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AUTHORS' ACCEPTED MANUSCRIPT

Building a baseline for habitat-forming corals by a multi-source approach, including Web Ecological Knowledge

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ABSTRACT

In the Mediterranean, habitat-forming corals often characterize essential fish habitats. While their distribution is sufficiently known for the western basin, few data are available from the Central-Eastern Mediterranean Sea (CEM). This study fills this gap supplying the largest dataset ever built on the geographical and bathymetric distribution of the most relevant habitat-forming corals (*Eunicella cavolini, Eunicella verrucosa, Eunicella singularis, Leptogorgia sarmentosa, Paramuricea clavata, Corallium rubrum* and *Savalia savaglia*) of the CEM. Information collected from different sources such as literature, citizen science, and from the World Wide Web (WWW) was combined. Videos published on the WWW provided additional information on the presence of fishing lines and signs of damage, as well as on the distribution of purple and yellow-purple colonies of *Paramuricea clavata*. The study highlighted the impressive amount of information that the WWW can offer to scientists, termed here as Web Ecological Knowledge (WEK). The WEK is constantly fuelled by internauts, representing a free, refreshable, long-term exploitable reservoir of information. A quick and easy method to retrieve data from the WWW was illustrated. In addition, the distribution of corals was overlapped to marine protected areas and to the distribution of environmental conditions suitable for coralligenous habitats, fragile biogenic Mediterranean structures hosting complex assemblages in need of strict protection. The collected data allowed identifying priority areas with high species diversity and sites that are impacted by fishing activities. Supplied data can correctly address conservation and restoration policies in the CEM, adding an important contribution to ecosystem-based marine spatial planning.

KEYWORDS

Biogeography · Citizen science · Foundation species · Mesophotic habitats · Social media · Web

ADDITIONAL KEYWORDS

European Union (EU) · Maria Sklodowska-Curie Actions · Grant Agreement No 643712 · Green Bubbles RISE for sustainable diving · Green Bubbles

INTRODUCTION

Dense populations of branched gorgonians and zoantharians give rise to coral forests, which are fundamental in marine ecosystems because they act as ecosystem engineers: they increase spatial complexity and enhance interspecific interactions (Cerrano et al. 2010, 2015; Di Camillo et al. 2013), often characterizing essential fish habitats (Tsounis et al. 2010). Loss of coral forests leads to changes in habitat architecture and entails cascading effects on other organisms composing the rocky bottom benthic assemblages (Ponti et al. 2014, 2016; Valisano et al. 2016). Many coral species can represent a valuable eco- nomic resource, besides their ecological role. Red coral is well known for its commercial value as precious jewel, but corals can also give rise to beautiful seascapes, which constitute a key attraction for recreational scuba divers, an aspect that is generally included in the cultural benefits of possible ecosystem services (Rodrigues et al. 2016). Hence, it is crucial to identify and properly manage coral species and their habitats, both for their ecological and economic potential (Crain and Bertness 2006).

With regards to the Mediterranean Sea, the majority of papers dealing with coral distribution or ecology provide information about species from the Western Mediterranean Sea (WM) (Gili et al. 1989; Linares et al. 2008; Huete-Stauffer et al. 2011; Gori et al. 2011; Santoretto and Francour 2012; Priori et al. 2013; Ponti et al. 2014; Cau et al. 2014, and many others), whereas little data is available from the Central-eastern Mediterranean Sea (CEM) (Adriatic Sea, Pax and Müller 1962; Novosel et al. 2002; Kružić 2002, 2007, Kružić and Popijač 2009; Zavodnik et al. 2005; Mercurio et al. 2012; Kipson et al. 2015; Sini et al. 2015; Aegean Sea, Vafidis et al. 1994; Vafidis and Koukouras 1998; Chintiroglou et al. 1989; Salomidi et al. 2012; Sea of Marmara, Artüz et al. 1990; Topçu and Öztürk 2013, 2015; Strait of Sicily, Ben Mustapha et al. 2002; Costantini et al. 2010; Deidun et al. 2010).

There is a general lack of knowledge about the diversity of habitat-forming corals of the CEM that impedes the development of proper conservation strategies. It is urgent, there- fore, to fill this gap, especially considering the increasing rate of spread of nonindigenous thermophilous species coming from the eastern basin (Galil and Zenetos 2002).

Marine citizen science projects are becoming of pivotal importance since volunteers are involved in underwater activities for the collection of scientific data (Silvertown 2009; Cerrano et al. 2017). Citizens have been increasingly involved in marine environmental science (Bramanti et al. 2011; Thiel et al. 2014; Pikesley et al. 2016).

Besides people who voluntarily participate in conservation or monitoring programs, there are millions of internauts who have unintentionally created a huge databank inside the World Wide Web (WWW), containing conspicuous information about the distribution of marine species, scattered among websites or social network pages of dive centres, underwater photographers and non-professional scuba divers. Since underwater video-cameras became digital, pocket-sized and cheaper, hundreds of scuba diving videos have been recorded and published on the WWW. This bulk of diffused data could be gathered to inte- grate or cross-validate scientific data and support marine conservation policy (Di Minin et al. 2015). All the ecological information contained in the WWW and exploitable for scientific purposes will be here termed as Web Ecological Knowledge (WEK).

The main aim of this work is to build the largest dataset on habitat-forming corals of the CEM combining information from scientific reports, citizen science, and the World Wide Web. Moreover, this research highlights the powerful role of the WEK: being constantly fuelled by internauts, it represents a free, refreshable and long-term exploitable reservoir of information.

The considered species include six octocorals [i.e., the yellow gorgonian *Eunicella cavolini* (Koch, 1887), the white gorgonian *Eunicella singularis* (Esper, 1791), the pink sea-fan *Eunicella verrucosa* (Pallas, 1766), *Leptogorgia sarmentosa* (Esper, 1789), the purple or yellow-purple gorgonian *Paramuricea clavata* (Risso, 1826), and the precious red coral *Corallium rubrum* (Linnaeus, 1758)] and one hexacoral, the zoanthid *Savalia savaglia* (Bertoloni, 1819), known as false black coral.
In order to show how much habitat-forming corals are protected, the distribution of these corals was compared with the distribution of marine protected areas and with the environmental conditions suitable for the development of coralligenous habitats: mesophotic, fragile biogenic

reefs in need of strict protection. Alongside data on geographical and depth distributions of the considered species, this work supplies additional information on the co-occurrence of fishing lines, the presence of damaged colonies, and coral substrate preference.

MATERIALS AND METHODS

Sources of information and data collection

Data on the geographical and depth distributions of selected coral species in the CEM (Fig. 1) were obtained by combining information from three main sources: scientific reports (SCI), the World Wide Web (WWW) and citizen science (CS).

Data from SCI were originally collected by scientific scuba divers or using remotely operated underwater vehicles (ROV), dredging, and fishing nets up to a depth of about 800 m (see Supplementary Data S1 for a complete list of references).

Information coming from the WWW included non-professional underwater videos (mostly published on the YouTube website; the last one to be retrieved was dated 8th September 2014), and pictures from websites and Facebook pages of dive centres or photographers (the latest information obtained was dated 1st January 2015). Authors of videos and pictures published on the WWW were contacted by phone or email to ask for further details about the record, such as the exact locality, depth and dive date. Records lacking this information have not been considered. The steps followed to retrieve information about species distribution from the WWW are given in Fig. 2.

Data from CS entirely come from the Reef Check web based Geographic Information System (Web-GIS) for the Mediterranean Sea (https://www.reefcheckmed.org/), developed and maintained by the Reef Check Italia (RCI) non-profit association. This is the largest Web-GIS of underwater observations carried out according to a standard protocol by volunteers in the Mediterranean Sea (Cerrano et al. 2017), even if it is better enforced in the western basin compared to the CEM. The data quality of the information from the RCI database was first assured by training non-scientific divers. Moreover, the trainings were conceived so as to select the most motivated volunteers. Finally, the considered species are quite easy to be identified due to strong differences in shape and colours. In order to assess the reliability of the collected information, the data were subjected to both automatic and manual quality checks (see Cerrano et al. 2017 for details).

