

Mediterranean Marine Science

Vol 22, No 2 (2021)

VOL 22, No 2 (2021)



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doi: [10.12681/mms.25125](https://doi.org/10.12681/mms.25125)

To cite this article:

CONSOLI, P., ALTOBELLI, C., PERZIA, P., BO, M., ROSSO, A., ALONGI, G., SERIO, D., CANESE, S., ROMEO, T., & ANDALORO, F. (2021). Species and habitats of conservation interest in the Ecologically and Biologically Significant Area of the Strait of Sicily: a contribution towards the creation of a Specially Protected Areas of Mediterranean Importance. *Mediterranean Marine Science*, 22(2), 297–316. <https://doi.org/10.12681/mms.25125>

Species and habitats of conservation interest in the Ecologically and Biologically Significant Area of the Strait of Sicily: a contribution towards the creation of a Specially Protected Area of Mediterranean Importance

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Contributing Editor: Vasilis GEROVASILEIOU

Received: 22 October 2020; Accepted: 5 March 2021; Published online: 10 May 2021

Abstract

In 2015, the Strait of Sicily, which includes several banks, was candidate as a future Specially Protected Area of Mediterranean Importance (SPAMI) by the Contracting Parties of the Barcelona Convention. In this context, the present study aims to provide the first biological and ecological characterisation of this poorly known area, focusing on habitats and species of conservation concern. Surveys were carried through a remotely operated vehicle (ROV) and allowed the identification of 19 habitat types, mostly considered of priority interest by the SPA/BD Protocol of the Barcelona Convention. A total of 269 taxa were also identified, mostly Porifera, Cnidaria and Pisces, among which 115 species are of conservation concern according to the IUCN (IUCN) Red Lists, the Habitats Directive, the Bern Convention, the SPA/BD Protocol and CITES. ROV surveys allowed some interesting observations on poorly known species and habitats. Results underlined that remarkable discrepancies in species conservation status assessment exist between the several lists of protected species considered. The IUCN Red Lists, although not legally binding for European States, are the most complete, but, in spite of this, the conservation policies in the EU are largely focused on the Habitats Directive, which is really not exhaustive. An exhaustive and legally binding instrument to protect species of conservation concern at European scale is highly recommended. Acquired results could be useful for the delimitation of a future SPAMI or a network of Marine Protected Areas (including the investigated banks) and the identification of zones within them suitable for different area-based management measures.

Keywords: Biodiversity; environmental protection; epibenthos; habitat; Habitats Directive; IUCN Red List; Mediterranean Sea banks; SPA/BD Protocol.

Introduction

The Mediterranean Sea is considered a hot spot of biodiversity with approximately 17,000 marine species (Coll *et al.*, 2010; Costello *et al.*, 2010). Since the beginning of the Anthropocene, following the industrial revolution, biodiversity loss accelerated massively (Rockström *et al.*, 2009a, 2009b) impacting marine ecosystem services, and increasingly impairing the ocean's capacity to provide food, maintain water quality, and recover from

perturbations (Worm *et al.*, 2006; Danovaro *et al.*, 2008; Cardinale *et al.*, 2012; Hooper *et al.*, 2012).

In the last decades, the deficient conservation status of many biota has led to initiatives aimed at halting the loss of biodiversity (Ban *et al.*, 2014; Boyes & Elliot, 2014). The main international actions for the protection of coastal and marine habitats are the Washington Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; UNEP, 1973), the Bern Convention (Conservation of European Wildlife and Natural Habi-

tats; Council of Europe, 1979), the United Nations Convention on Biological Diversity (CBD; UNEP, 1992), the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD Protocol) of the Barcelona Convention (UNEP/MAP, 1995) and the International Union for Conservation of Nature (IUCN, 2015). The Habitats Directive (EU, 1992) and the Birds Directive (EU, 2009), allowing the establishment of the largest continent-wide Natura 2000 network of Special Areas of Conservation (SACs; Hochkirch *et al.*, 2013), and the Marine Strategy Framework Directive (EU, 2008) are among the most important European Union directives on this topic.

In the Mediterranean Sea, the SPA/BD Protocol of the Barcelona Convention (UNEP/MAP, 1995) led to the establishment of 32 Specially Protected Areas of Mediterranean Importance (SPAMIs), in order to promote cooperation in the management and conservation of natural areas, as well as in the protection of threatened species and their habitats.

In 2015, during the second meeting of the RAC/SPA (Regional Activity Centre for Specially Protected Areas), established by the Contracting Parties to the Barcelona Convention and its Protocols in order to assist Mediterranean countries in implementing the SPA/BD Protocol, experts started a review of the existing literature regarding the Strait of Sicily (central Mediterranean Sea) in order to assess the possibility of creating one or more SPAMIs in this area (RAC/SPA, 2008). The Strait of Sicily (or Sicily Channel), which includes several banks (submarine reliefs such as shallows, ridges, knolls, pinnacles and seamounts) of different sizes and origins, has been already recognised as an Ecologically or Biologically Significant Area (EBSA) by the contracting parties of the Convention on Biological Diversity, due to its high naturalistic importance (CBD-COP 12 Decisions, 2014).

In general, banks are ecologically important, especially those located close to, or falling within, the photic zone because they present high productivity, biomass and biodiversity, usually benefitting from enhanced organic inputs under low pollution conditions compared to coastal areas. Moreover, banks are important aggregating zones (feeding, nursery, spawning and/or recruitment areas) for many migratory fish, cetaceans, seabirds and cephalopods (Koslow, 1996; Pitcher *et al.*, 2007; Fiorentino *et al.*, 2011; Kvile *et al.*, 2014). In spite of this, banks are among the least investigated marine areas in the world, due to survey difficulties related to their rough topography, their location (usually offshore), and the vigorous current regime to which they are exposed (Bo *et al.*, 2012a). In the last few decades, however, the employment of increasingly sophisticated remotely operated vehicles (ROVs) has allowed more intensified exploration. Non-destructive ROV surveys have been revealing the high complexity and ecological value of banks, as well as the human disturbances that threaten their environmental status (Bo *et al.*, 2012a; 2014; Angiolillo *et al.*, 2015; Consoli *et al.*, 2016, 2018).

