, especially in the winter season, contributed to a reduced number of fishing operations assessed compared to the majority of the areas. Fishing operation assessment was restricted to set nets only (i.e. trammel nets, gillnets and combined trammel-gillnets). There were various reasons for this choice: in the sector of the Mediterranean Sea considered, set nets are the most commonly used fishing gear (Grati *et al.*, 2022, but see also the Results of this study); moreover, although potential differences in the type of nets may exist, focusing on a single category of gears allows for a reliable comparison of fishery descriptors (e.g. catch per unit of effort, CPUE, and revenue per unit of effort, RPUE) between areas and fishing grounds. In order to obtain detailed and verifiable data on SSF catches, we used a photo-sampling technique for catches at landing (see Calò *et al.*, 2022; Di Lorenzo *et al.*, 2022 for additional details). This approach also minimized sampling time in the field, fish manipulation, and caused fishers the least disturbance possible during monitoring operations. More specifically, at the port, the operator waited for the fisher to return from the fishing trip, and scheduled the monitoring in advance in order to avoid any fish being sold before the monitoring. Additionally, fishers were requested to land the entire catch, without throwing overboard any specimen fished, with the aim of ensuring reliable full documentation of set net fisheries in the areas. The operator spread out the catch over a flat horizontal surface (e.g. a table or by directly arranging the fishes in the fish box to minimize manipulation), and took one or more (for the largest catches) pictures of the entire catch, along with a ruler (as length reference) placed within the same frame (Fig. S1 Supplementary Material). Each picture was associated with a unique identifier of the fishing operation (e.g. a small paper tag with a unique reference code) for the subsequent image analysis (Fig. S1). For all the fishing operations monitored, the type of set net used and the net length were also recorded, thus enabling the calculation of catch and revenue per unit of effort (CPUE and RPUE, respectively). An operator using the image-analysis free software ImageJ (Abràmoff *et al.,* 2004) then processed the images. From each picture, we extracted information on species composition and frequency of occurrence in the catches. Individual specimens were identified to the lowest possible taxonomic level (usually species).

Size, Biomass and CPUE estimation

We measured the total length of each individual to the nearest 1 mm using the ruler in the picture as a reference for calibrating the measurement tool in ImageJ, and estimated the biomass (i.e. wet weight) of each specimen using specific length-weight relationships (LWR) available from www.fishbase.org (Froese & Pauly, 2019). For crustaceans and cephalopods (mollusks), respectively, carapace length and mantle length was measured, using length-weight information from www.sealifebase.ca (Palomares & Pauly, 2022) to estimate the biomass. We selected LWR parameters referred to Mediterranean samples. The accuracy of the photo-sampling method was tested in one of the study areas (Zakynthos island) by comparing the length of individuals measured directly at landing using a fish-measuring device with those assessed through ImageJ. Results showed that the deviation between individuals' length measured in the field and lab-estimated length from pictures was negligible (0.68% ± 0.72, mean ± se) (see Supplementary Material for details). Whenever one or more specimens were not completely visible from pictures, the fishing operation was not retained for further analyses (36 out of 1,292 cases, i.e. 2.8% of all fishing operations). The biomass of each species and the total biomass of each fishing operation were used to estimate the catch per unit of effort (CPUE, measured as kg/1000 m of net), standardizing for the length of the net.

$$CPUE = \frac{biomass\ of\ the\ fishing\ operation}{length\ of\ the\ net\ used}$$

where

$$biomass\ of\ the\ fishing\ operation = \sum_{k=1}^{n} \quad (biomass)_k$$

with n the total number of species (k) occurring in the fishing operation

Ex-vessel price and RPUE estimation

We built an ex-vessel price (i.e. the price that fishers receive directly for their catch, Tai *et al.,* 2017) database for each species appearing in the catches. To do so, during summer 2018, in each area a group of fishers was asked about the yearly average price per kilogram they charge to sell their fish. These values were successively used to estimate the revenue per unit of effort (RPUE, measured as euros/1000 m of net) for each fishing operation and for each species within it, by combining prices with the biomass of each species in the catch:

$$RPUE = \frac{revenue\ of\ the\ fishing\ operation}{length\ of\ the\ net\ used}$$

where

$$revenue\ of\ the\ fishing\ operation = \sum_{k=1}^{n}$$

$$(biomass * ex.vesselprice)_k$$

with n the total number of species (k) occurring in the fishing operation

We therefore refer to 'revenue' as the landed value of the catch (i.e. the total amount of money a fisher gains by selling the catch without considering any fixed cost or expense incurred by fishers) in accordance with Sala *et al.,* (2018).

Data analyses

The main characteristics of the fishing fleets were investigated through descriptive statistics.

Species richness (measured as total number of species in the catch) and the frequency of occurrence (i.e. the number of fishing operations in which a species occurred at least once divided by the total number of fishing operations monitored) were used to characterize the composition of catches in each area. The species occurrence over the monitoring period was assessed by pooling fishing operations by season and by month. A specific assessment concerned the presence of species considered at risk of extinction in the Mediterranean Sea with the aim of providing preliminary insights on the potential impacts set nets may have on these species. For this, following the criteria defined in Lloret *et al.* (2019), we identified the species in the catches that are considered as threatened, therefore falling within 'Critically Endangered' (CR), 'Endangered' (EN) or 'Vulnerable' (VU) categories (as listed in the IUCN Red List), or vulnerable to fishing (using a vulnerability index based on life history traits and ecological characteristics of a marine fish, Cheung *et al.,* 2007). Moreover, we checked for the presence of non-indigenous species for the Mediterranean Sea according to the Marine Mediterranean Invasive Alien Species (MAMIAS) database (UNEP & RAC/SPA, 2019).

Differences in size distribution between areas were graphically inspected through boxplots for the most relevant species in terms of contribution to total biomass caught (see Results). For the species with minimum conservation reference size (MCRS, EU 2008), we estimated the fraction of specimens below this size. In addition, we investigated the potential effect of the gears used on the frequency of occurrence of undersized individuals for these species. To do so, we implemented a generalized linear model on the ratio ''number of undersized individuals/total number of individuals'', including the mesh size as covariate and the species as fixed categorical factor, thus taking into account also the interaction term Mesh size × species. This analysis was restricted to 5 species (*Diplodus vulgaris, D. annularis, D. sargus, Pagellus acarne* and *Palinurus elephas*), being those for which a number of individuals high enough to run robust analyses was recorded (see Results).

Total biomass of each species and mean biomass per area were computed to identify the species contributing the most to the catches of each area. Due to the large number of species identified and to improve CPUE description and visualization, all species identified during photo-analysis were also lumped into categories (see Table S3) based on the main taxonomic groups.

Fish ex-vessel prices were assessed to identify the most valuable species per unit of biomass. Mean RPUEs values per species and per area were analyzed in order to assess which species contributed the most to fishers' revenues locally (i.e. in each area) and at the regional level (i.e. over the spatial domain considered).

All statistical analyses were performed using R 3.6.3 (R Core Team 2020).

Results

Fleet characterization

In total, 149 fishers were interviewed to characterize the fishing fleet in the study area (Table S1). The majority of interviewed fishers (85%) owned a single boat while the rest owned two (12%) or more boats (up to 4 boats, 3%). Mean boat LOA was 7.9 ± 0.2m (mean ± se), 13% belonging to the size class <6m and 87% to the class 6-12m and with a mean per study area comprised between 5.8 ± 0.4m (at Strunjan) and 9.4 ± 0.4m (at Zakynthos island, Table 1). Overall, fishers used from one to six categories of gears (Fig. S2). Set nets were the only gear category used in all areas (Fig. 2), and by far the gear most widely used by small scale fishers, with almost 92% of the fishers interviewed using these nets, and were also always the most widely used gear in the case of fishers using multiple gear categories (Fig. 2 and Fig. S2). Fishers declared that they went fishing on a variable number of days in the different areas, ranging between 120 ± 18 days (in South Corsica) and 275 ± 12 days (around Zakynthos island) (Table 1).

Catch composition

A total of 1,292 fishing operations in the 11 areas were assessed (ranging from 37 at Dugi-Otok island to 169 at Straits of Ibiza and Formentera) (Table S1). Out of all fishing operations monitored, about 95% deployed trammel nets, 4% gillnets and 1% combined trammel-gillnets. Fishing operations were unevenly distributed among seasons, with a lower number of fishing operations assessed in winter (9.6% of all fishing operations), and higher and comparable numbers in the other seasons (Table S2). In all, we identified 33,439 individuals in the catches (in-

Table 1. Small scale fishing fleet characteristics in each area.