The resulting data set comprises separate records for each single species found by each observer in a diving site. Diving sites were localised using geographical coordinates (Datum WGS84) and a minimum accuracy of ± 6′′ (= ± 0.00167°) was assured. In most of the cases, data records include the minimum and maximum depth at which the species was found.

Data analysis

A general analysis on the spatial distribution of the data gathered according to the three main typologies (i.e., SCI, WWW and CS) was performed aggregating records by a 15′ grid (= 0.25°, i.e., 15 nautical miles in latitude). The proportion of the three typologies in each grid cell has been graphically represented using a ternary colour scale (Red, Green and Blue). Taking into account the chosen minimum required positioning accuracy, detailed species distributions and their depth range were analysed by pooling together multiple observations within a 15′′ grid (= 0.00417°, i.e., 1⁄4 of nautical mile in latitude). Vertical frequency distributions were calculated by summing the observations from all grid cells and species, between the minimum and maximum-recorded depths, one-meter step.

Spatial analyses and mapping were done using QGIS (QGIS Development Team 2017), while statistical analyses and plots were performed in R (R Core Team 2017). The distribution of coral species were compared with those of MPAs, the boundaries of which were obtained by the World Database on Protected Areas (WDPA; www.protectedplanet.net, last accessed on the 16th February 2015). The consistency of the WDPA in the eastern Mediterranean basin is still low, but it is enough to get an overall idea of the conservation status of the analysed area.

C. rubrum, E. cavolini, P. clavata and S. savaglia are typical of Mediterranean coralligenous habitats (Ballesteros 2006) and their geographic distribution should be closely related to the environmental conditions that promote the development of these biogenic reefs. In order to corroborate this hypothesis, the occurrence of these species were compared to the probability of occurrence of the coralligenous habitat estimated by a prediction model based on environmental variables (e.g., seafloor bathymetry and slope, bottom salinity and temperature, nutrients, distance to port) provided by Martin et al. (2014). For each 15′′-grid cell that included one or more of these four typical coralligenous species, the probability of coralligenous habitat occurrence as calculated by the model was assigned. The probability of occurrence of coralligenous habitats associated with the verified presence of typical coralligenous corals was mapped and analysed in terms of frequency distribution.

Analysis of the amateur videos published on the web

As mentioned above, part of the data on the coral distribution (*P. clavata, S. savaglia, E. cavolini, E. singularis* and *C. rubrum*) were obtained through the analysis of 42 videos taken at 30 sites between the eastern Adriatic Sea and the Apulian coasts (when surfing the Web, videos on other CEM localities were not found). The majority of the videos were taken between 30 and 60 m depth.

Pictures and videos also allowed the estimation of the percentage of the two chromatic variations in *Paramuricea clavata*, which can be monochromatic (purple form) or dichromatic (yellow-purple form, Weinberg 1977). *P. clavata* colour data was available only for a small subset of the data set and, therefore, it was analysed separately.

Additional information about occurrence of fishing lines and coral substrates preferences was given. In particular, semi-quantitative observation frequency of fishing line was estimated by selecting clips where the substrate was visible, avoiding open water footages or macro framings, and establishing the following categories of frequency: absent (no fish- ing lines); occasional (< 1 fishing line in 1′ of video); frequent (1–2 fishing lines in 1′ of video); very frequent (> 2 fishing lines in 1′ of video). Notes on signs of damage were also taken. Substrate preference was determined for each species as percentage of colonies living on horizontal/sub-horizontal substrates and colonies living on vertical walls.

RESULTS

The first result of this work was the creation of a database containing the information on geographical and depth distributions of *Eunicella cavolini, E. singularis, E. verrucosa, Leptogorgia sarmentosa, Paramuricea clavata, Corallium rubrum* and *Savaglia savaglia* in the CEM. The database includes 1257 records gathered from data collected from 1862 to 2015 (Fig. 3a), which are all listed with their sources in Supplementary Data S1.

The majority of the information comes from SCI (about 79%), while about 10% of the data was obtained by CS. Over 11% of the data was taken from the WWW, although the information obtained by interviewing the staff of dive centres was scant (of about 100 dive centres contacted, only 20% answered). Retrieved data were not evenly distributed in the investigated area, nevertheless the distribution map clearly show the high complementarity of these three data sources, despite a prevalence of data from SCI (Fig. 4). Considering the spatial distribution of the selected species in the CEM at high resolution, investigated coral species were found in 983 15′ grid cells. Most of these cells enclosed only one species (86.8%), more than one species per cell was very rare (2 = 8.5%, 3 = 3.1%, 4 = 0.8%, 5 = 0.7%, 6 = 0.1%), and in no case were all seven species found in the same cell (Fig. 3b). The localities with higher numbers of recorded species per cell include Leuca (the boundary between the Ionian and Adriatic Sea) and Telašćica Nature Park (Croatia), both with 6 species (all except *L. sarmentosa*); several places along the Ionian and Adriatic coasts of the Apulian region (5 species); and Pantelleria Island (Sicily, 5 species).

Only 211 (16.8%) out of 1257 records (Fig. 3c) were within priority conservation areas (e.g., Adventure and nearby banks, Southern Strait of Sicily, North and Central Adriatic Sea, Leuca, Northeastern Ionian, Thracian Sea, Northeastern Levantine Sea and Rhodes Gyre, UNEP/MAP-

RAC/SPA 2010) or protected areas (e.g., Telašćica Nature Park, Kornati National Park, Lastovo Archipelago Nature Park, National Marine Park of Alonissos Northern Sporades, MPAs of Isole Tremiti, Porto Cesareo, Mljet, and Pelagie).

The distribution of species typical of coralligenous habitats (i.e., *C. rubrum, E. cavolini, P. clavata* and *S. savaglia*) was strongly related with the occurrence of environmental conditions that promote the development of these biogenic reefs, as predicted by the habitat suitability model provided by Martin et al. (2014), particularly along the eastern coasts of the Adriatic Sea (Fig. 3d). Indeed, in 415 15′′ grid cells containing at least one of these indicator species, the estimated mean probability of occurrence of coralligenous habitats was 0.689 ± 0.165 SD and its frequency distribution was largely skewed towards higher probabilities Fig. 5). Practically, 56% of the grid cells in which the presence of these corals was verified have more than 70% of probability to accommodate coralligenous habitats according to the environmental features considered in the habitat suitability model proposed by Martin et al. (2014).

Coral spatial distribution

Excluding the Sea of Marmara, which comprises over 44% of the grid cells hosting at least one coral species (almost all referred to *S. savaglia* from Artüz et al. 1990), the eastern side of the Adriatic Sea was the area with the highest number of records (about 30% of the cells); on the contrary, the western side of this sub-basin included just 7% of the findings. The Ionian Sea comprises 6% of the cells, mainly concentrated along the Ionian Apulian coasts, while the cells from the Aegean Sea (8%) were localized mainly in the northern basin. Few reports came from western Sicily and Tunisia (4%) and the Levantine basin (1%).

The distribution of the records of each species is illustrated in Fig. 6a–d. The species present in the smallest number of grid cells (1.5%) was *L. sarmentosa*, which was mainly reported along the Adriatic coasts, followed by *E. verrucosa* (4.8%), mainly on the eastern Adriatic and Apulian coasts, and E. singularis (5.9%, north-eastern Adriatic, Apulian coasts, North Aegean Sea, western Sicily and Tunisia). In contrast, the most recorded species were *C. rubrum* (11.3%, common in all the CEM except the western Adriatic Sea and Tunisian coasts), *E. cavolini* (17.4%, common in all the CEM except the north-western Adriatic Sea), *P. clavata* (17.4%, mainly in eastern Adriatic, Apulian coasts and Aegean Sea) and *S. savaglia* (62.2%, eastern Adriatic, Apulian coasts and, most of all, the Sea of Marmara).