Altobelli *et al.* (2017) evaluated the ecological and biological value of the Graham, Nereo and Pantelleria

Vecchia Banks in the Strait of Sicily and indicated that they represent unknown hot spots of biodiversity threatened by human activities in the wide and diversified 'Sicily Channel' EBSA. According to Altobelli *et al.* (2017) and Consoli *et al.* (2018), fishing, marine debris, invasive alien species and oil and gas extraction represent the major pressures and threats to these banks. Using a semi-quantitative methodology, Altobelli *et al.* (2017) also showed that these banks could represent eligible sites for the implementation of efficient and realistic area-based management measures (SPAMI, MPAs), as expected by the 2015 RAC/SPA meeting to be able to guarantee protection and sustainable use.

In light of this, the main aim of the present research was to provide a useful baseline for the establishment of a future SPAMI associated with these banks by assessing species and habitat diversity with a particular focus on those of conservation concern according to the main international conservation policies.

Material and Methods

Study area

The term 'banks' will be hereafter used to indicate submarine reliefs such as shallows, ridges, knolls and pinnacles. Within banks we also include seamounts, i.e., submarine elevations of volcanic origin occurring in the Strait of Sicily; according to the definition by Staudigel *et al.* (2010) these refer to 'any geographically isolated topographic feature on the sea floor taller than 100 m, including ones whose summit regions may temporarily emerge above sea level, but not including features that are located on continental shelves or that are part of other major landmasses'.

Owing to its location, the Strait of Sicily represents a crucial connection between the Western and Eastern Mediterranean basins. Located between Italy, Tunisia and Malta, it is a vast physiographic structure of about 250000 km² oriented NW-SE between the African continent and Sicily. It consists of continental shelves dissected by regional fault systems to form grabens (the Pantelleria, Malta and Linosa grabens, over 1300, 1500 and 1700 m deep, respectively) and horsts elevating locally into numerous banks. Three of these banks, namely the Graham, Nereo and Pantelleria Vecchia Banks were investigated (Fig. 1). They are located in international waters (UNCLOS, 1982) between Pantelleria Island and the south-western coast of Sicily.

The Graham Bank, along with Terrible Bank and Nerita Bank, is part of a large underwater horseshoe-shaped volcanic relief named the Empedocle Seamount, located between 250 and 500 m in depth. The Graham Bank, in turn, is composed of numerous volcanic cones, mainly aligned NW-SE, including the Ferdinanda Bank. These cones vary widely in both size and depth, most of them having tops located at 45-80 m, except for the Ferdinanda Bank, which rises to 9 m depth (Falzone *et al.*, 2009; Würtz & Rovere, 2015).

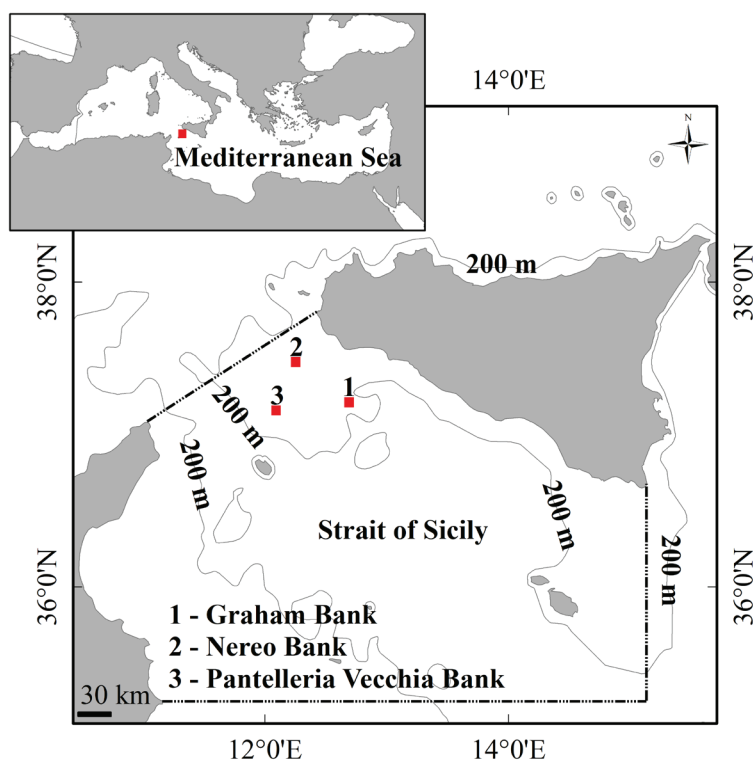


Fig. 1: Investigated banks (square points) of the Strait of Sicily following the official delimitation by the Italian Navy Hydrographic Institute.

The Nereo Bank is one of the numerous shallows on the Adventure Plateau, rising from the wide continental shelf in the north-western sector of the Strait of Sicily (Colantoni *et al.*, 1985). These morphological highs, including the Pantelleria Vecchia Bank, compose the Adventure Archipelago. The Nereo Bank shows a very irregular shape and a rough morphology and consists of three main NE-trending minor shoals parallel to each other and separated by narrow channels. In this study, the main northern ridge was investigated. It is about 3.7 km long and 3.5 km wide, ranging from about 30 m to 60 m in depth (Civile *et al.*, 2008).

The Pantelleria Vecchia Bank is composed of two main shoals, which elevate from 46-60 m to 16-24 m depth, and a number of smaller isolated bathymetric highs (Lodolo & Ben-Avraham, 2015).