Location	Mean boat length (m) (Mean ± SE)	Mean Engine power (CV) (Mean ± SE)	Mean number of gear categories used (Mean ± SE)	Number of annual fishing days (Mean ± SE)
South Corsica (SCO)	8.3 ± 0.5	157 ± 27	3.9 ± 0.4	120 ± 18
Cabo de Palos & Murcia coast (CPM)	8.2 ± 0.5	114 ± 29	3.1 ± 0.3	239 ± 12
Cap Roux (CRO)	7.2 ± 0.3	80 ± 11	2.8 ± 0.2	198 ± 12
Cote Bleue (CBL)	8.8 ± 0.7	107 ± 22	2.2 ± 0.3	213 ± 13
Egadi archipelago & Trapani coast (EAT)	7.6 ± 0.2	22 ± 1	2.7 ± 0.3	217 ± 16
Straits of Ibiza and Formentera (SIF)	8.6 ± 0.3	119 ± 15	3.9 ± 0.3	198 ± 8
Portofino promontory (POR)	7.4 ± 0.2	66 ± 9	2.1 ± 0.3	193 ± 29
Strunjan (STR)	5.8 ± 0.4	33 ± 14	1.2 ± 0.1	204 ± 23
Dugi-Otok island (DOI)	7.1 ± 0.8	47 ± 9	1.1 ± 0.1	274 ± 16
North Brindisi coast (NBC)	6.2 ± 0.4	40 ± 5	1.4 ± 0.4	209 ± 18
Zakynthos island (ZAI)	9.4 ± 0.4	67 ± 9	3.7 ± 0.1	275 ± 12

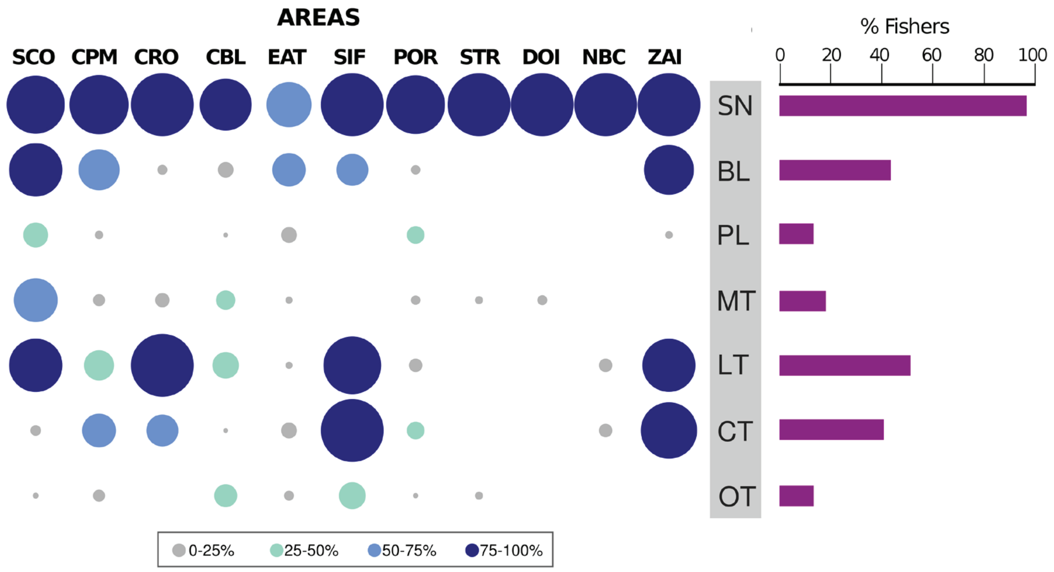

Fig. 2: Proportion of fishers using different categories of fishing gears in each area (SN=Set Nets, BL=Bottom Longlines, PL=Pelagic Longlines, MT=Multispecies traps, LT=Lobster Traps, CT=Cephalopods traps, OT=Other gears). Dot radius is proportional to the number of interviewed fishers using that relative gear in each area (refer to Table 1 for area names). The barplot on the right shows the total percentage of fishers using each category of gear.

cluding cartilaginous and bony fishes, crustaceans and mollusks). The total number of taxa caught was 142, encompassing 106 taxa of bony fishes (specifically, 105 identified at species level plus the family of Mugilidae), 24 species of cartilaginous fishes, 8 species of crustaceans and 4 species of mollusks (Table S3). Note that, from now on, in order to avoid confusion with the terminology, we also use the term 'species' when referring to a group of species including the family Mugilidae.

Out of the 142 species identified, 98.5% appeared at least once in trammel net catches; 38.2% appeared at least once in gillnets; 11% appeared at least once in combined trammel-gillnets. Regarding the uniqueness, only 2 species appeared in gillnets, but not on trammel-nets. In all other cases, species caught with gillnets (52 in total) were also observed in trammel-nets.

Concerning the species associated with a risk of extinction in the Mediterranean Sea, around 12% of all species identified (17) are considered threatened by the IUCN, i.e. belonging to the 'Critically Endangered' (CR), 'Endangered' (EN) or 'Vulnerable' (VU) groups (Table S3). Specifically, 2 species are listed as CR (the rays *Dipturus batis* and *Leucoraja fullonica*), 4 species are listed as EN (the dusky grouper *Epinephelus marginatus* and the cartilaginous fishes *Rhinobatos rhinobatos, Rostroraja alba* and *Raja radula*), and 11 as VU (these including the Common Spiny lobster *Palinurus elephas*). Some of these species sporadically occurred in the catches with very low abundances, as in the case of the two CR species (2 individuals caught for both species) and the EN *R. rhinobatos* (1 individual) (Table S4). In contrast, other species such as the EN rays *R. alba* and *R. radula* were caught with higher frequencies of occurrence, reaching in some cases almost 25% of occurrence in the catches locally [e.g. Straits of Ibiza and Formentera (Table S4)]. Overall, 'vulnerable' bony fishes appeared in almost all areas with similar frequency of occurrence, while shark and ray species belonging to the same risk category predominantly occurred only in specific areas (Table S4).

Evident differences among areas were also observed in the case of non-indigenous species for the Mediterranean Sea, i.e. the rabbit fishes (*Siganus luridus* and *S.rivulatus*) and the silver-cheeked toadfish (*Lagocephalus sceleratus*). These three species were in fact caught exclusively around Zakynthos Island.

The total number of species caught per area ranged between 40 at Strunjan and 85 at Straits of Ibiza and Formentera (Fig. S3), with a mean of 65.2 ± 4.3 species per area (mean ± se). Concerning the variation in the number of species over the year, overall higher numbers of species were caught in spring (111) and summer (121), while lower numbers were caught in autumn (97) and winter (82).

The most frequent species was the red scorpionfish *Scorpaena scrofa* (present in 45.6% of the catches), followed by the brown scorpionfish *S. porcus* (32.0%), the striped red mullet *Mullus surmuletus* (30.4%), the cuttlefish *Sepia officinalis* (26.5%) and the common pandora *Pagellus erythrinus* (23.7%) (Fig. S4). At the local level, a diversified pattern was observed with the most frequent species varying among areas (Table S5), but with *S. scrofa* being the most frequent species in 5 out of 11 areas. Considering species frequency of occurrence over the year, some species showed a relative stability over the twelve-month period, (e.g. *P. erythrinus* ranged between 11% in October and 33% in August, Fig. 3), while other species showed wider fluctuations (e.g. the cuttlefish *S. officinalis* ranged from 6% of occurrence in October to 61% in March and *Sparus aurata* ranged from 4% in August to 51% in October, Fig. 3). The species *S. scrofa*, *M. surmuletus*, *P. erythrinus*, *D. vulgaris* and *S. porcus* had a frequency of occurrence >10% for all the months of the year (Fig. 3).

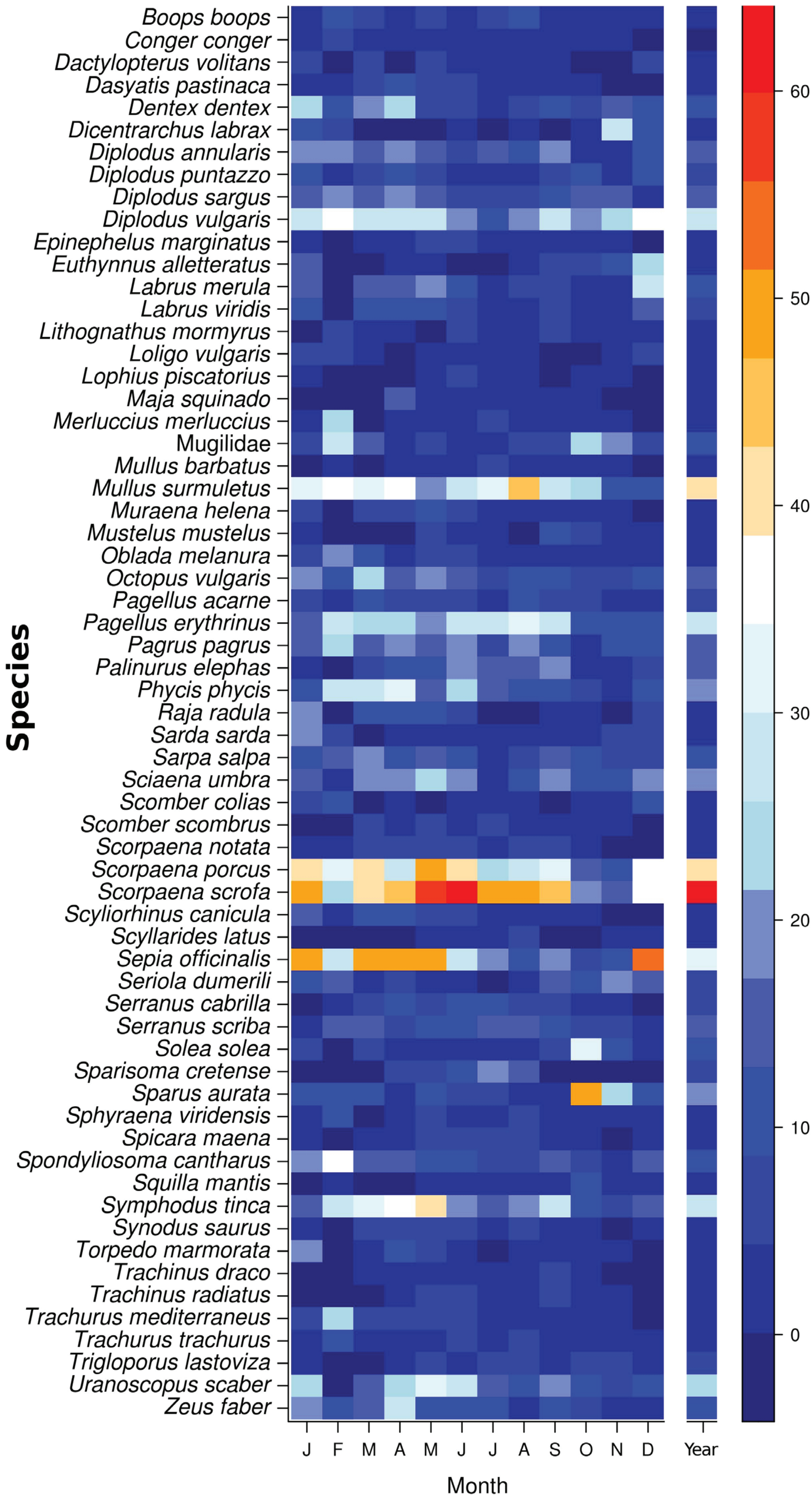

Fig. 3: Species frequency of occurrence in set net catches (for the species present in at least 1% of all fishing operations) per month and over the year. The colored scale on the right represents the relative frequency of occurrence, i.e. the number of fishing operations in which a species occurs divided by the total number of fishing operations carried out in a specific period (i.e. each month or the entire year).