The most frequent association was that between *P. clavata* and *E. cavolini*, followed by *P. clavata* and *S. savaglia,* then *E. cavolini* and *E. singularis* (Table 1).

Bathymetric distribution

The bathymetric distribution of the considered species is shown in Fig. 7. The species with the widest bathymetric range was *C. rubrum*, which was mainly found from 20 m to 200 m; however, deep colonies of red coral have been reported off Linosa Island (deeper than 800 m, Costantini et al. 2010) and recently from Maltese Islands (down to 1016 m, Knittweis et al. 2016). A wide depth range was also shown for *E. cavolini* (from 4 to 220 m of depth) and *E. singularis* (from 5 to 170 m); on the contrary, *E. verrucosa* (12–90 m), *L. sarmentosa* (10–61 m), *P. clavata* (15–105 m) and *S. savaglia* (15–90 m) showed a narrower bathymetric interval. Most of the records (about 35%) fall between 50 and 100 m.

Additional information gathered from amateur videos

Video analysis allowed estimating the distribution of two different chromatic variations in *Paramuricea clavata* along the Adriatic and Apulian coasts, highlighting that mono-chromatic populations (purple) were more common (about 60%) than dichromatic (yellow-purple) populations (about 40%) (Fig. 8a). When present, the dichromatic colonies generally dominated the populations, varying from 63% (Capraia, Tremiti Islands) to 100% (Sant'Andrea, Gallipoli). The only exception was Leuca (Apulia), where the yellow-purple colonies represent 1%.

P. clavata was present in 34 of the 42 videos analysed (81%), forming dense forests in Leuca (Apulia) and Vodenjak. Retrieved videos recorded dense populations of *Corallium rubrum* in Otranto (Apulia) and on Otok Sveti Andrija (Croatia). The most peculiar site was the Rivanjski Kanal, where scattered rocks exposed by strong currents stretch out on a sandy seabed at 20–30 m depth (www.ronjenjehrvatska.com). Here, small but abundant colonies of *P. clavata* shared the habitat with dense populations of many other invertebrates and the protected seagrass *Posidonia oceanica* (Linnaeus) Delile, 1813 (Boudouresque et al. 2012).

The presence of fishing lines was observed in 55% of the videos, with the highest frequency at 'Secca delle Gorgonie' (Otranto), Porto Cesareo MPA (Apulia), Rivanjski Kanal, Kampanel, and Otočić Blitvenica (Croatia) (Fig. 8b). Moreover, several colonies of *P. clavata* from the Croatian localities Plić Tenki (Krk) and Kampanel (Hvar), as well as *E. cavolini* from Bijelac (Lastovo) were heavily colonized by other sessile organisms, suggesting that the colonies had been likely damaged in the past. Concerning the substrate preferences, *C. rubrum, E. cavolini* and *P. clavata* were observed mostly on vertical walls (93, 69 and 62% of the colonies, respectively), while *E. singularis* and 85% of *S. savaglia* were found on horizontal/sub-horizontal substrates.

DISCUSSION

This work highlights how the collection and the combination of data from different sources, including WEK, provide new insights about the geographical distribution and abundance of important habitat-forming corals living in the eu- and mesophotic zone of the Central-Eastern Mediterranean Sea. This approach and related results are basilar to support the evaluation of biodiversity and its ecosystem services, to adequately address conservation and restoration policies (TEEB, an interim Report 2008).

Cross-validation of data from literature, citizen science and the WWW allowed the identification of some valuable naturalistic areas with great richness of the considered species. Only a few of a number of dive centres consulted for this study opted to collaborate, highlighting the importance to increase their awareness towards science and research activities. The inclusion of adequate ocean literacy programs in the teaching protocols should sound as a priority in the diving system worldwide.

In the present work, the information obtained through the WWW and CS, representing over 20% of the dataset, is congruent with that collected by scientists. Citizen science pro- duces most of the terrestrial biodiversity observations (Groom et al. 2017), with a notable potential for growth in volunteer recruitment even in the field of the marine citizen science (Martin et al. 2016). However, data collected through CS are not always openly available for reuse (Groom et al. 2017). On the contrary, the WWW contains an unintentional and disorganized huge databank that is freely accessible. The steps illustrated in Fig. 2 simplify and shorten the process to retrieve data useful for scientific purposes through search engines.

Videos published on the WWW can provided additional information allowing to (i) extract species diversity data at local scale, (ii) detect changes in time in the most popular dive sites, (iii) find unexpected interactions between species, (iv) locate particularly vulnerable sites, (v) detect the presence of lost fishing lines and damaged colonies, all this without the costs of a true field expedition. Videos are useful to establish which areas should be scientifically monitored due to their species richness or to evident anthropogenic impact. Since videos may provide additional information compared to photographs and visual observations, simple standard protocols for video recording should be included in marine CS programs to obtain comparable images in different locations and times. Videos by trained amateurs, as well as all CS data, should be shared on the WWW to be freely available to scientists.

Differences between the coral populations in the CEM

The gap of detailed knowledge on habitat and species distribution in the Central-Eastern Mediterranean basin is feeding the theory that in the Eastern Mediterranean there is a lower species diversity compared to the Western basin. Our analysis highlights a discontinuous distribution of the considered species, with an eastwards decrease in species diversity, at least regarding the photic zone. The scarce number of findings from the Levantine basin is probably related to several factors, including ultra-oligotrophy (Danovaro et al. 2010; UNEP/MAP-RAC/SPA 2010; Coll et al. 2012; Lavigne et al. 2015), which is mainly due to its water circulation and scarce riverine discharge (Galil and Zenetos 2002; Krom et al. 2010). The low diversity could also be due to the complex geological history of the Levantine basin, characterized by a more frequent environmental instability (Fink et al. 2012), and to more frequent episodic mortality events, as documented by the highest frequency of sapropel layers in the sea bottom sediments (Grimm et al. 2015).

Along the Croatian coasts we collected 30% of the records, where the peculiar geo- morphology, with numerous bays and channels between the islands, leads to a complex circulation system, local effects of winds, tidal currents, anthropogenic pressures, and underground river discharge (Morovic et al. 2004; Viličić et al. 2011; Vidjak et al. 2012; Ninčević-Gladan et al. 2015).

The north-western and central-western Adriatic Sea is characterized by shallow and turbid waters and mainly sandy bottoms (Artegiani et al. 1997a, b; Giordani et al. 2002; Civitarese et al. 2010; UNEP/MAP-RAC/SPA 2015). In the northern Adriatic Sea the rarity of corals could be due to the peculiarity of the substrate, consisting in recent biogenic outcrops (Ponti et al. 2011; Falace et al. 2015; Fava et al. 2016), but also to frequent episodes of hypoxia/anoxia (Stachowitsch 1984, 1991; Djakovac et al. 2015) or disease (Stachowitsch 1991; Di Camillo et al. 2013, 2015). Moreover, the northern basin is subjected to trawling and dredging fishing activities that, besides the direct impact on the corals, cause resuspension of sediments that could trigger and/or enhance the intensity and duration of hypoxic crises (Tudela 2004). However, there is no evidence that habitat-forming corals were abundant in this area in the past. Moving southwards, corals (and coralligenous habitats, Martin et al. 2014) are almost absent along the Ionian coasts of Calabria. Here, the abruptness of the shelf, together with the conspicuous riverine loads and the strong seismicity and instability of the area (Gallignani 1982; Martorelli et al. 2014), affect the morphological dynamics along the Ionian coast (Morelli et al. 2009) and probably make this area unsuitable for corals and other long-living benthic species. Contrary to the Ionian coasts of Calabria, Apulia is rich in habitat-forming corals. The Apulian coasts are characterized by a wide and stable shelf where terraces, coralline algal banks and bioclastic sands are common (Martorelli et al. 2014); these are also found quite far from the coast, in the mesophotic zone up to 50–80 m depth. The low sedimentation and the higher stability of the Apulian shelf allow the occurrence of well-developed coralligenous assemblages (Martorelli et al. 2014).