Field sampling methods

Surveys were carried out in June-July 2014 and June 2015 by the Italian Institute for Environmental Protection and Research (ISPRA) on board of the R/V Astrea. Surveys were carried out as part of the research project 'Observatory of the biodiversity of the marine and terrestrial environment of the Sicily Region' aimed at developing monitoring techniques to assess protected species and habitats associated with the Nereo, Graham and Pantelleria Vecchia Banks in the Strait of Sicily.

First of all, the study area was mapped using a Kongsberg EM2040 Multibeam echosounder (Kongsberg, Norway); data acquisition frequency was 300-400 kHz with

a 40% lateral overlap. Multibeam data were processed by Caris HIPS 8.1 software. Then, species and habitat diversity were qualitatively investigated by video recordings using an ROV along 14 transects.

The ROV ('Pollux III' Global Electric Italiana) was equipped with several instruments, as already described by Consoli *et al.* (2018).

In order to verify the presence of species of conservation concern undetectable from images, four small samples of coarse biogenic substrate were collected by the ROV grabber in particular habitats (maërl and rhodolith beds) selected by visual census.

Video and data analysis

Overall, 14 transects ranging from 46 to 1760 m length were performed at depths of 20-220 m (perpendicular to the respective isobaths, from bank tops to greater depths) for a total distance of approximately 14 km. The characteristics of each transect are reported in Table 1.

A digital archive providing over 20 h of high-definition videos was created and 1630 images were obtained every 10 seconds through the extraction of frames from the video tracks by means of free internet software (DVDVideoSoft). These images corresponded to almost 16500 m² of analysed surface (each frame measuring about 3 m², as estimated by ImageJ software).

Video frames and images were examined by experts for the identification of organisms, at the lowest taxonomic level possible, and habitats.

As regards samples collected by ROV grabber, select-

Table 1. Summary of the 14 transects performed by the ROV. Surveyed areas per transect were calculated using the ROV track lengths (estimated by the GIS software ESRI ArcMAP 10.1) and an estimated width visibility (visual field) of 2 m.

Area	ID dive	Year	Transect length (m)	Visual swept area (m ²)	Depth range (m)	Mean depth (m)
Graham	1	2014	1387	2774	80-180	113
Graham	2	2014	1123	2246	40-100	92
Graham	3	2014	916	1832	120-220	153
Graham	4	2014	987	1974	100-180	75
Graham	5	2014	46	92	80-90	82
Graham	6	2014	1250	2500	70-170	96
Graham	7	2015	484	968	20-120	65
Graham	8	2015	1310	2620	80-200	150
Nereo	9	2014	925	1850	35-45	40
Nereo	10	2014	882	1764	25-50	38
Nereo	11	2014	1600	3200	30-60	47
Pantelleria Vecchia	12	2014	879	1758	20-51	34
Pantelleria Vecchia	13	2014	1760	3520	20-52	35
Pantelleria Vecchia	14	2015	713	1426	20-60	43
Total			14262	28524		

ed dry and uncleaned specimens of Bryozoa were examined under a scanning electron microscope (SEM) and, for Corallinales, species were identified according to the standard methodology (see Alongi *et al.*, 2002). Taxonomy and nomenclature, as well as the status assessment for bryozoans, followed Rosso & Di Martino (2016) and references therein.

List of habitats, species and their conservation status

The habitat types, including biocoenoses, associations and facies (Pérès & Picard, 1964) and their conservation status, were assessed following the Annex I – ‘Natural habitat types of Community Interest whose conservation requires the designation of Special Areas of Conservation’ of the EU Habitats Directive (92/43/EC; EU, 1992), the Interpretation Manual of European Union Habitats – EUR28 (European Commission, 2013), and the identification sheets of priority habitats according to the SPA/BD Protocol (Relini & Giaccone, 2009).

Lists of species from the studied banks (observed through the ROV video recordings and collected through ROV grabber) were compared with those reported in the Habitats Directive, and several other international conventions and protocols (i.e., CITES, Bern Convention, SPA/BD Protocol of the Barcelona Convention), in order to identify protected or endangered species or those species whose exploitation is regulated.

Furthermore, in order to include a larger number of species of conservation concern, the status of each species and its relative Population Trend (Decreasing Population

Trend – DPT, or Unknown Population Trend – UPT) was assessed using the IUCN Red List (not legally binding for European member states) at Global, Mediterranean (IUCN, 2015) and National level (Italian Committee of IUCN, 2016).

The IUCN Red Lists were also used to calculate the Red List Index (RLI; see Moser *et al.*, 2016) for the taxonomic groups of Cnidaria and Pisces. The RLI measures the rate of biodiversity loss; it is an index of the proportion of species expected to remain extant in the near future in the absence of any conservation action (Butchart, 2007).

The revised RLI is defined as:

$$RLI_t = 1 - \frac{\sum_{s=1}^N W_{c(t,s)}}{W_{EX} * N}$$

where ‘t’ is the year; ‘Σs’ is a summation over all assessed non-Data Deficient species; ‘W_{c(t,s)}’ is the weight of category ‘c’ assigned to species in year ‘t’ (weight ranges from 0 – Least Concern to 5 – Extinct); ‘W_{EX}’ is the weight assigned to Extinct species (given the value 5 using the recommended ‘equal steps’ weights, with Critically Endangered = 4, Endangered = 3, Vulnerable = 2, Near Threatened = 1, Least Concern = 0); and ‘N’ is the total number of assessed species, excluding those considered Data Deficient and those assessed as Extinct in the year the set of species was first assessed. For species defined as ‘Data Deficient’ or ‘Not Evaluated’ in the Italian Red List, we looked at the category indicated in the Mediterranean list; if the species was still ‘Not Evaluated’, we

searched the Global list. The species was then considered 'Not Evaluated' or 'Data Deficient' when this status was present in all three lists.

RLI values can vary from 0 (all species are Extinct) to 1 (all species are of Least Concern).