Size, Biomass and CPUE

The size distribution of the 12 most abundant species differed among areas (Fig. S5). Although differences between areas showed an inconsistent pattern among species, some areas (e.g. Dugi-Otok island and Portofino promontory) were generally associated with smaller fish sizes at landing, while others (e.g. South Corsica) were generally associated with larger sizes (Fig. S5). Out of the 28 species with MCRS, only 7 (*Dicentrarchus labrax, Merluccius merluccius,* Mugilidae, *Mullus barbatus, Sardina pilchardus, Scomber japonicus* and *Trachurus mediterraneus*) were always fished above their MCRS, while for all other species, undersized individuals were observed with variable frequency of occurrence (Table 2). Six species had a limited proportion of undersized individuals (<2%), while groupers were fished systematically at a size below MCRS (from 67.5% to 100% of undersized individuals depending on the species). A high proportion of undersized individuals was also found for *P. acarne* (51.2%) and *P. bogaraveo* (100%, although this species was only caught 3 times). Furthermore, seabream were frequently fished under their MCRS: *D. vulgaris* (35.6%), *D. annularis* (29.7%), *D. sargus* (28.5%). Almost half (46.4%) of all European spiny lobsters (*P. elephas*) fished were below the relative MCRS (Table 2). A negative relationship between mesh size and the percentage of undersized individuals (i.e. in relation to the total number of conspecific individuals in the same catch) was observed for the four fish species considered (Table S6). That is, the percentage of undersized individuals decreased with increasing mesh size, with a variable coefficient depending on the species (Fig. S6). Only in the case of *P. elephas* was the relationship null, with a rather constant rate of undersized individuals regardless of the mesh size (Fig. S6), generating the significant interaction

Table 2. Species with Minimum Conservation Reference Size (MCRS, EU 2008) among those recorded in our study. Absolute and relative number of undersized individuals observed in the study, total number of individuals measured and overall mean ± se per each species. Species are ranked from the highest percentage of undersized individuals to the lowest.

Species	MCRS (cm)	Number of undersized individuals	% of undersized individuals	Number of individuals measured	Mean size ± SE (cm)
Epinephelus caninus	45	1	100	1	43.01 ± NA
Pagellus bogaraveo	33	3	100	3	18.08 ± 2.71
Epinephelus costae	45	8	80	10	29.54 ± 2.16
Epinephelus marginatus	45	27	67.5	40	43.58 ± 2.69
Pagellus acarne	17	215	51.19	420	17.24 ± 0.13
Palinurus elephas	9	186	46.38	401	9.39 ± 0.11
Diplodus vulgaris	18	351	35.56	987	19.82 ± 0.14
Diplodus annularis	12	169	29.7	569	13.29 ± 0.1
Diplodus sargus	23	140	28.51	491	25.27 ± 0.2
Lithognathus mormyrus	20	18	26.47	68	23.97 ± 0.66
Pagrus pagrus	18	58	19.4	299	23.76 ± 0.4
Diplodus puntazzo	18	14	13.46	104	24.06 ± 0.56
Pagellus erythrinus	15	108	12.2	885	21.64 ± 0.2
Scomber colias	18	6	6.59	91	34.5 ± 0.85
Euthynnus alletteratus	30	12	4.07	295	41.72 ± 0.39
Sarda sarda	25	2	1.92	104	48.4 ± 0.79
Sparus aurata	20	79	1.85	4265	26.48 ± 0.06
Trachurus trachurus	15	2	1.54	130	25.11 ± 0.44
Scomber scombrus	18	1	0.66	152	28.75 ± 0.33
Mullus surmuletus	11	15	0.3	4966	19.26 ± 0.05
Solea solea	20	1	0.18	562	29.29 ± 0.17
Dicentrarchus labrax	25	0	0	178	37.76 ± 0.4
Merluccius merluccius	20	0	0	573	33.54 ± 0.27
Mugilidae	20	0	0	496	40.15 ± 0.28
Mullus barbatus	11	0	0	169	18.43 ± 0.21
Sardina pilchardus	11	0	0	1	17.99 ± NA
Scomber japonicus	18	0	0	24	30.38 ± 0.96
Trachurus mediterraneus	15	0	0	260	26.48 ± 0.27

between mesh size and species.

The total biomass estimated during the study accounted for 10,154 kg. In contrast to the frequency of occurrence, the most fished species in terms of biomass was *S. aurata* with a total biomass caught of 1,226 kg over the monitoring period, followed by *S. scrofa* (1,046 kg) and *S. officinalis* (778 kg) (Fig. 4). The ten most caught species in terms of biomass (namely: *S. aurata, S. scrofa, S. officinalis,* Mugilidae*, M. surmuletus, S. dumerili, E. alletteratus, S. porcus, P. elephas* and *O. vulgaris*) together accounted for almost 60% of the total biomass caught. Interestingly, among the species with the highest biomass recorded, some were associated with relatively low frequencies in the catches (i.e. *S. dumerili*, Mugilidae and *E. alletteratus*). Mullet (Mugilidae), for example, turned out to be the 4th most caught taxon in terms of biomass, but the 22nd in terms of frequency of occurrence in the catches (Fig. 4 and Fig. S4).

Considering all areas, the total biomass of a fishing operation ranged between less than 0.1 kg and more than 150 kg, with a mean value of 8.08 ± 0.33 kg (mean ± se). Mean value of CPUE was 13.05 ± 0.55 kg per 1000 m of net. The lowest mean value of CPUE was recorded at Egadi archipelago and Trapani coast (5.49 ± 0.55 kg per 1000 m of net), and the highest at Cabo de Palos-Murcia coast (34.08 ± 5.64 kg per 1000 m of net). The proportion of main fished groups in terms of CPUE widely varied among areas (refer to donut-plots reported in Fig. 1), but with seabream and scorpionfish often occurring among the main fished categories (see also Fig. S7 in Supplementary materials for all groups considered). In some areas (e.g. Côte Bleue, Strunjan, Cabo de Palos-Murcia coast and South Corsica), a few (from one to three) groups of fishes accounted for the majority of CPUE, while all other categories represented less than 20% of mean CPUE (Fig. 1). In other areas, fishery catches appeared more diversified with an even proportion of the main fished groups and a strong contribution to CPUE from a set of less fished groups (e.g. at Zakynthos island, Straits of Ibiza and Formentera, Portofino promontory). Also at species level, a certain variability of the most fished species in terms of mean CPUE was found (Table 3).

Ex-vessel price and RPUE

The average ex-vessel prices (± se) for all the species identified in the catches are provided in Fig. S8. Lobsters (*P. elephas, P. mauritanicus, H. gammarus* and *S. latus*) are by far and consistently the species with the highest ex-vessel price. Among fishes, the species with highest price are the dusky grouper (*E. marginatus*), the common dentex (*D. dentex*) and the John Dory (*Z. faber*). At the local level, the species generating the highest revenue per unit of effort (RPUE) values corresponded to the most fished species in terms of CPUE in 8 out of 11 areas (Table 3).

Considering all areas, the total revenues of a fishing operation ranged between less than 10 euros and almost 3,000 euros, with a mean value of 129.6 ± 5.5 euros (mean ± se). Mean value of RPUE was 220.06 ± 11.4 euros per 1000 m of net. The lowest mean value of RPUE was recorded at Egadi archipelago and Trapani coast (72.9 ± 7.8 euros per 1000 m of net) and the highest at Cabo de Palos-Murcia coast (584.4 ± 126.3 euros per 1000 m of net). The proportion of fish groups contributing to RPUE varied among areas, but, as for CPUE, seabreams, scorpionfish and lobsters were often found among the most strongly contributing groups among all areas (Fig. S9).

Table 3. Most important species in terms of frequency of occurrence, catch per unit of effort (CPUE) and revenue per unit of effort (RPUE) in the 11 areas.