The Sea of Marmara hosts dense coral forests. This semi-enclosed sea is characterized by waters with strong differences in salinity coming from the Mediterranean and Black Seas, and deep depressions and sills that give rise to a peculiar two-layer current system (Beşiktepe et al. 1994; Chiggiato et al. 2012). A halocline separates an upper layer com- posed of brackish and oxygenated waters from a denser and less oxygenated water body. Gradients of temperature, salinity and oxygen represent boundaries for the distribution of benthic organisms (Chendeş et al. 2004). The particular hydrology of the area makes the conditions to develop a unique (Öztürk and Öztürk 1996; Topçu and Öztürk 2013) but poorly explored biota. Since the marine life of the basin is seriously threatened by agricultural and industrial run-off, maritime traffic, oil spills, and fishery and anthropogenic discharges (Polat et al. 1998; PAP/RAC 2005; Caglar and Albayrak 2012), it is urgent that studies be carried out on the biodiversity of this area to support coastal management.

Comparison between corals in the WM and the CEM

There are many differences in the distribution of corals in the WM and the CEM. The spatio-temporal distribution and the dynamics of the considered species may depend on the variability at local scale of several abiotic (depth, light intensity, current, temperature, substrate topography, sedimentation rate) and biotic (predation, competition, recruitment, food preferences) factors (Weinberg 1975, 1979, 1980; Weinbauer and Velimirov 1996; Cocito et al. 1997; Gili and Coma 1998; Gori et al. 2011, 2013), as well as on mechanical disturbances (Linares et al. 2008; Markantonatou et al. 2014), water temperature anomalies (Rossi et al. 2011) and mass mortalities (Cerrano et al. 2005; Garrabou et al. 2009; Vezzulli et al. 2013). Some differences between the assemblages in the WM and the CEM, useful for predicting habitat suitability of habitat-forming corals, are highlighted in Supplementary Material S2.

Distribution of corals, marine protected areas, and coralligenous habitats

Concerning the protection status, the CEM coasts can be considered “areas of conservation concern” (Coll et al. 2012), where high biodiversity and cumulative threats overlap. The considered coral species are long-living but slow-growing invertebrates (Mistri and Cec- cherelli 1994; Bramanti et al. 2005), with low recruitment rates (Cupido et al. 2008). Sea fans are key species in the coralligenous assemblage and most of these show low resilience to mortality events (Coma et al. 2004; Garrabou et al. 2001) and there is no possibility to recover damaged portions when colonized by pioneer species (Bavestrello et al. 1997). Due to their ecological importance and their low resilience, sea fans are worthy of greater attention, and small scale studies on their population structure should be encouraged.

Among the mentioned species, both *Corallium rubrum* and *Savalia savaglia* are under protection (Table 2) The red coral has been also proposed for inclusion in Appendix II of the Convention on International Trade in Endangered Species (CITES 2010); however, the species has not yet been included in this list (https://cites.org/eng/app/appendices.php. Last accessed in November 2017). The red coral is mainly threatened by overexploitation and illegal harvesting in many areas of the Mediterranean Sea and at present there are no adequate protection measures to assure its sustainable fishing (Kružić 2007; Kružić and Popijač 2009; Deidun et al. 2010; Tsounis et al. 2010, 2013). The Mediterranean red list of the International Union for Conservation of Nature considers only *C. rubrum* as “endangered” (IUCN ver 3.1, http://www. iucnredlist.org/initiatives/ mediterranean, Table 3). However, all the considered species are threatened by harvesting, fishing, pollution, anchoring, mucilage aggregates and climate change (Bavestrello et al. 1994, 1997; Coma et al. 2006; Linares et al. 2008). Fishing lines have been observed in over half of the examined videos, with high densities even in protected areas, suggesting that surveillance of MPAs is not enough to preserve coralligenous and coral forests. Injuries due to fishing line entanglements are likely involved in a reduction of the resilience of the colonies to several stressors (Vezzulli et al. 2013).

According to the “Action plan for the protection of the coralligenous and other calcareous bio-concretion in the Mediterranean Sea” (UNEP/MAP-RAC/SPA 2008), the coralligenous is worthy of protection at the same level as posidonia meadows and should be considered as a priority habitat in the European Habitats Directive (Directive 92/43/EEC). Most of the species considered in this work are typical of the coralligenous outcrops (Ballesteros 2006; Martin et al. 2014; and Fig. 3d); indeed, our analysis shows the high probability of co-occurrence of corals and coralligenous habitats.

Our data is a useful inventory of the localities where sea fans spread and could be employed to define sites of particular naturalistic interest. The results of this work high- light that less than 17% of the grid cells hosting habitat-forming corals are in priority conservation areas, demonstrating that most of the corals in the CEM are in urgent need of protection.

CONCLUSIONS

The bulk of the supplied data could support the modelling of a spatial distribution, and, at the same time, highlight that further studies conducted at a local scale (Bakran-Petricioli et al. 2006) should be boosted to assess the plasticity of each species and delimit their ecological niche. The validity of these spatial models is weak when the scale is at basin or global level. Stronger results must be developed merging several local analyses (Zapata et al. 2016). Much attention should be given to places where corals were not recorded, or those areas which have been only poorly or never explored (for example, Cyprus).

Notwithstanding data from SCI represent the major contribute to the dataset, it is evi- dent the huge potential of data shared on the WWW to integrate scientific research even in case of little funding for fieldwork. Since many dive spots are mostly frequented by recreational divers rather than scientists, it is more likely that non-scientific divers were in the right place at the right time to unintentionally record species, peculiar behaviours or responses to unpredictable disturbance events. For this reason, the diving system could address specific commercial strategies focused on the potential of CS projects. The WEK is easily and freely accessible, constantly updated, and it is expected to grow.

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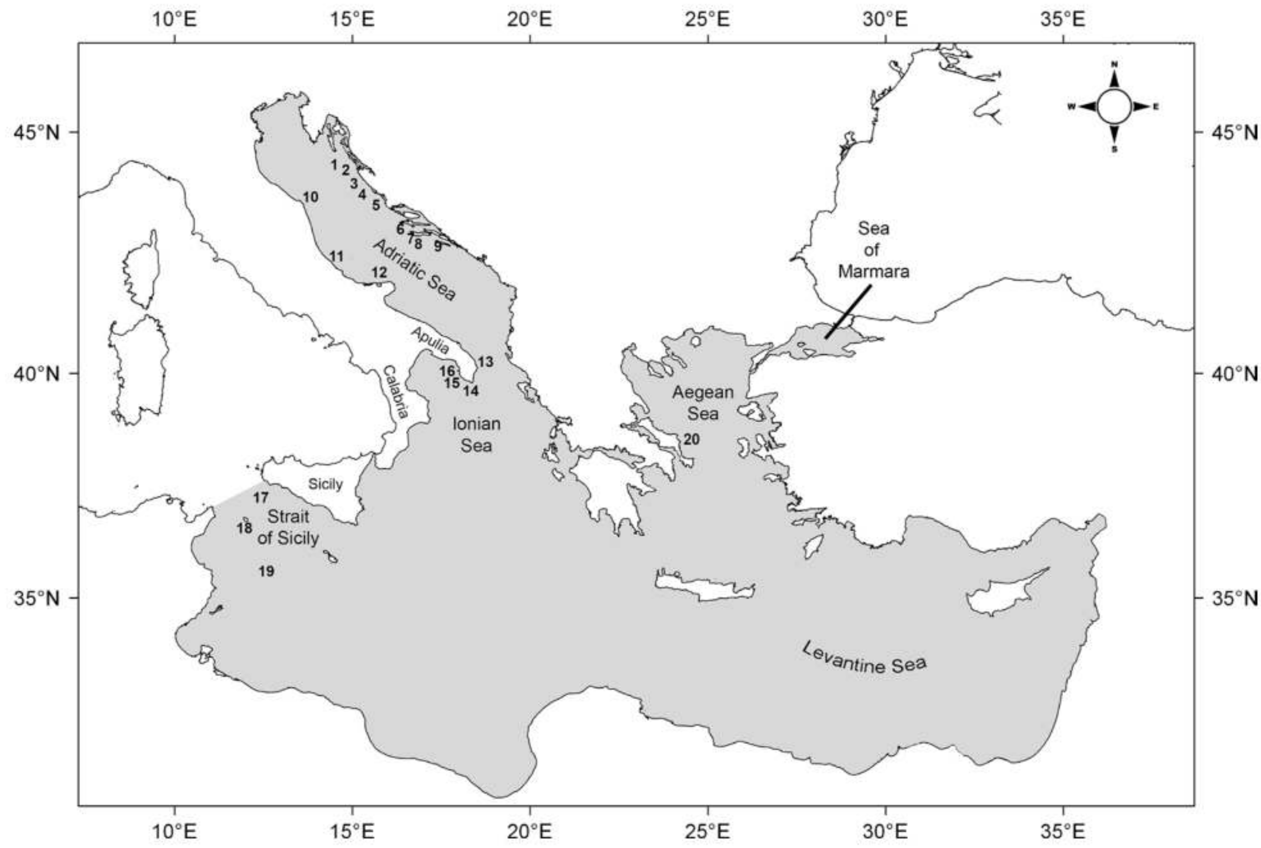