Results

Census of habitat types

The ROV survey along the transects on the Graham, Nereo and Pantelleria Vecchia Banks (Figs 2-4) allowed identification of a total of 19 habitat types (17 if 'associations with rhodoliths and maërl' are counted as a single habitat type), including biocoenoses, associations and facies (Table 2). According to the Interpretation Manual of European Union Habitats – EUR28 (European Commission, 2013), 13 of them belong to three marine habitat types ('1120-*Posidonia oceanica* meadows', '1170-Reefs', and '8330-Submerged or partially submerged sea caves') included in the Annex I of the EU Habitats Directive. In particular, '*Posidonia* meadows' are considered a priority natural habitat type by the Habitats Directive. Moreover, according to the SPA/BD Protocol (Barcelona Convention), 14 of the 19 registered habitats are considered of priority interest (habitats whose conservation is mandatory), whereas four are listed as remarkable (habitats that deserve specific attention or management). The SPA/BD classification system takes into account five habitat variables: vulnerability, rarity, heritage value, aesthetic value and economic value, each of which is evaluated on three levels (high, medium and low). On the basis of the above-mentioned habitat variables, habitats are classified into three main categories (P: Priority; R: Remarkable; OH: Other Habitat) (Relini & Giaccone, 2009; Fig. 5). In the study area, the 'association with rhodoliths' (IV.2.2.1.) within the 'biocoenosis of the coastal detritic bottom' is the only habitat listed as OH. It is important to note that according to the SPA/BD Protocol the 'association with rhodoliths' and the 'facies with maërl' are found in two distinct biocoenoses (i.e., 'biocoenosis of coarse sands and fine gravels under the influence of bottom currents', and 'biocoenosis of coastal detritic bottom'), and their classifications change from P to OH and from P to R, respectively (Table 2).

Census of species

A total of 269 taxa (Appendix S1) were identified through ROV videos, among which 185 were at species level. These taxa belong to: Macrophyta (Rhodophyta, Chlorophyta, Ochrophyta and Tracheophyta), Porifera, Cnidaria, Annelida, Mollusca, Bryozoa, Arthropoda, Echinodermata, and Chordata (Tunicata and Pisces). The number of taxa for the most abundant taxonomic groups is shown in Fig. 6. The largest number of taxa detected belonged to Porifera, Cnidaria and Pisces, with marked differences in identification level. Indeed, even though it

was possible to distinguish 97 taxa of Porifera, only 42% were identified at species level through visual census. For Cnidaria, 63 taxa were distinguished, 51 of which at species level (81%) and for Pisces, 51 species out of 54 taxa (95%). It was also possible to identify 13 species of Echinodermata and 10 species of Macrophyta.

Moreover, the analysis of samples collected through ROV grabber in "maërl and rhodolith beds" led to the identification of 13 taxa of calcareous Rhodophyceae forming free-living biogenic concretions, and 68 taxa of associated Bryozoa (Appendix S1).

The visual census allowed identification of 115 taxa of conservation concern, i.e., whose conservation or exploitation is regulated by several international directives and conventions (Table 3): 108 taxa, mostly represented by Cnidaria and Pisces, are listed in the Global, Mediterranean (IUCN, 2015) and Italian (Italian Committee of IUCN, 2016) IUCN Red Lists, 22 in the SPA/BD protocols, 16 in the Bern Convention, 10 in the CITES and only four are included in the Habitats Directive.

Twenty-two taxa out of the 108 listed in the IUCN Red List fell into threatened categories, although to different degrees: 1 'Critically Endangered' (*Funiculina quadrangularis*), according to the Italian IUCN Red List, 7 'Endangered', and 17 'Vulnerable' (Fig. 7). Only *Corallium rubrum*, which is considered as Endangered in the Mediterranean and Italian Red Lists, is included in the Habitats Directive, Annex V regarding species of 'Community interest whose taking in the wild and exploitation may be subject to management measures'. Most of the 22 taxa falling into threatened categories (V, E, CE) showed a decreasing population trend. The RLI was calculated for Pisces and Cnidaria, the taxonomic groups with the highest number of taxa identified at species level listed in the IUCN Red Lists. For Pisces the RLI was 0.97 and for Cnidaria 0.89.

The analysis of samples collected by ROV grabber led to the identification of two calcareous Rhodophyceae of conservation concern, namely *Phymatolithon calcareum* and *Lithothamnion corallioides*, included in the Annex IV of the Habitats Directive (Table 3).

The endemic ecological status is a relevant parameter to assess whether a species is of 'Community Interest' according to the Habitats Directive and then listed in the Annex II and/or Annex IV or V. Six endemic species of 'Community Interest' according to the Habitats Directive were identified through visual census. They belong to Macrophyta, Cnidaria, Bryozoa and Tunicata. Moreover, the analysis of ROV samples collected by grabber allowed identification of 12 Mediterranean endemic bryozoan species living on red algae which form maërl and/or rhodoliths (Table 4).

Graham Bank

The Ferdinanda shoal is the only investigated edifice of this bank, falling within the euphotic zone (Fig. 2J). From the peak down to about 20/30 m this shoal shows a highly complex, mainly rocky bottom, covered by dense