Area	Most frequent species	Highest CPUE species	Highest RPUE species
South Corsica	*Scorpaena scrofa*	*Palinurus elephas*	*Palinurus elephas*
Cabo de Palos and adjacent Murcia coast	*Scorpaena porcus*	*Seriola dumerili*	*Euthynnus alletteratus*
Cap Roux	*Scorpaena scrofa*	*Scorpaena scrofa*	*Scorpaena scrofa*
Cote Bleue	*Sparus aurata*	*Sparus aurata*	*Sparus aurata*
Egadi archipelago and Trapani coast	*Scorpaena scrofa*	*Mustelus mustelus*	*Mustelus mustelus*
Straits of Ibiza and Formentera	*Scorpaena scrofa*	*Sepia officinalis*	*Scorpaena scrofa*
Portofino promontory	*Mullus surmuletus*	*Seriola dumerili*	*Seriola dumerili*
Strunjan	*Sparus aurata*	*Sparus aurata*	*Sparus aurata*
Dugi-Otok island	*Sparus aurata*	*Mustelus mustelus*	*Sparus aurata*
North Brindisi coast	*Mullus surmuletus*	*Scorpaena scrofa*	*Scorpaena scrofa*
Zakynthos island	*Scorpaena scrofa*	*Mullus surmuletus*	*Mullus surmuletus*

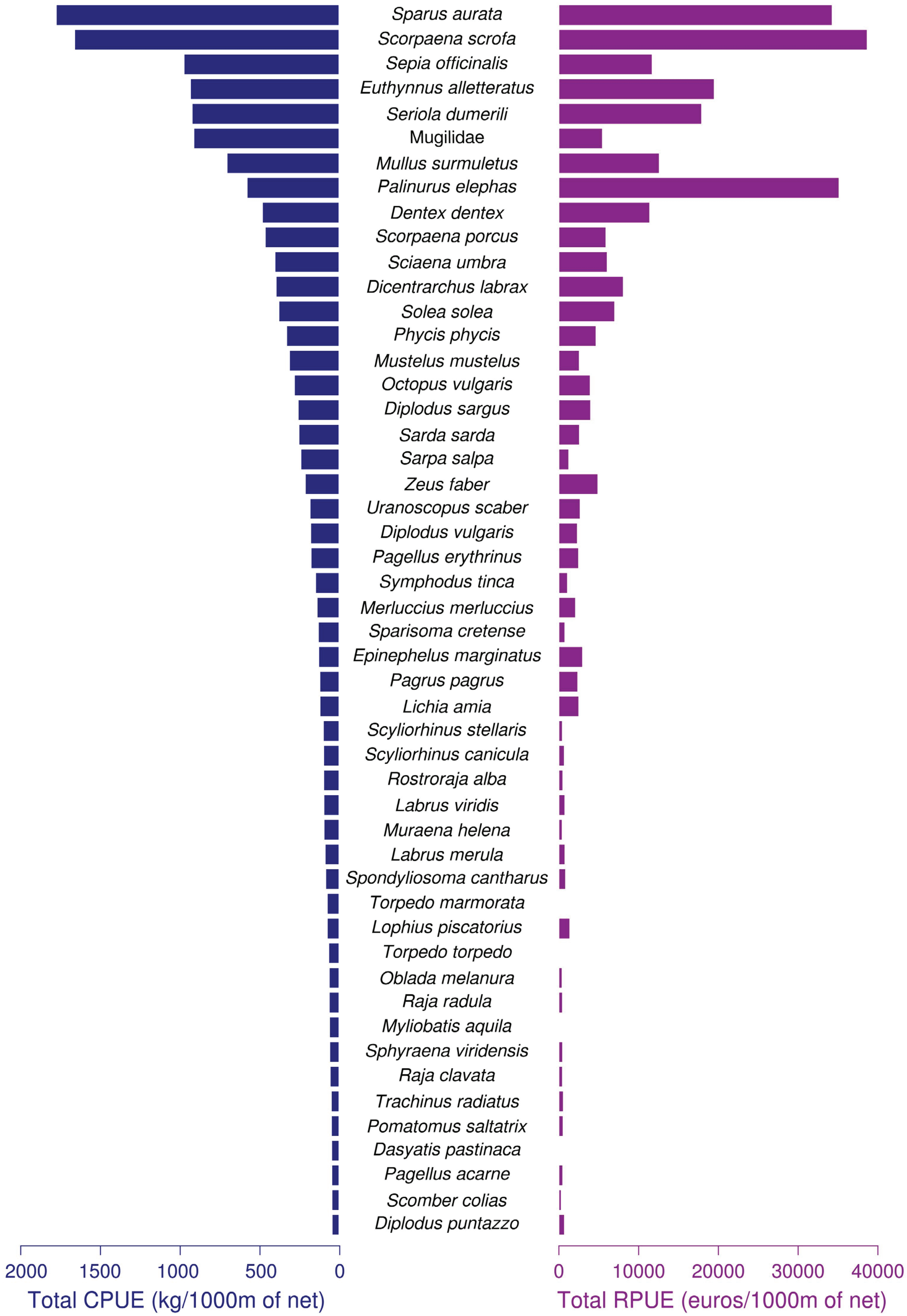

Fig. 4: First 50 most abundant species in terms of CPUE (blue bars) and relative RPUE generated (purple bars). All fishing operations from the 11 areas were pooled.

Discussion

Our multi-area study revealed the multi-scale and multi-faceted nature of Mediterranean set net fisheries in the context of MPAs, evidencing both common social-ecological patterns emerging at regional level and peculiarities characterizing SSF communities at local level.

Common features between areas were observed concerning fleet characteristics. Common features among SSF communities in different Mediterranean regions are to be expected because, besides being driven by traditions and culture, they arise from common EU fisheries policies implemented at national level. Confirming what has been previously observed, both at Mediterranean and global level, we highlighted that small-scale fishers generally use owner-operated boats, and that fishers rarely own more than one boat (Jacquet & Pauly 2008; Quetglas *et al.,* 2016; Tzanatos *et al.*, 2020). Boats are small and equipped with low/medium power engines, reflecting the coastal and local nature of this fishery. However, a certain variability can also be observed in vessel features both among and within areas. In some cases, specific fleet traits seem to be determined by external features, such as the geo-political context in which fisheries are embedded. This is the case at Strunjan (Slovenia) where fishers own, on average, smaller boats than in other areas. Considering that small-scale fishers do not generally cross borders during fishing operations, and that Slovenia has a relatively short coastline (less than 50 km), the distances that can be covered for fishing are simply imposed by the length of the Slovenian coastline. Interestingly, although SSF are generally considered as multi-gear fisheries (Too Big To Ignore, 2017), there are cases in which most of the community uses only one category of fishing gears (set nets). This is the case at Strunjan, Dugi-Otok island and North Brindisi coast, where only very few fishers declared the use of other gear categories. In contrast, in some areas (e.g. Zakynthos island, Straits of Ibiza and Cabo de Palos-Murcia coast), the use of multiple gear categories seems to be the rule. This is a relevant aspect when specific traditional fishing gears are subject to changes in regulations at local or regional level, for example following the establishment of new MPAs. In some cases, the implementation of new spatial protection measures can result in a negative effect on traditional coastal gears (primarily set-nets), whose fishing effort is relocated outside the MPA (Mallol *et al.*, 2019). These changes can be highly detrimental for those communities strictly depending on the gears affected by new regulations and, in general, may give rise to disadvantages especially for older fishers associated to traditional fishing gears and may give grounds for deciding to retire, finally resulting too in the significant loss of fishers' traditional knowledge (Lloret *et al.*, 2018, Mallol *et al.*, 2019).

In all, species diversity was relatively high, in accordance with other studies conducted at local level in the same geographic context for SSF (Battaglia *et al.,* 2010; Forcada *et al.,* 2010; Falautano *et al.,* 2018). From this perspective, we highlight here that our assessment is the first in the Mediterranean Sea to implement a standardized monitoring approach in multiple areas and spanning such an extensive geographical domain. This approach enabled us to achieve an unprecedented characterization of species diversity in SSF catches that, to the best of our knowledge, is the highest ever recorded in the Mediterranean Sea. Yet this figure is rather conservative and should not be considered as representative of SSF in general, since we focused only on a single category of fishing gears (i.e. set nets) and hence the number of species harvested by SSF is likely to be higher. Catch composition certainly depends on the availability and abundance of species, but the predominant occurrence in terms of frequency and biomass of a restricted set of species is also a consequence of specific fishing choices, in terms of gears and tactics, made by fishers (Maynou *et al.,* 2011). In fact, although small-scale fishers exploit a wide range of species, they probably focus their effort on a limited group of species (Damasio *et al.,* 2020). From this perspective, the multi-specific nature of SSF appears to be the consequence of an opportunistic strategy to take advantage of non-target species, unlike what happens in the case of large-scale fisheries where most of non-target species are discarded (Jacquet & Pauly, 2008).