Fig. 1 Map of the study area (Central-eastern Mediterranean Sea, in grey) and its sub-basins (Mercator projection, datum WGS84). Numbers indicate the localities mentioned in the text: 1 Vodenjak 2 Rivanjski Kanal 3 Telašćica Nature Park 4 Kornati National Park 5 Otočić Blitvenica 6 Otok Sveti Andrija 7 Korčula 8 Lastovo Nature Park 9 Mljet MPA (Croatia) 10 Conero 11 Ortona 12 Tremiti Island MPA 13 Otranto 14 Leuca 15 Sant'Andrea 16 Porto Cesareo AMP 17 Adventure and nearby banks 18 Pantelleria 19 Pelagie MPA (Italy) 20 National Marine Park of Alonissos (Greece)

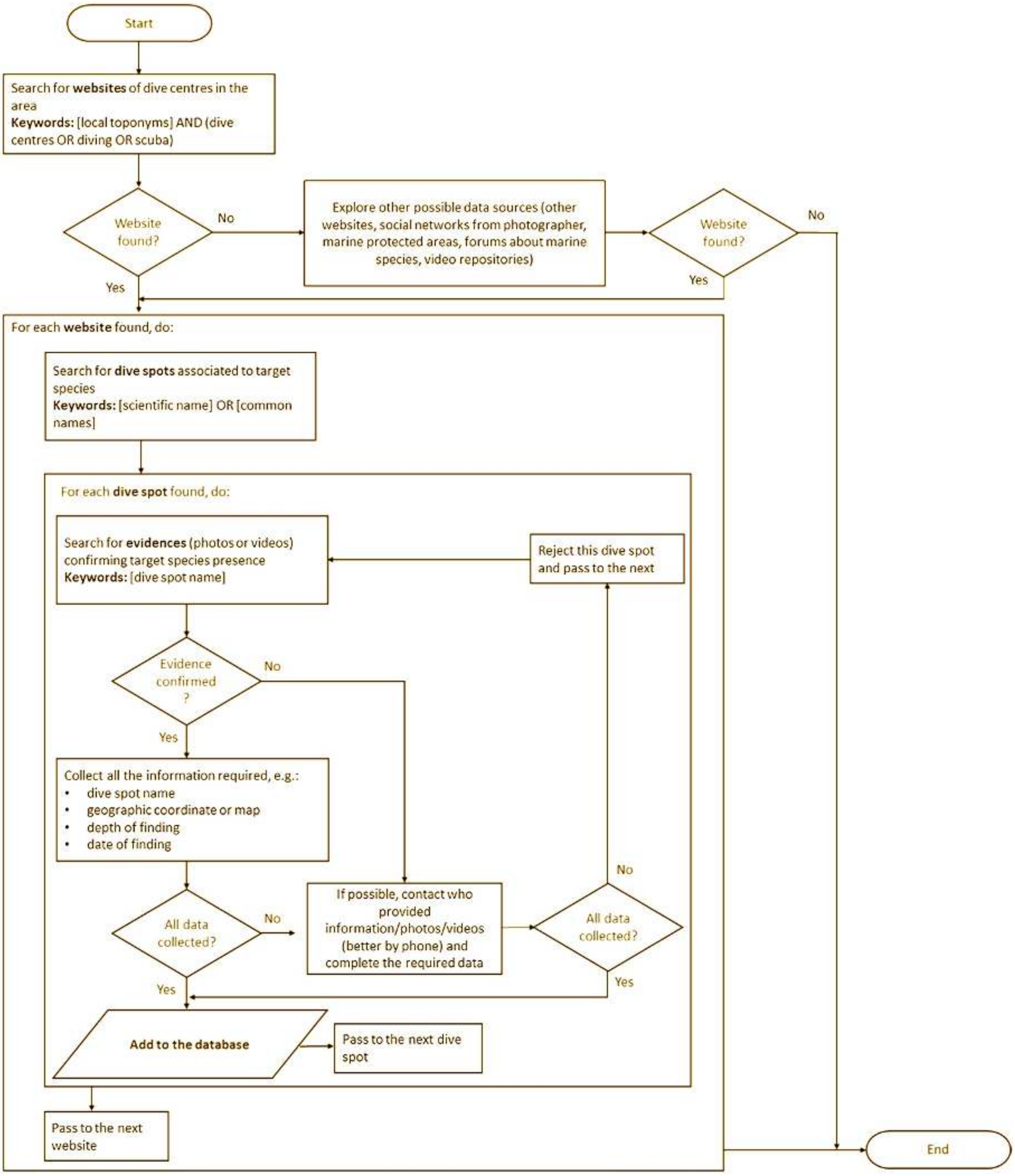

Fig. 2 Scheme summarizing the steps followed to retrieve information about species distribution from the WWW.