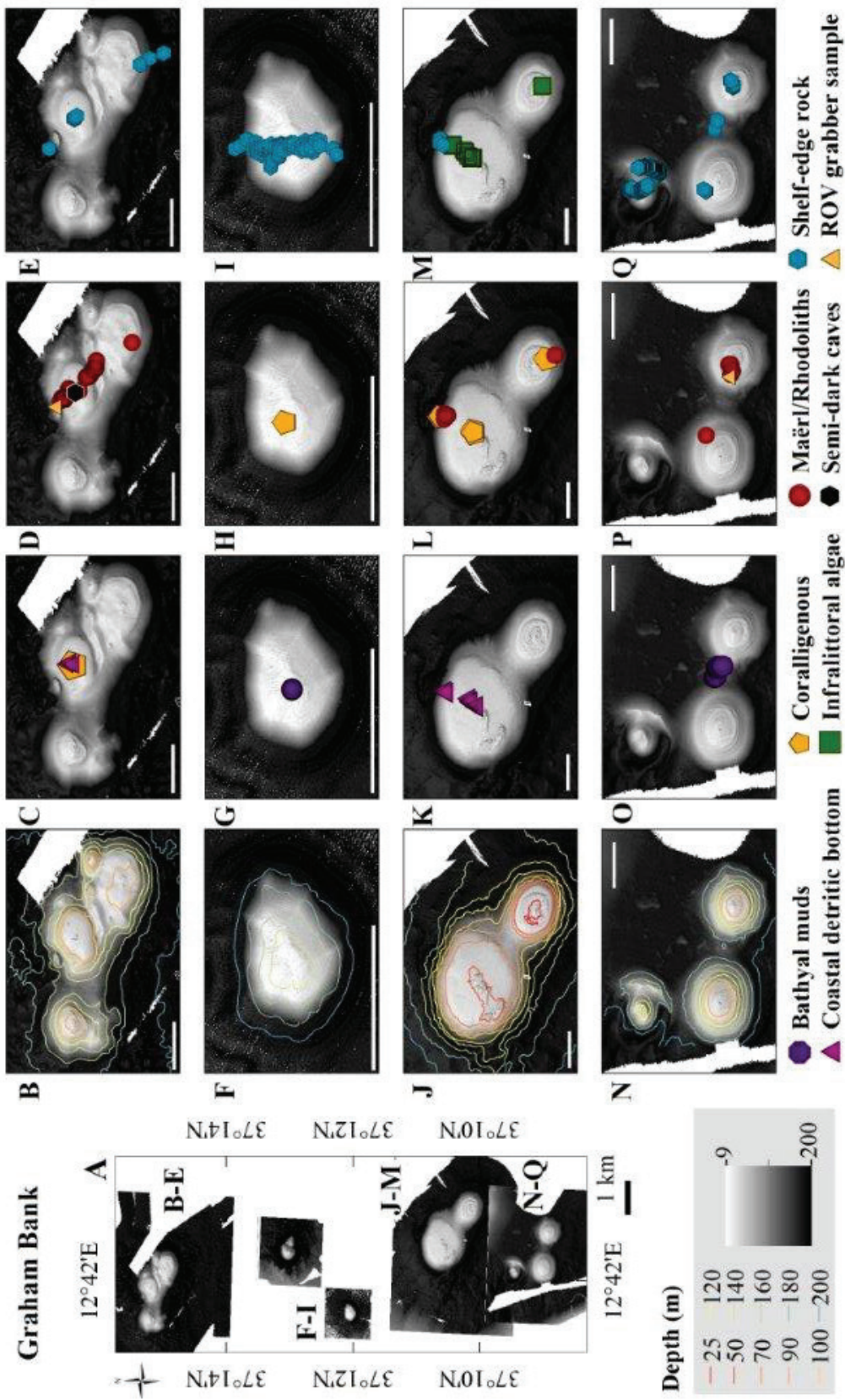


Fig. 2: Distribution of the main habitats along the ROV tracks on the high-resolution morpho-bathymetric map of the Graham Bank: A) volcanic cones; B) morpho-bathymetric map of B-E cones; C) distribution of coralligenous and coastal detritic bottom habitats on B-E cones; D) distribution of maërl/rhodoliths and semi-dark caves habitats and ROV grabber sample point on B-E cones; E) distribution of shelf-edge rock habitat on B-E cone; F) morpho-bathymetric map of F-I cones; G) distribution of bathyal muds habitat on F-I cones; H) distribution of coralligenous habitat on F-I cones; I) distribution of shelf-edge rock habitat on F-I cones; J) morpho-bathymetric map of J-M cones; K) distribution of infralittoral algae and shelf-edge rock habitat on J-M cones; L) distribution of coralligenous, and maërl/rhodoliths habitats on J-M cones; M) distribution of infralittoral algae and shelf-edge rock habitats on J-M cones; N) morpho-bathymetric map of N-Q cones; O) distribution of bathyal muds habitat on N-Q cones; P) distribution of maërl/rhodoliths habitat and ROV grabber sample point on N-Q cones; Q) distribution of shelf-edge rock habitat on N-Q cones. The habitats were identified through ROV visual assessment. The scale bars of figures B-Q corresponds to 0.5 km.