Regional common patterns also emerged in terms of catch composition. The scorpionfishes (*S. scrofa* and *S. porcus*), the striped red mullet (*M. surmuletus*) and the common pandora (*P. erythrinus*), were the most frequently caught species overall (lumping together all fishing operations), and among the ten most caught species in almost all areas. Across the Mediterranean Sea, fishers have developed particular strategies (i.e. *metiérs*) to target these species (Stergiou *et al.,* 2006; Ulrich *et al.* 2012), based on local ecological knowledge that has enabled fishers to identify the periods and the areas in which these species are more frequent and more abundant (Raicevich *et al.,* 2020). It is not by chance that over the year the above-mentioned species are among those widely changing in frequency of occurrence, but always maintaining a relatively high frequency and abundance in catches year-round. Frequency is probably driven by the natural fluctuation of abundance of these species over the year, but fishers are able to foresee this variability and target areas and periods to optimize their catches (Forcada *et al.,* 2010; Maynou *et al.,* 2011; Quetglas *et al.,* 2016). Overall, in our assessment two species appeared in gillnets only, while all other species caught by gillnets were also observed in trammel-nets. It is important to note, however, that gillnets and combined nets may be considerably underrepresented, due to the extreme imbalance in the use of these gears in our work compared to trammel nets. On the other hand, our results also highlighted relevant differences in catch composition between areas, with some areas associated with twice the number of species as others. It is important to underline here that almost all the areas were monitored throughout the year, and only in the case of Strunjan were catch data gathered over a shorter time window (only during autumn). This could contribute to explaining the lowest value for the number of species recorded in this area. All areas also differed in terms of the proportion of main fish groups, although a few groups such as scorpionfishes and seabreams were found to strongly contribute to both CPUEs and RPUEs in many areas. The predominance of species with specific ecological traits in the catches of a given area (e.g. demersal vs. pelagic) is likely a consequence of morpho-ecological differences between areas and therefore of the fishing strategies (e.g. the *metiér*) adopted by local communities, as well as key biological and ecological processes (e.g. recruitment and migration) which may depend, in turn, on regional environmental fluctuations (Marengo *et al.,* 2016). As highlighted in other studies, in some areas of the Mediterranean small-scale fishers mainly catch demersal resources, while elsewhere catches are largely composed of pelagic species (Stergiou *et al.,* 2006; Battaglia *et al.,* 2010; Falautano *et al.,* 2018; Tzanatos *et al.,* 2005). This broad separation is also evident from the results of this study: carangids, small tunas and other pelagic species represent an important proportion of the catch in some areas (Cabo de Palos-Murcia, Egadi Archipelago-Trapani and Dugi-Otok island), while in all others they are almost completely absent in favor of benthic species. This differentiation is also highlighted by the presence in the catches of species exclusive to some areas. The three non-indigenous species (NIS) recorded (two rabbit fishes and the silver-cheeked toadfish) are Lessepsian invaders and only found around Zakynthos island, this area being the easternmost, and thus the first in the studied domain to face this immigration from the Indo-Pacific region through the Suez Canal (Giakoumi *et al.,* 2019a). The rapid expansion of NIS is nowadays one of the major ecological and socio-economic issues the Mediterranean Sea is facing (Giakoumi *et al.,* 2019b), capable of causing major economic losses for the SSF sector (Lloret *et al.*, 2018). This problem is exacerbated in central Mediterranean areas where NIS do not yet represent a valuable resource for fishers and local markets, probably as a consequence of their recent arrival. This also determines low fishing pressure where fishing is allowed, and the consequently low control of NIS populations, conversely from what occurs in eastern Mediterranean countries (e.g. Lebanon, Cyprus), where edible Lessepsian species (e.g. rabbit fishes) have nowadays an important role for the SSF economy and represent a significant proportion of catches (Kleitou *et al.,* 2022). Even more alarming is the case of Lessepsian non-edible species, because of their toxicity (as it is the case for the silver-cheeked toadfish), that besides exerting a detrimental effect on fishing nets and entangled fishes, may pose serious risks to human health (Lloret *et al.*, 2018). These species will likely never represent a fishing resource, thus relevant actions for controlling the expansion of their populations cannot count on local market adaptation and the role played by the SSF communities.

In addition to environmental features, different geographical and social factors between areas probably produced a variety of cultural facets and consumption habits of local people that strongly influence the commercial value of the species caught, finally shaping the composition of landings. Certain species considered non-commercial, and thus only occasionally present, in some areas are among the most intensively fished in others. This is the case of skates (Rajidae), a taxon usually associated with a very low or null economic value, but that in the Balearic archipelago (here represented by the SSF communities operating in the Straits of Ibiza and Formentera) is a resource historically integrated within the local fishery traditions (Quetglas *et al.,* 2016). Remarkably, some areas seem to depend on few or a single category of species, while in others greater diversification was observed. At Côte Bleue and Strunjan, the majority of CPUE is represented by seabreams (Sparidae), while at Cabo de Palos-Murcia and Cap Roux, half of CPUE is composed of small tunas/carangids and scorpionfishes (Scorpaenidae), respectively. This information has to be taken into account when specific species are targeted by management measures at the Mediterranean level as some communities, strongly dependent on those species, could be deeply affected economically and be unable to adapt to the new regulations.

The dependence on a few species may also be an indication of a high fishing pressure on those species, which could contribute to the local and regional depletion of some resources. In this sense, the size distribution of targeted species could reflect population traits of fished resources, also providing information on the fishing effort exerted on them. Our focus on the size distribution of economically relevant species highlighted important differences between areas in terms of landing sizes, potentially indicating different fishing habits among the communities investigated, either as consequence of a variable compliance with the fishing regulations in force at multiple levels or in terms of fishers' personal choices. Some species, in fact, may be fished on purpose only at specific sizes (either large or small), because highly marketable or associated with a higher price per kg. This aspect is especially concerning when high biomasses of small individuals are caught. From this perspective, we highlight that in our assessment a very low frequency of undersized individuals was observed for about half of the species presenting a MCRS and the two most fished species of this list in terms of abundance (i.e. *S. aurata* and *M. surmuletus*) were associated with values for undersized individuals close to zero, suggesting a relatively low potential impact of SSF on these fishery resources. On the other hand, multiple species were occasionally, or systematically, fished below the relative MCRS, as in the case of groupers, lobsters and seabreams, this pattern being consistent in many areas. This further improves our knowledge on the potential impact SSF may have on coastal resources even when carried out in the context of MPAs, suggesting that the mere presence of protected grounds where set nets operate does not guarantee a halt to unsustainable fishing practices both for commercially valuable species and for those associated with a low or null economic value (i.e. in the case of bycatch). The harvesting of species at different sizes also likely depends on the conservation status of the local fish stocks and overall coastal ecosystems in each area, which in turn is related to a variety of environmental and management factors, such as primary productivity (Piroddi *et al.,* 2017), the complexity and heterogeneity of structural habitat (García-Charton *et al.,* 2004; Di Franco *et al.,* 2021), the fishing pressure both historically (Piroddi *et al.,* 2017; Leitao *et al.,* 2019) and in present times, and the effectiveness of management tools such as MPAs (Di Franco *et al.,* 2016; Giakoumi *et al.,* 2017; Guidetti *et al.,* 2014; Rojo *et al.,* 2019). From this perspective, we speculate that the occurrence of undersized individuals of multiple species observed in our study could be exacerbated in completely unprotected areas, where fishing regulations are generally less strict and enforcement levels potentially lower, as is the health status of fished populations. An additional factor in this context concerns the decreasing number of undersized individuals with increasing mesh size we observed for a set of selected species, suggesting that sustainability in the SSF sector could be improved by fostering the adoption of more size-selective gears (Lucchetti *et al.,* 2020).

On the other hand, our results also show that multiple species caught by set nets in our assessment are, in fact, considered threatened by the IUCN at Mediterranean level, and thus worthy of special management measures. Remarkably, some species listed as 'Vulnerable' or 'Endangered' were associated with high landed biomass and catch values (e.g. *P. elephas*, *E. marginatus* and *M. merluccius*), being target species for Mediterranean SSF. These species were also associated with a relatively similar frequency of occurrence in many areas, indicating that the fishing of threatened species is a common feature of set net fisheries, even within or around MPAs. Other threatened species, mainly among sharks and rays, although less valuable, were also caught at relatively high frequency and biomass, and in some specific cases appear among the most caught species. This is the case for example of the 'Endangered' rays *R. radula* and *R. alba* or the common smooth-hound (*M. mustelus*). These results are in line with those of other studies carried out in other Mediterranean contexts highlighting a significant proportion of endangered sharks and rays in SSF catches (Lloret *et al.,* 2019, Marengo *et al.*, 2023). These various considerations may be seen as an addition to the sparse available literature recognizing that although SSF is often considered to have a limited ecological impact on coastal ecosystems, it may actually represent a non-negligible threat for coastal species, targeted or unintentionally caught by fishers (Lloret *et al.,* 2019, Marengo *et al.*, 2023). This aspect is highly relevant for those SSF target species that are already particularly vulnerable due to their biological traits and especially their reproductive biology. This is the case, for example, of species with complex mating strategies (such as some labrids and scorpenids) and species showing sex-reversal, in particular protogynous ones such as the dusky grouper *E. marginatus*, for which the size selection by SSF may be magnified (Lloret *et al.*, 2012).

Concerning the economic descriptors, differences in the species mostly contributing to RPUEs seem to reflect the variability in CPUE between areas, as higher catches produce, generally, higher revenues. However, RPUE is also driven by catch composition, as certain species are more valuable than others. For example, as shown also in other global ex-vessel price databases and local studies carried out in the Mediterranean Sea, lobsters are the species with the highest ex-vessel price (Gómez *et al.*, 2006; Sumaila *et al.,* 2007; Swartz *et al.,* 2013), and often represent a key economic resource for the viability of Mediterranean small scale fishers (Gómez *et al.*, 2006). The range of mean RPUE was relatively wide, with the highest recorded (Cabo de Palos-Murcia coast) more than six times higher than the lowest (Egadi archipelago and Trapani coast). These values should be contextualized with reference to the socio-economic context in which the areas are embedded as the cost of living can strongly contribute to shaping differences, both in terms of ex-vessel price (that determines revenue, as defined here following Sala *et al.,* 2018) and in terms of potential profit for fishers that can impact individual economic wellbeing. From this perspective, the relative differences in RPUE between areas observed in this study may not necessarily mirror differences in fishers' net incomes and overall wellbeing, which are also related to the expenses fishers incur and the cost of living of a certain area. In that respect, a more detailed investigation of fishers' revenues should also take into account the variation in species ex-vessel price due to the total amount of fish caught in a day (the price of a species generally decreases with increasing amounts caught) (Sumaila *et al.,* 2007). Although we did not take these elements into account in our analyses, we highlight that the ex-vessel database compiled in this study is, to our knowledge, the most detailed and complete available for coastal species of the Mediterranean Sea, and complements other global databases being built for large-scale data-rich fisheries that are scarcely applicable for assessing economic aspects of SSF at regional or local scales (Swartz *et al.,* 2013; Tai *et al.,* 2017).