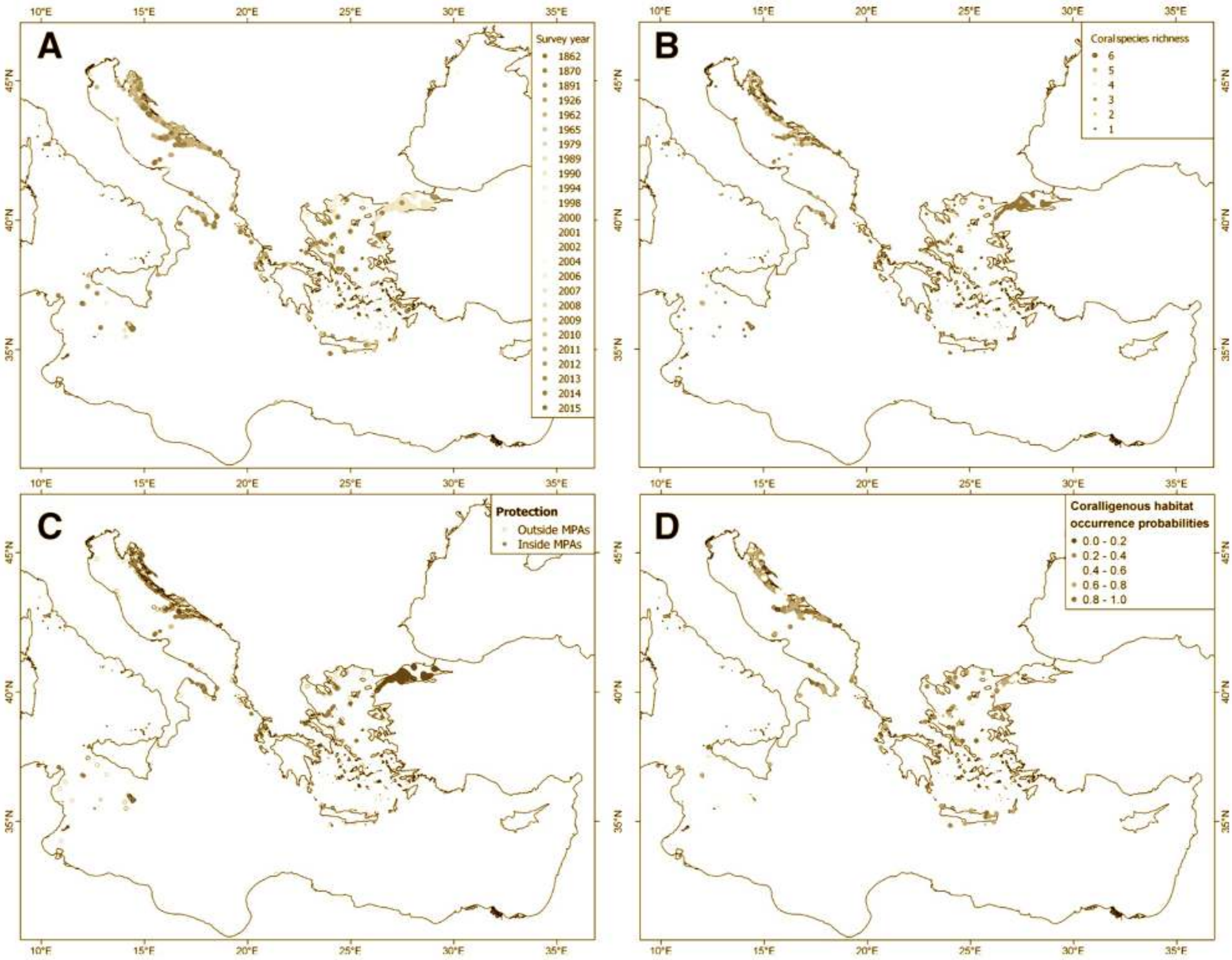

Fig. 3 a Temporal and spatial distribution of the obtained records; b Coral species richness in the 983 15′′- grid cells; c Records of corals into (red, about 17%) and outside (blue) priority conservation areas; d Coralligenous habitat occurrence probabilities, estimated by a prediction model based on environmental conditions (Martin et al. 2014), within cells containing typical coralligenous corals: *Corallium rubrum, Eunicella cavolini, Paramuricea clavata* and *Savalia savaglia.*

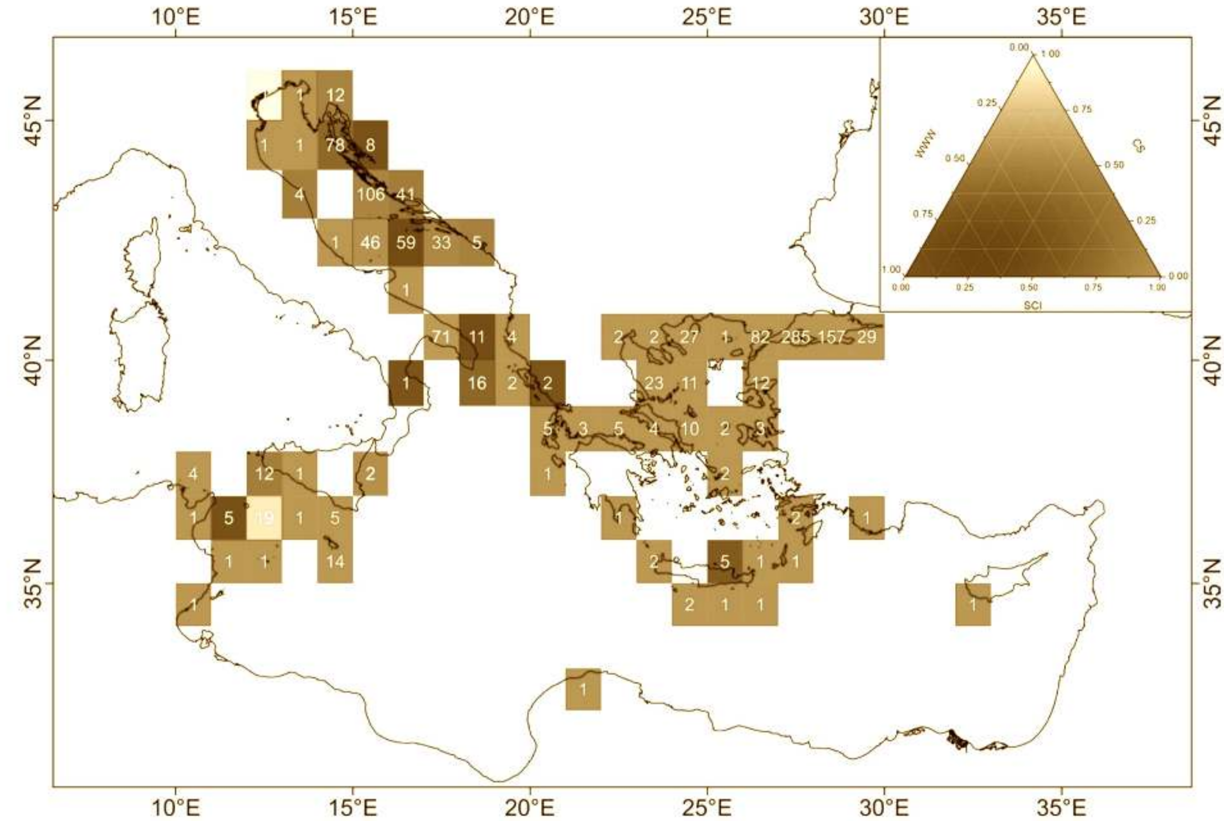

Fig. 4 Geographic distribution of the 1257 records, summarised in 68 15′-grid cells. The proportion of the three typologies (SCI, CS, WWW) in each grid cell has been represented using a ternary colour scale (Red, Green and Blue).