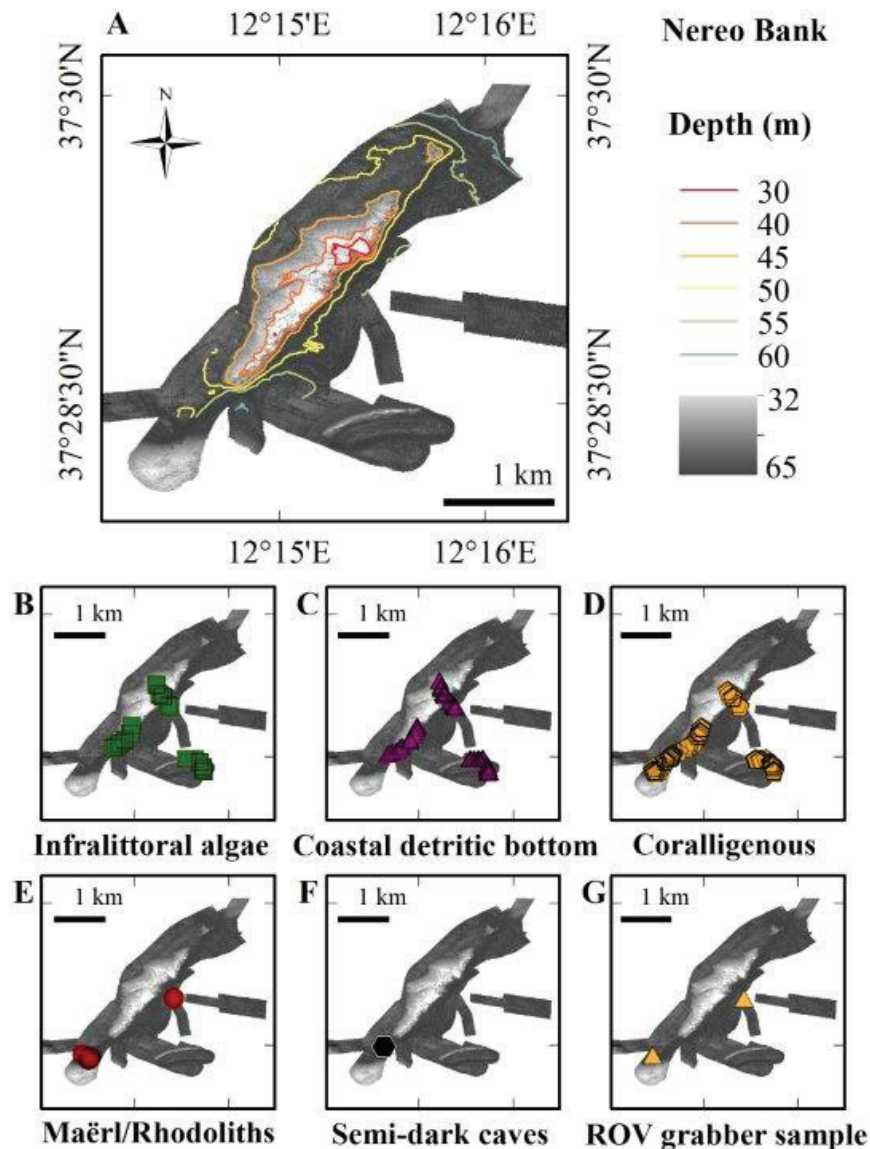


Fig. 3: Distribution of the main habitats along the ROV tracks on the high-resolution morpho-bathymetric map of the Nereo Bank: morpho-bathymetric map (A); distribution of infralittoral algae (B), coastal detritic bottom (C), coralligenous (D), maërl/rhodoliths (E), and semi-dark caves (F) habitats; ROV grabber sample points (G). The habitats were identified through ROV visual assessment.

populations of infralittoral algae, including *Dictyota* spp., *Sargassum* sp. and species belonging to the ‘*Cystoseira*’ complex¹. Between 30 and 40 m depth, an extensive and dense facies with species of *Ceriantharia* (Fig. 8A) was spotted on a flat bottom composed of coarse volcanic sand. This facies was found interspersed with ‘maërl-rhodolith’ beds. All soft bottoms between 50 and 70/80 m depth on the Graham volcanic edifices host the ‘coastal detritic bottom biocoenosis’, frequently characterised by ‘maërl facies’ and by ‘association with rhodoliths’ (Fig. 2C-D and 2K-L), mostly formed by *P. calcareum* and *L. corallioides* (Table 3). *Laminaria rodriguezii*, an endemic Mediterranean brown algae of conservation concern,

was detected in the circalittoral disphotic zone associated with ‘coastal detritic’ bottoms. At 40-70 m depth, hard substrates host the ‘coralligenous biocoenosis’ (Fig. 2C, 2H, 2L) of two different aspects: one dominated by macrophytes (*Sargassum* spp., *L. rodriguezii*, and many other unidentified brown and red algae) and one by megafauna (mainly gorgonians, such as *Paramuricea clavata* and *Eunicella cavolinii*, bryozoans, including *Smittina cervicornis*, *Hornera frondiculata*, *Margaretta cereoides*, *Myriapora truncata*, *Pentapora fascialis*, *Reteporella* spp., and sponges such as *Axinella polypoides* and *A. damicornis*). The ‘association with *Sargassum* spp.’, the ‘facies with *E. cavolinii*’, the ‘facies with *P. clavata*’ and ‘corallig-

¹ The species previously allocated within the genus *Cystoseira* have been largely revised and new synonyms and allocations have been proposed (Orellana et al., 2019; Molinari & Guiry, 2020). Since identification at a specific level is not possible through video analysis, we indicate them with the term ‘*Cystoseira*’ complex.