Overall, our integrated approach for data collection enabled us to comprehensively gather an unprecedented amount of information, reconciling data quality (ensuring accurate information for each fish individual caught and fishing operation monitored) with feasibility (minimizing the time required for fishers and the manipulation of the catch). In this sense, this study provides elements for the development of an integrated approach potentially able to overcome issues currently hampering the systematic and reliable collection of SSF data in multiple contexts. The participatory engagement of local communities was a fundamental component to ensure high and stable support of and willingness to take part in the monitoring survey. The effective implementation of the data collection in all areas considered, in terms of the quantity and accuracy of data collected, suggests that in a participatory environment, the availability of fishers can be kept high also when the sampling effort is intense. This is extremely important for the monitoring of the SSF sector, especially in the case of MPAs, as it would allow identification of trends over time in catch descriptors, crucial to develop sound management actions. Directly involving local fishers in monitoring SSF activities offered the opportunity for knowledge coproduction and for the development of a tailored methodology based on the mutual availability of fishers and operators. A major issue for the monitoring of SSF is, in fact, the difficulty of taking into account fishers' daily availability and time, often related to multiple rapidly changing factors (e.g. weather conditions, time of fishing). This could induce fishers to prefer self-declarative forms (e.g. logbooks) or other forms of daily or monthly declarations to operators. In both cases, collected data are provided in an aggregated form, without any detail on single fishing operations and often suffer from low levels of reliability (STECF, 2021). In contrast, the constant presence of an operator, readily available for the sampling on the basis of fishers' availability, gave us the possibility to increase the resolution of SSF monitoring, collecting data on single fishing operations. We highlight here that this was only possible by engaging local MPAs and their staff for the data collection, guaranteeing a capillary and continuous presence of operators at local level.

The creation and design of initiatives involving working hand-in-hand with fishers has been demonstrated to ease and enhance the management of SSF resources on numerous occasions in the case of MPAs too (Guidetti *et al.,* 2010; Guidetti & Claudet 2010; Lloret *et al.*, 2012; Lleonart *et al.,* 2014; Morales-Nin *et al.,* 2017). The collaborative approach used in our project fostered increased support from fishers toward management initiatives (Di Franco *et al.,* 2020). On one hand, this enabled the implementation of the photo-sampling methodology as opposed to declarative approaches, commonly used in the monitoring of SSF (Homes *et al.,* 2018). On the other hand, it enabled us to monitor the entire catch, obtaining full documentation of the sector in the areas considered (*sensu* Mangi *et al.,* 2015), finally contributing to achieving high reliability and accuracy of catch data and providing a basis for supporting improved management of the harvested resources in the near future. It is important to emphasize that the approach deployed here is not devoid of potential errors, especially in situations where the collaboration platform involving managers, researchers, and fishers is not robust or mature enough. In fact, the monitoring at landing always relies on the willingness of fishers to fully display their catches, including, as for example in our case, part of the bycatch that in normal conditions would have been discarded at sea before reaching the port. In this regard, further accuracy can be achieved through the on-board presence of the monitoring operator, who would have the opportunity to monitor all individuals hauled in by the net, also allowing the accurate analysis of discards or any portion of the catch that a fisher might hide (Lloret *et al.*, 2012; Mallol *et al.*, 2019; Gil *et al.*, 2018; Marengo *et al.*, 2023). However, on-board sampling, unless carried out directly by trained and trusted fishers within a self-sampling program (see Lloret *et al.*, 2012), represents a very challenging task for systematic implementation at EU level as national legal aspects, mainly related to safety issues, currently prevent external operators in many EU countries from being present on the boat during fishing operations. In addition, the large number of SSF vessels operating in the Mediterranean Sea (68,800, FAO 2022) makes it extremely difficult to sample a relevant percentage of fishing operations distributed across the entire area, through the adoption of on-board trained observers.

Conclusions

Quantitative and qualitative information on SSF is generally lacking, and when available, it tends to be scattered or very localized, which makes it unusable for informing regional policies (Too Big To Ignore, 2017; FAO, 2018). To develop sound management strategies, important international policy instruments such as the Voluntary Guidelines for SSF (FAO, 2015), the Common Fishery Policy (EU, 2013) and the Marine Strategy Framework Directive (EU, 2008) advocate a solid knowledge of the ecological and socio-economic characteristics of the SSF sector and its targeted resources. These assessments cannot overlook the fundamental role MPAs will have in the near future for the management of coastal ecosystems. In the next years, coastal areas will likely be affected by the establishment of new MPAs, that are projected to increase in number and surface area in order to match international commitments concerning protection targets (e.g. Aichi target 11, Convention of Biological Diversity; 2030 Agenda for Sustainable Development). It is thus crucial to gather accurate and wide-ranging information on a broad range of human activities that will be carried out within or around future MPAs. Small-scale fisheries will certainly have a crucial role for the economy and wellbeing of local communities associated with protected marine ecosystems and will likely be one of the pillars of blue growth in coastal areas. In this sense, the results of our assessment set an important and novel baseline for the future assessments of Mediterranean SSF conducted in fishing areas including or close to MPAs, providing elements for the implementation of an integrated approach for the study of SSF at Mediterranean level, in line with its multifaceted nature.

Our study highlights that regional patterns of SSF associated with MPAs derive from a multitude of facets at local scale, that can profoundly differ even at relatively small spatial scales. This being so, governance and management actions cannot neglect the particular characteristics of SSF when specific regulations target fleet characteristics, gears and species. Regional management measures (e.g. in terms of fishing gears or species restrictions) could unevenly affect communities with different socio-ecological features, in some cases potentially disadvantaging SSF communities dependent on few/single species or gears.

Overall, the approach used in this study enabled us to gather an unprecedentedly detailed dataset on SSF socio-ecological features associated with Mediterranean MPAs, both in terms of data reliability and spatial coverage, and to draw conclusions at large scale (covering multiple locations) highlighting at the same time local specificities. In this regard, we may point out that a systematic and reliable assessment of SSF socio-ecological aspects could be streamlined, not only in the context of MPAs, if 1) a sound monitoring protocol (maximizing accuracy while minimizing fishers' time and fish manipulation) is adopted; 2) local management authorities (e.g. the MPA management bodies in our study) are appointed for the capillary and systematic collection of data (this can eventually involve fishers associations or partnerships between private and public fishery stakeholders such as EU Fisheries Local Action Groups - FLAGS); 3) the data collection is based on a collaborative platform that engages and trains fishers for the monitoring, giving them the opportunity to contribute to the co-development of an efficient data collection protocol, adapted to the specific aims and circumstances of the data collection. All this can be implemented only if adequate economic resources are allocated, as is currently the case for other fishery sectors (e.g. large-scale fisheries).

Acknowledgements

This research was carried out in the framework of the FishMPABlue2 and FishMPABlue2 Plus projects (https://fishmpablue-2.interreg-med.eu/) funded by the European Territorial Cooperation Programme MED and co-financed by the European Regional Development Fund (ERDF), and of the MAPAFISH-MED study (CINEA/EMFF/2021/3.1.2/SI2.868140-SC02) funded by the European Maritime, Fisheries and Aquaculture Fund (EMFAF). Antonio Calò was also funded by the Italian Ministry of Education, University and Research (MIUR) in the framework of the PON 'Research and Innovation 2014-2020' (D.D. 407/2018 and D.M. 1062/2021), co-financed by the European Social Fund. Authors are grateful to Frédéric Bachet, Olivier Bretton, Milena Ramov, Leila Seddiki and Valentina Cappanera for their invaluable help in data collection. Authors are grateful to all volunteer fishers who took part in the study. The paper is dedicated to the memory of Prof. Patrice Francour.

Data availability statement: All the data that support the findings are available upon reasonable request to Dr. Antonio Calò and Dr. Antonio Di Franco.

References

Abràmoff, M.,D., Magalhães, P.J., Ram, S.J., 2004. Image processing with imageJ. *Biophotonics*, Int 11, 36-41.

Basurto, X., Franz, N., Mills, D.J., Virdin, J., Westlund, L., 2017. Improving our knowledge on small-scale fisheries: data needs and methodologies. FAO, Rome (Italy). Fisheries and Aquaculture Department. Rome, 104 pp.

Battaglia P., Romeo T., Consoli P., Scotti, G., Andaloro, F., 2010. Characterization of the artisanal fishery and its socio-economic aspects in the central Mediterranean Sea (Aeolian Islands, Italy). *Fisheries Research*, 102, 87-97.

Bousquet, C., Bouet, M., Patrissi, M., Cesari, F., Lanfranchi J.P. *et al.,* 2022. Assessment of catch composition, production and fishing effort of small-scale fisheries: The case study of Corsica Island (Mediterranean Sea). *Ocean & Coastal Managemen*t, 218, 105998.

Bryman, A. 2012. Social Research Methods, Fourth. Oxford University Press, New York, 809 pp.

Calò, A., Di Franco. A., Quattrocchi, F. Dimitriadis, C., Ventura, P. *et al.*, 2022. Multi-specific small-scale fisheries rely on few, locally essential, species: evidence from a multi-area study in the Mediterranean. *Fish and Fisheries,* 23, (6), 1299-1312.

Cheung, W.W., Watson, R., Morato, T., Pitcher, T.J., Pauly, D., 2007. Intrinsic vulnerability in the global fish catch. *Marine Ecology Progress Series,* 333, 1-12.

Chuenpagdee, R., Jentoft, S., 2016. Transdisciplinarity for Small-Scale Fisheries Governance: Analysis and Practice. Springer International, Cham, Switzerland, 477 pp.

Chuenpagdee, R., Rocklin, D., Bishop, D., Hynes, M., Greene, R. *et al.*, 2019. The global information system on small-scale fisheries (ISSF): A crowdsourced knowledge platform. *Marine Policy*, 101, 158-166.

Cohen, P.J., Allison, E.H., Andrew, N.L., Cinner, J., Evans, L.S. *et al.,* 2019. Securing a just space for small-scale fisheries in the blue economy. *Frontiers in Marine Science,* 6, 1-8.

Coll, M., Piroddi, C., Albouy, C., Ben Rais Lasram, F., Cheung, W.W. *et al.*, 2012. The Mediterranean Sea under siege: Spatial overlap between marine biodiversity, cumulative threats and marine reserves. *Global Ecology & Biogeografy*, 21 (4), 465-480.