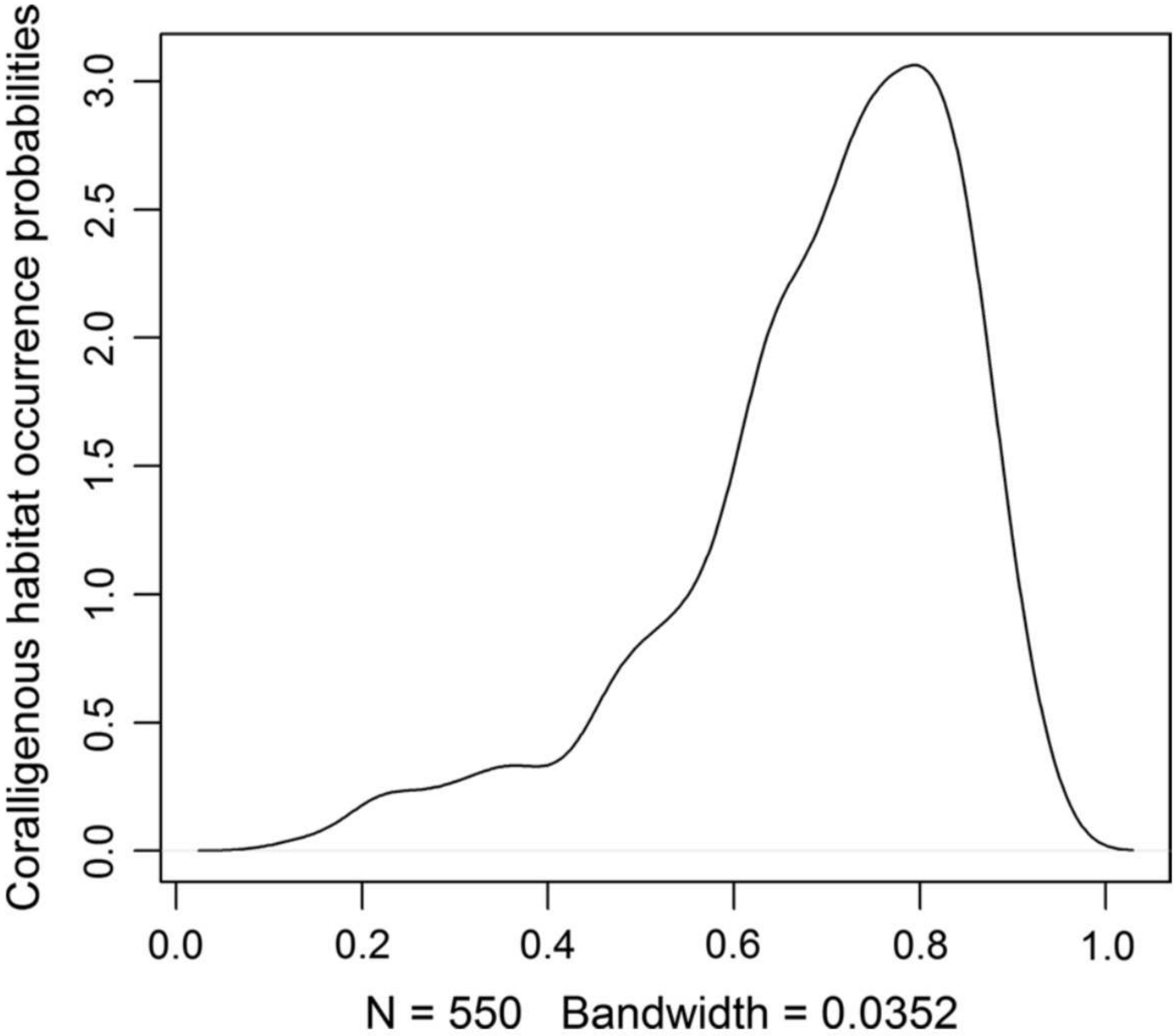

Fig. 5 Frequency distribution of coralligenous habitat occurrence probability in 415 15′′-grid cells containing at least one of the four coral species typically associated with this habitats: *Corallium rubrum, Eunicella cavolini, Paramuricea clavata* and *Savalia savaglia*

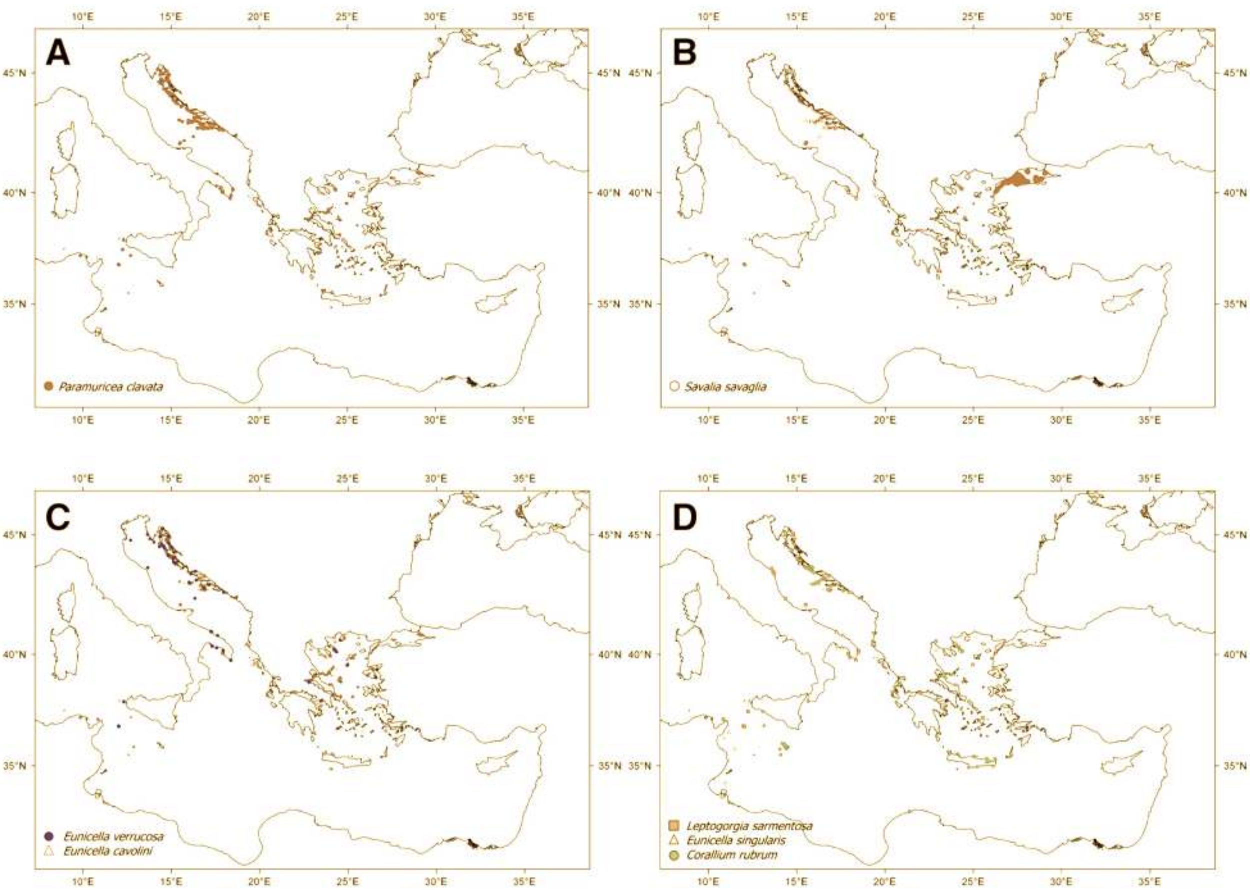

Fig. 6 Distribution of the considered coral species in the CEM (15′′-grid cells): P*aramuricea clavata* (a), *Savalia savaglia* (b), *Eunicella cavolini* and *E. verrucosa* (c), *Leptogorgia sarmentosa, E. singularis* and *Corallium rubrum* (d).

	S. savaglia (%)	*E. cavolini* (%)	*P. clavata* (%)	*C. rubrum* (%)	*E.singularis* (%)	*E. verrucosa* (%)
Eunicella cavolini	12.3					
Paramuricea clavata	35.4	45.4				
Corallium rubrum	6.2	10.8	12.3			
Eunicella singularis	6.9	29.2	15.4	4.6		
Eunicella verrucosa	3.1	15.4	9.2	3.1	13.1	
Leptogorgia sarmentosa	2.3	3.8	2.3	1.5	3.8	0.0

Table 1 Percentage of pair-associations of the total number of grid cells with two or more species (n = 130)