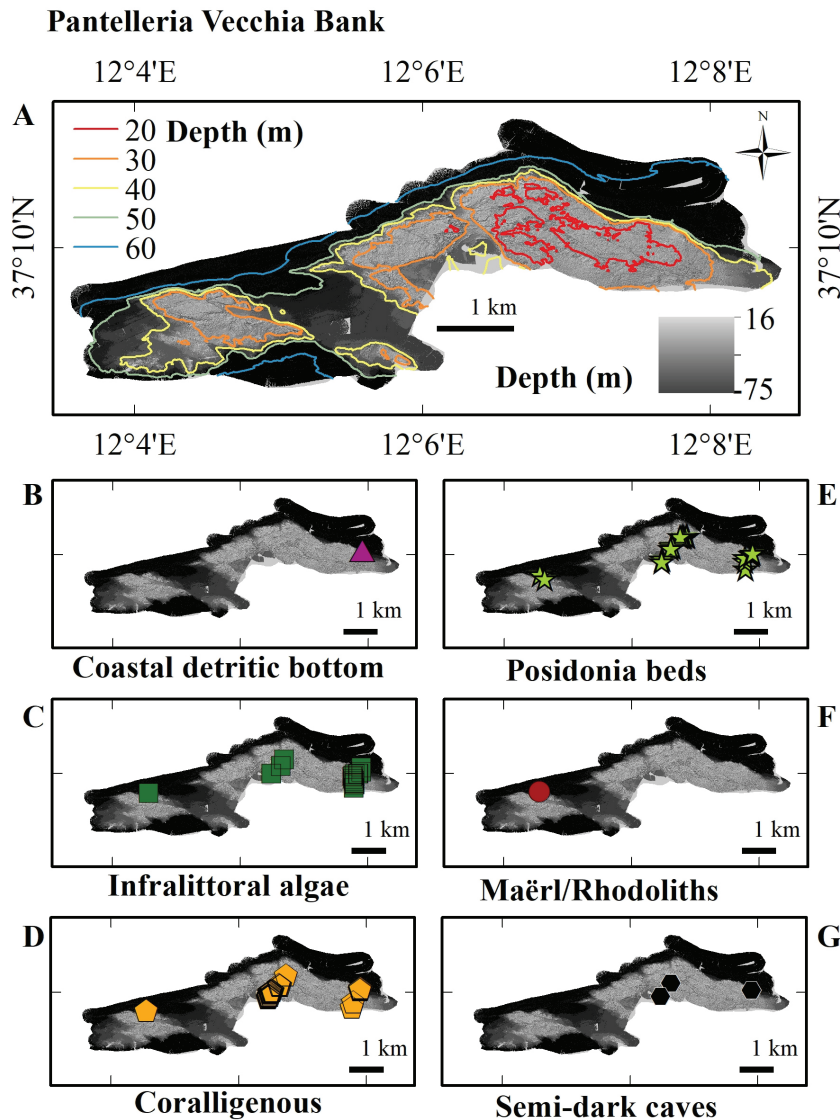


Fig. 4: Distribution of the main habitats along the ROV tracks on the high-resolution morpho-bathymetric map of the Pantelleria Vecchia Bank: A) morpho-bathymetric map; B) distribution of coastal detritic bottom, C) infralittoral algae, D) coralligenous, E) *Posidonia* beds, F) maërl/rhodoliths, and G) semi-dark caves habitats. The habitats were identified through ROV visual assessment.

enous platforms' were visually distinguished. At this bathymetric range, transitional areas (ecotones) between 'coastal detritic bottom' and 'coralligenous biocoenosis' are also conspicuous, characterised by soft corals such as *Paralcyonium spinulosum*, rhodoliths and soft-bodied algae such as *L. rodriguezii*. The 'semi-dark cave biocoenosis' is also present in overhangs in both infralittoral and circalittoral zones (Fig. 2D). This biocoenosis shows different aspects depending on the occurrence and dominance of species, mainly encrusting Porifera and Cnidaria such as *Hexadella racovitzae*, *Leptosammia pruvoti* and *Parazoanthus axinellae*. These species were often grouped in almost monospecific aggregations, such as the 'facies with *P. axinellae*'. Between 100 and 200 m, the 'shelf-edge rock biocoenosis' is present with flourishing coral gardens (Fig. 2E, 2I, 2M, 2Q and Fig. 8B) composed of black corals, zoanths and gorgonians, such as *Antipathes dichotoma*, *Antipathella subpinnata*, *Coralli-*

um rubrum (Fig. 8C), *Leiopathes glaberrima* (Fig. 8D), *Dendrophyllia ramea* (Fig. 8E), *Savalia savaglia* (Fig. 8F), *Callogorgia verticillata* and *Parantipathes larix*. Most of these species are protected by international directives and conventions and are included in the threatened categories of the IUCN Anthozoan Red List (Table 3). These corals can form dense monospecific gardens (*C. rubrum*) and/or multi-specific gardens (anthipatharians and gorgonians), hosting epibenthic Echinodermata such as *Astrospartus mediterraneus*. It is worth noting that the observed facies with *C. rubrum* was not the one occurring within the 'semi-dark cave biocoenosis', listed in the SPA/BD Protocol as a priority habitat (IV.3.2.2.), but a facies neither described nor listed in the SPA/BD Protocol, which develops on open rocks and on gently sloping substrates and is characterised by upwardly growing red coral colonies. Moreover, on the Graham Bank and in its vicinity alongside some volcanic reliefs, at 140-180 m

Table 2. Habitat types (including benthic biocoenoses, with relative associations and/or facies) detected on the Graham, Nereo and Pantelleria Vecchia Banks by ROV video recordings. The habitat classification[‡] follows the identification sheets of priority habitats according to the SPA/BD Protocol (Relini & Giaccone, 2009) and reports the SPA/BD Protocol (Barcelona Convention) codes and the correspondent Habitats Directive (92/43/EEC) identification codes (Annex I ‘Natural habitat types of Community Interest whose conservation requires the designation of Special Areas of Conservation’; EU, 1992).