Coppola, S.R., 2006. Inventory of artisanal fishery communities in the Western and Central Mediterranean. Studies and Reviews. General Fisheries Commission for the Mediterranean. No. 77. FAO, Rome, 82 pp.

Damasio, L.M.A., Peninno, M.G., Lopes P.F.M., 2020. Small changes, big impacts: Geographic expansion in small-scale fisheries. *Fisheries Research,* 226, 105533.

Di Franco, A., Bodilis, P., Piante, C., Di Carlo, G., Thiriet, P. *et al.*, 2014. Fishermen Engagement in Mediterranean Marine Protected Areas: a key element to the success of artisanal fisheries management. MedPAN North Project. WWF, France. 135 pages.

Di Franco, A., Thiriet, P., Di Carlo, G., Dimitriadis, C., Francour, P. *et al.,* 2016. Five key attributes can increase marine protected areas performance for small-scale fisheries management. *Scientific Reports*, 6, 1-9.

Di Franco, A., Hogg, K.E., Calò, A., Bennett, N.J., Sévin-Allouet, M.A. *et al.,* 2020. Improving marine protected area governance through collaboration and co-production. *Journal of Environmental Management*, 269.

Di Franco, E., Di Franco, A., Calò, A., Di Lorenzo, M., Mangialajo, L. *et al.*, 2021. Inconsistent relationships among protection, benthic assemblage, habitat complexity and fish biomass in Mediterranean temperate rocky reefs. *Ecological Indicators*, 128, 107850.

Di Lorenzo, M., Calò, A., Di Franco, A., Milisenda, G., Aglieri, G. *et al.*, 2022. Small-scale fisheries catch more threatened elasmobranchs inside partially protected areas than in unprotected areas. *Nature Communications*, 13, 4381.

European Union (EU), 2014. Regulation (EU) No. 508/2014 of the European Parliament and of the Council on the European Maritime and Fisheries Fund and repealing Council Regulations (EC), 148 pp.

European Union (EU), 2008. Council Regulation (EC) No 1967/2006 of 21 December 2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea, amending Regulation (EEC) No 2847/93 and repealing Regulation (EC) No 1626/94. 112 pp.

EU, (2013). Regulation (EU) no 1380/2013 of the European parliament and of the council of 11 December 2013 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. 98 pp.

European Union (EU), 2008. 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. *Official Journal of the European Union*, L 164/19, 78 pp.

Falautano, M., Castriota, L., Cillari, T., Vivona, P., Finoia, M.G. *et al.*, 2018. Characterization of artisanal fishery in a coastal area of the Strait of Sicily (Mediterranean Sea): Evaluation of legal and IUU fishing. *Ocean & Coastal Management,* 151, 77-91.

FAO (Food and Agriculture Organization), 2015. Voluntary guidelines for securing sustainable small-scale fisheries in the context of food security and poverty eradication. FAO. www.fao.org/fishery/ssf/guidelines/en. 34 pp.

FAO (Food and Agriculture Organization), 2018. The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome. 227 pp.

FAO (Food and Agriculture Organization) – GFCM (General Fisheries Commission for the Mediterranean), 2022 The State of Mediterranean and Black Sea Fisheries. Rome.

Forcada, A., Valle, C., Sánchez-Lizaso, J.L., Bayle-Sempere, J.T., Corsi, F., 2010. Structure and spatio-temporal dynamics of artisanal fisheries around a Mediterranean marine protected area. *ICES Journal of Marine Science*, 67, 191-203.

Froese, R., Pauly, D., 2019. FishBase. World Wide Web electronic publication. https://www.fishbase.se/search.php%0AFroese,

García-Charton, J.A., Pérez-Ruzafa, Á., Sánchez-Jerez, P., Bayle-Sempere, J.T., Reñones, O. *et al.*, 2004. Multi-scale spatial heterogeneity, habitat structure, and the effect of marine reserves on Western Mediterranean rocky reef fish assemblages. *Marine Biology*, 144, 161-182.

Giakoumi, S., Scianna, C., Plass-Johnson, J., Micheli, F., Grorud-Kolvert, K. et al., 2017. Ecological effects of full and partial protection in the crowded Mediterranean Sea: A regional meta-analysis. *Scientific Reports*, 7, 1-12.

Giakoumi, S., Pey, A., Di Franco, A., Francour P., Kizilkaya Z., *et al.*, 2019a. Exploring the relationships between marine protected areas and invasive fish in the world's most invaded sea. *Ecological Applications,* 29 (1), e01809.

Giakoumi, S., Katsanevakis, S., Albano, P.G., Azzurro, E., Cardoso, A.C. et al., 2019b. Management priorities for marine invasive species. *Science of the Total Environment*, 688, 976-982.

Gil, M.M., Catanese, G., Palmer, M., Hinz, H., Pastor, E. *et al.*, 2018. Commercial catches and discards of a Mediterranean small-scale cuttlefish fishery: implications of the new EU discard policy. *Scientia Marina*, 155-164.

Gill, D.A., Oxenford, H.A., Turner, R.A., Schuhmann, P.W., 2019. Making the most of data-poor fisheries: Low cost mapping of small island fisheries to inform policy. *Mar Policy,* 101, 198-207.

Gómez, S., Lloret, J., Riera, V., 2006. The Decline of the Artisanal Fisheries in Mediterranean Coastal Areas: The Case of Cap de Creus (Cape Creus). *Coastal Management*, 34, 217-232.

Gómez, S., Cerreño, A., Lloret, J., 2021. Cultural heritage and environmental ethical values in governance models: Conflicts between recreational fisheries and other maritime activities in Mediterranean marine protected areas. *Marine Policy*, 129, 104529.

Grati, F., Azzurro, E., Scanu, M., Tassetti, A.N., Bolognini, L. *et al*., 2022. Mapping small-scale fisheries through a coordinated participatory strategy. *Fish and Fisheries*, 1-13.

Grorud-Colvert, K., Sullivan-Stack, J., Roberts, C., Constant, V., Horta e Costa, B. *et al.*, 2021. The MPA Guide: A framework to achieve global goals for the ocean. *Science*, 373, 6560.

Guidetti, P., Claudet, J., 2010. Comanagement practices enhance fisheries in marine protected areas. *Conservation Biology*, 24 (1), 312-8.

Guidetti, P., Baiata, P., Ballesteros, E., Di Franco, A., Hereu, B. et al., 2014. Large-scale assessment of mediterranean marine protected areas effects on fish assemblages. PLoS One, 9 (4): e91841.

Guidetti, P., Bussotti, S., Pizzolante, F., Ciccolella, A., 2010. Assessing the potential of an artisanal fishing co-management in the Marine Protected Area of Torre Guaceto (southern Adriatic Sea, SE Italy). *Fisheries research,* 101, 180-187.

Guyader, O., Fahy, E., Gaspar, M.B., *et al.*, 2013. Small scale fisheries in Europe: A comparative analysis based on a selection of case studies. *Fisheries Research*, 140, 1-13.

Halim, A., Wiryawan, B., Loneragan, N.R., Hordyk, A., Fedi, M. *et al.*, 2019. Developing a functional definition of small-scale fisheries in support of marine capture fisheries management in Indonesia. *Marine Policy*, 100, 238-248.

Jacquet, J., Pauly, D. 2008. Funding priorities: Big barriers to small-scale fisheries. *Conservation Biology*, 22, 832-835.

Jentoft, S., Chuenpagdee, R., Barragán-Paladines, M.J., Franz, N., 2017. The Small-Scale Fisheries Guidelines: Global Implementation. Springer International. Cham, Switzerland, 850 pp.

Kittinger, J.N., Finkbeiner, E.M., Ban, N.C., Broad, K., Carr, M. *et al.*, 2013. Emerging frontiers in social-ecological systems research for sustainability of small-scale fisheries. *Current Opinion in Environmental Sustainability,* 5, 352-357.

Kleitou, P., Moutopoulos, D.K., Giovos, I., Kletou, D., Savva, I. *et al.*, 2022. Conflicting interests and growing importance of non-indigenous species in commercial and recreational fisheries of the Mediterranean Sea. *Fisheries Management and Ecology*, 29, 169-182.

Leitao, P., Henriques, S., Pérez-Ibarra, I. et al., Trujillo, M., Garcia-Charton, J.A. *et a*l., 2019. Shifting baselines in a Mediterranean small-scale fishery. *Ocean and Coastal Management*, 183, 104985.

Leleu, K., Pelletier, D., Charbonnel, E., Letourneur, Y., Alban, F. *et al.*, 2014. Métiers, effort and catches of a Mediterranean small-scale coastal fishery: The case of the CÔte Bleue Marine Park. *Fisheries Research*, 154, 93-101.

Lleonart, J., Demestre, M., Martín, P., Rodon, J., Sainz-Trapaga, S. *et al.*, 2014. The co-management of the sand eel fishery of Catalonia (NW Mediterranean): the story of a process. *Scientia Marina*, 78 (S1), 87-93.

Lloret, J., Muñoz, M., Casadevall, M., 2012. Threats posed by artisanal fisheries to the reproduction of coastal fish species in a Mediterranean marine protected area. *Estuarine Coastal and Shelf Science*, 113, 133e140.

Lloret, J., Cowx, I.G., Cabral, H., Castro, M., Font, T. *et al.*, 2018. Small-scale coastal fisheries in European Seas are not what they were: Ecological, social and economic change. Marine Policy, 98, 176-186.

Lloret, J., Biton-Porsmoguer, S., Cerreño, A., Di Franco, A., Sahyoun, R. *et al.*, 2019. Recreational and small-scale fisheries may pose a threat to vulnerable species in coastal and offshore waters of the western Mediterranean. *ICES Journal of Marince Science*, 77 (6), 2255-2264.