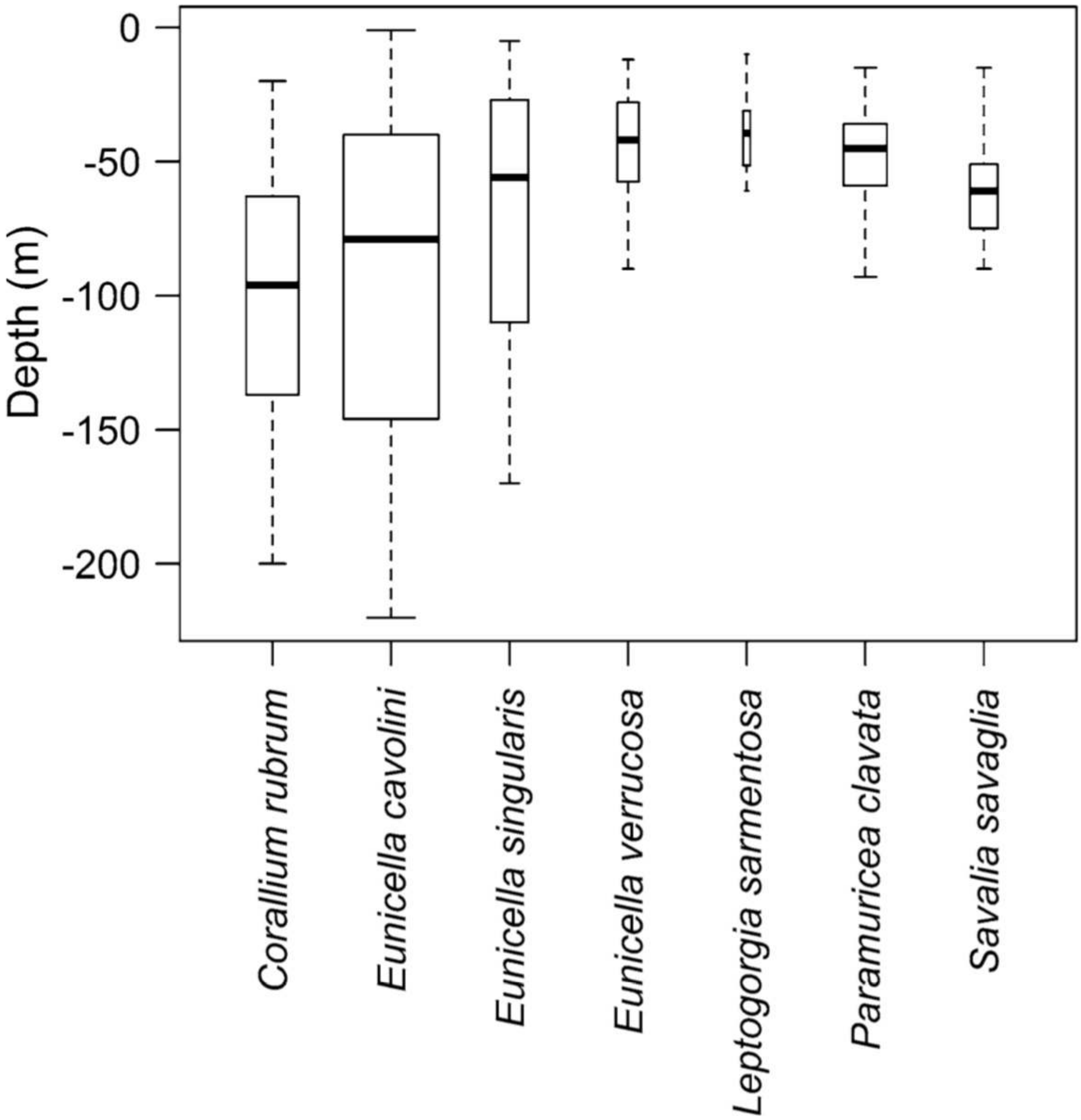

Fig. 7 Bathymetric distribution of the considered coral species

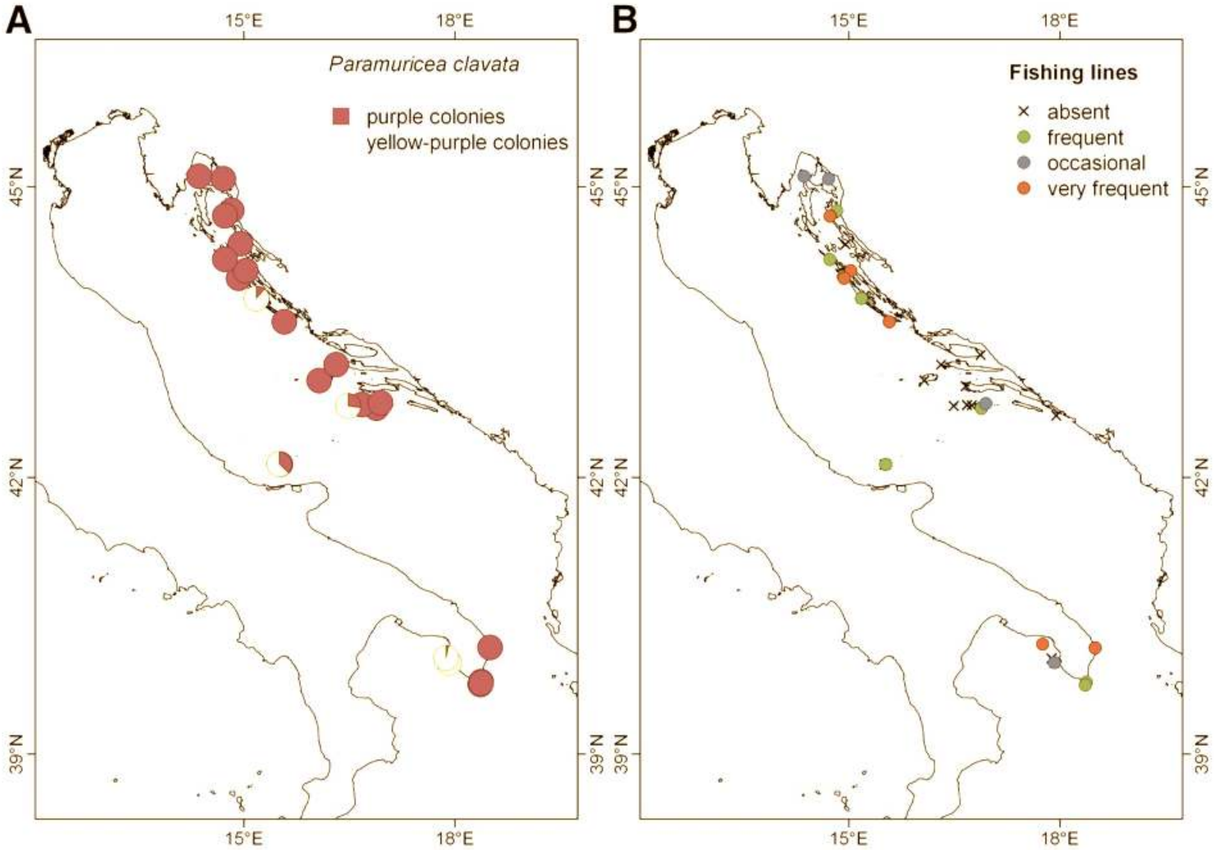

Fig. 8 Data obtained by the analysis of the YouTube videos taken along the Adriatic and Apulian coasts. a Distribution and mean percentage of monochromatic (purple) and dichromatic yellow-purple colonies of *Paramuricea clavata*; b Observation frequency of fishing lines.

Species	Regulation/convention		
	Bern convention on the conservation of European wildlife and natural habitats, 1979	Protocol concerning Mediterranean specially protected areas and biological diversity SPAMI 1995, after Barcelona convention 1976	European habitat directive 92/43/EEC
Eunicella cavolini	–	–	–
Eunicella verrucosa	–	–	–
Leptogorgia sarmentosa	–	–	–
Paramuricea clavata	–	–	–
Savalia savaglia	Annex 2	Annex 2	–
Eunicella singularis	–	–	–
Corallium rubrum	Annex 2	Annex 3	Annex 5

Table 2 Protection status of the considered species

Species	Categories	Population trend
Eunicella cavolini	Near threatened	Decreasing
Eunicella verrucosa	Near threatened	Decreasing
Leptogorgia sarmentosa	Least concern	Unknown
Paramuricea clavata	Vulnerable	Decreasing
Savalia savaglia	Near threatened	Decreasing
Eunicella singularis	Near threatened	Decreasing
Corallium rubrum	Endangered	Decreasing

Table 3 Status of the considered species according to the Mediterranean red list of the International Union for Conservation of Nature (IUCN ver 3.1, http://www.iucnredlist. org/ initiatives/mediterranean)