Lucchetti, A., Virgili, M., Petetta, A., Sartor, P. 2020. An overview of gill net and trammel net size selectivity in the Mediterranean Sea. *Fisheries Research*, 230, 105677.

Mangi, C.S., Dolder, P.J., Catchpole, T.L., Rodmell, D., de Rozarieux, N., 2015. Approaches to fully documented fisheries: practical issues and stakeholder perceptions. *Fish and Fisheries*, 16, 426-452.

Mallol, S., Goñi, R., 2019. Unintended changes of artisanal fisheries métiers upon implementation of an MPA. *Marine Policy*, 101, 237-245.

Marengo, M., Pere, A., Marchand, B., Lejune, P., Durieux, E.D.H., 2016. Catch variation and demographic structure of common dentex (*Sparidae*) exploited by Mediterranean artisanal fisheries. *Bulletine of Marine Science*, 92 (2), 191-206.

Marengo, M., Vanalderweireldt, L., Horri, K., Patrissi, M., Santoni, M.C. *et al.*, 2023. Combining indicator trends to evaluate a typical Mediterranean small-scale fishery: The case study of Corsica. *Regional Studies in Marine Science*, 65, 103087.

Maynou, F., Recasens, L., Lombarte, A. 2011. Fishing tactics dynamics of a Mediterranean small-scale coastal fishery. *Aquatic Living Resources*, 24, 149-159.

Morales-Nin, B., Grau, A.M., Aguilar, J.S., Gil, M.M., Pastor, E., 2017. Balearic Islands boat seine fisheries: the transparent goby fishery an example of co-management. *ICES Journal of Marine Science*, 74 (7), 2053-2058.

Outeiro, L., Villasante, S., Sumaila, R., 2018. Estimating fishers' net income in small-scale fisheries: Minimum wage or average wage? *Ocean and Coastal Management*, 165, 307-318.

Palomares, M.L.D., Pauly, D., 2022. SeaLifeBase. World Wide Web electronic publication. www.sealifebase.org, version (04/2022).

Pauly, D., 1997. Small-Scale Fisheries in the Tropics: Marginality, Marginalization, and Some Implications for Fisheries Management. *Global Trends in Fisheries Management*, 40-49.

Pauly, D., Charles, A., 2015. Counting on small- scale fisheries. *Science,* 80, 347, 242.

Pauly, D., Zeller, D., 2016. Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. *Nature Communications*, 7, 1-9.

Piroddi, C., Coll, M., Liquete, C., Macias, D., Greer, K. et al., 2017. Historical changes of the Mediterranean Sea ecosystem: Modelling the role and impact of primary productivity and fisheries changes over time. Scientific Reports, 7, 1-18.

Pita, C., Villasante, S., Pascual-Fernández, J.J., 2019. Managing small-scale fisheries under data poor scenarios: lessons from around the world. *Marine Policy*, 101, 154-157.

Quetglas, A., Merino, G., Ordines, F., Guijarro, B., Garau, A. et al., 2016. Assessment and management of western Mediterranean small-scale fisheries. *Ocean and Coastal Management*, 133, 95-104.

R Core Team, 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing.

Raicevich, S., Grati, F., Giovanardi, O., Sartor, P., Sbrana, M. *et al.*, 2020. The unexploited potential of small-scale fisheries in Italy: Analysis and perspectives on the status and resilience of a neglected fishery sector. In Small-scale fisheries in Europe: Status, resilience and governance. Ed. Pascual-Fernández J. (Switzerland:Springer Nature), 191-211.

Rojo, I., Sánchez-Meca, J., García-Charton, J.A., 2019. Small-sized and well-enforced Marine Protected Areas provide ecological benefits for piscivorous fish populations worldwide. *Marine Environmental Research*, 149, 100-110.

Sala, E., Mayorga, J., Costello, C., Kroodsma, M., Palomares, M.L.D. *et al.*, 2018. The economics of fishing the high seas. *Science Advances*, 4: eaat2504, 1-14.

Scientific, Technical and Economic Committee for Fisheries (STECF), 2021. Fisheries Dependent - Information – FDI (STECF-21-12). EUR 28359 EN, Publications Office of the Europe an Union, 2021, ISBN 978-92-76-45887-6.

Smith, H., Basurto, X., 2019. Defining Small-Scale Fisheries and Examining the Role of Science in Shaping Perceptions of Who and What Counts : A Systematic Review. *Frontiers in Marine Science*, 6.

Stergiou, K.I., Moutopoulos, D.K., Soriguer, M.C., Puente, E., Lino, P. *et al*., 2006. Trammel net catch species composition, catch rates and métiers in southern European waters: A multivariate approach. *Fisheries Research*, 79, 170-182.

Stoll, J.S., Risley, S.C., Henriques, P.R., 2023. A review of small-scale marine fisheries in the United States: Definitions, scale, drivers of change, and policy gaps. *Marine Policy,* 148, 105409.

Sumaila, U.R., Marsden, A.D., Watson, R., Pauly, D., 2007. A global ex-vessel fish price database: Construction and applications. *Journal of Bioeconomics,* 9, 39-51.

Swartz, W., Sumaila, R., Watson, R., 2013. Global Ex-vessel Fish Price Database Revisited: A New Approach for Estimating "Missing" Prices. *Environmental Resources and Economy*, 56, 467-480.

Tai, T.C., Cashion, T., Lam, V.W.Y., Swartz, W., Sumaila, R.U., 2017. Ex-vessel fish price database: Disaggregating prices for low-priced species from reduction fisheries. *Frontiers in Marine Science*, 4, 1-10.

Teh, L.C.L., Pauly, D., 2018. Who Brings in the Fish? The Relative Contribution of Small-Scale and Industrial Fisheries to Food Security in Southeast Asia. *Frontiers in Marine Science*, 5, 1-9.

Teh, L.S.L., Teh, L.C.L., Sumaila, U.R., 2011. Quantifying the overlooked socio-economic contribution of small-scale fisheries in Sabah, Malaysia. *Fisheries Research*, 110, 450-458.

Too Big To Ignore, 2017. European Small-Scale Fisheries: A regional synthesis. St. John's. http://toobigtoignore.net/

Tsikliras, A.C., Dinouli, A., Tsiros, V.Z., Tsalkou, E., 2015. The Mediterranean and Black Sea fisheries at risk from overexploitation. *PLoS One,* 10, 1-19.

Tzanatos, E., Dimitriou, E., Katselis, G., Georgiadis, M., Koutsikopoulos, C., 2005. Composition, temporal dynamics and regional characteristics of small-scale fisheries in Greece. *Fisheries Research*, 73, 147-158.

Tzanatos, E., Georgiadis, M., Peristeraki, P., 2020. Small-Scale Fisheries in Greece: Status, Problems, and Management. In Small-scale fisheries in Europe: Status, resilience and governance. Ed. Pascual-Fernández J. (Switzerland:Springer Nature), 125-150.

Ulrich, C., Wilson, D.C.K., Nielsen, J.R., Bastardie, F., Reevs, S.A. *et al*., 2012. Challenges and opportunities for fleet- and métier-based approaches for fisheries management under the European Common Fishery Policy. *Ocean and Coastal Management*, 70, 38-47.

Zupan, M., Fragkopoulou, E., Claudet, J., Erzini, K., Horta e Costa, B. *et al.,* 2018. Marine partially protected areas: drivers of ecological effectiveness. Frontiers in Ecology and Environment, 16, 381-387.

Supplementary Data

The following supplementary information is available online for the article:

Table S1. Main details of the survey carried out with questionnaires administered to fishers

Table S2. Distribution of the fishing operations over the year

Table S3. Species identified in the catches monitored. Major Taxa: Elasmobranchii (CF), Osteichthyes (F), Cephalopoda Mollusca (M) and Crustacea (C). Vulnerability: Least concern (LC), Near-threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR). For the reference numbers of the locations investigated, see Table S1

Table S4. Relative frequency of occurrence (F %) of threatened species (i.e. belonging to the IUCN categories CR=red, EN=orange and VU=yellow) in the considered areas.

Table S5. The 5 most frequently caught species in SSF catches for each area

Table S6. Results from the glm on the ration undersized/total individuals for 5 species with a MCRS.

Fig. S1: Example of a picture composing the photo-sample of a set net catch

Fig. S2: Percentage of fishers using different categories of gear with increasing number categories. On top of each bar, the percentage of fishers using the relative number of gear categories is reported.

Fig. S3: Barplot of total number of species recorded in SSF catches in each area. Different colors represent different Taxa: C=Crustaceans, CF=Elasmobranchii, F=Osteichthyes, M=Cephalopos Mollusks. For the location codes, see Table S1.

Fig. S4: Species relative frequency of occurrence for species present in at least 1% of catches

Fig. S5: Boxplots of size (cm) distribution for the 12 most abundant species in terms of biomass caught. Width of boxplots proportional to the number of specimens. For each species, boxplots are ordered from the bottom to the top on the basis of increasing median size in each area considered. Red dashed lines represent the species MCRSs, where present.

Fig. S6: Relationship between the relative frequency of occurrence of undersized (total length<MCRS) individuals (in relation to the total number of conspecific individuals present in the catch) and the mesh size, for 5 species with a MCRS (Dv=Diplodus vulgaris, Da=Diplodus annularis, Ds=Diplodus sargus, Pa-Pagellus acarne, Pe=Palinurus elephas)

Fig. S7: Proportion of CPUE for each group of species in each area. Values for each area sum up to 100. The codes of the locations are shown in Table S1, those of the groups in Table S3.

Fig. S8: Prices (euro per kg) at landing for the species assessed in SSF catches. Dots represent mean prices for all areas, segments represent standard errors.

Fig. S9: Proportion of RPUE for each group of species in each area. The codes of the locations are shown in Table S1, those of the groups in Table S3.

Questionnaire administered for fishing fleet characterization.