Biocoenosis	Association A./Facies F.	Habitat Dir. Identification code	SPA/BD Protocol Identification code (Classification) [‡]	Bank [†]	Range depth (m)
<i>Posidonia oceanica</i> beds	<i>A. Posidonia oceanica</i>	1120	III.5.1 (P)	Pa	20-40
Biocoenosis of coarse sands and fine gravels under the influence of bottom currents	A. with rhodoliths	-	III.2.2.2. (P)	Gr, Ne, Pa	90-120 (Gr) 30-50 (Ne, Pa)
Biocoenosis of coastal detritic bottom	F. maërl	-	III.3.2.1. (P)	Gr, Ne, Pa	90-120 (Gr) 30-50 (Ne, Pa)
	<i>A. Laminaria rodriguezii</i>	-	IV.2.2.7. (P)	Gr, Ne	40-60
	A. with rhodoliths	-	IV.2.2.1. (OH)	Gr, Ne, Pa	80-100 (Gr) 50-55 (Ne, Pa)
	F. maërl	-	IV.2.2.2. (R)	Gr, Ne, Pa	80-100 (Gr) 50-55 (Ne, Pa)
Biocoenosis of infralittoral algae	-	1170	III.6.1. (P)	Gr, Ne, Pa	40-60 (Gr) 30-50 (Ne, Pa)
	A./F. Coralligenous in enclaves	1170	III.6.1.35. (P)	Pa	30-50
Biocoenosis of coralligenous	-	1170	IV.3.1. (P)	Gr, Ne, Pa	25-50
	<i>A. Sargassum</i> spp.	1170	IV.3.1.5. (P)	Gr, Pa	20
	<i>F. Eunicella cavolinii</i>	1170	IV.3.1.10. (P)	Gr	50-100
	<i>F. Eunicella singularis</i>	1170	IV.3.1.11. (P)	Ne	30-55
	<i>F. Paramuricea clavata</i>	1170	IV.3.1.13. (P)	Gr	50-120
	Coralligenous platforms	1170	IV.3.1.15. (P)	Gr	80-160
Biocoenosis of shelf-edge rock	-	1170	IV.3.3. (R)	Gr	80-160
Biocoenosis of semi-dark caves	-	8330	IV.3.2. (P)	Gr, Ne, Pa	80 (Gr) 50 (Ne) 20-40 (Pa)
	<i>F. Parazoanthus axinellae</i>	8330	IV.3.2. 1. (R)	Gr, Ne, Pa	80
Biocoenosis of bathyal muds	-	-	V.1.1. (R)	Gr	180
	F. soft muds with <i>Funiculina quadrangularis</i>	-	V.1.1.3. (P)	Gr	180

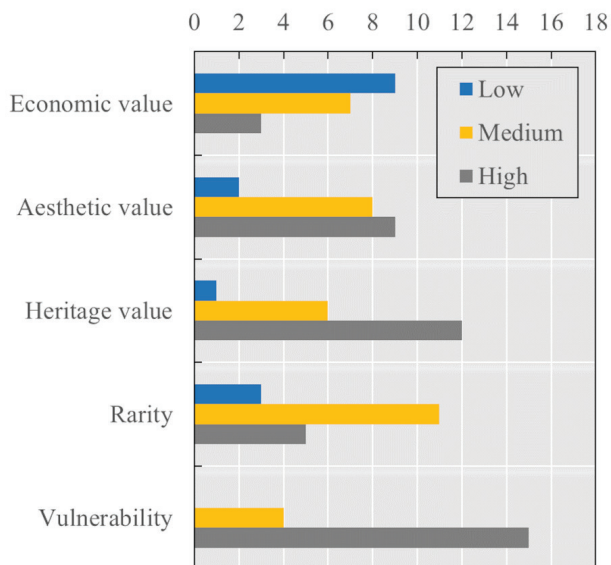


Fig. 5: Number of identified habitats for each degree (low, medium, high) assigned to the following habitat variables: vulnerability, rarity, heritage value, aesthetic value and economic value, following the classification proposed by Relini & Giaccone (2009).

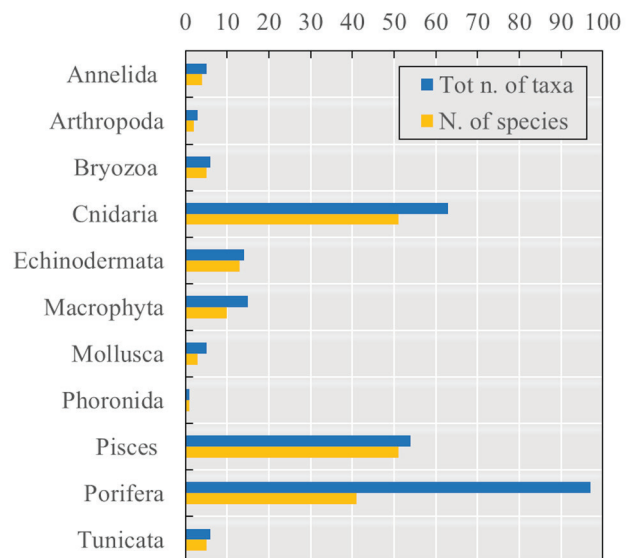


Fig. 6: Number of taxa identified at species level or higher taxonomic rank including genus, family and even phylum level through ROV visual assessment on the Graham, Nereo and Pantelleria Vecchia banks.

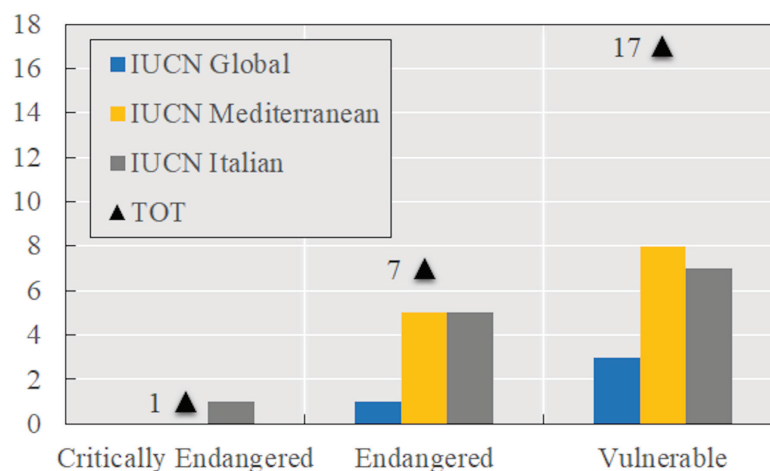


Fig. 7: Number of species detected on the Graham, Nereo and Pantelleria Vecchia banks through ROV visual assessment included in the threatened categories of the Global, Mediterranean and/or Italian IUCN Red Lists (IUCN, 2015; Italian Committee of IUCN, 2016). The total number of species in each category is shown (dark triangles); note that species can be present in more than one list.

depth on the muddy sea floor, three areas were observed, including dead fragments (thanatocoenoses) of red coral and *Dendrophyllia* spp. According to Lodolo *et al.* (2017) these deposits have accumulated primarily (or partly) as a consequence of volcanic activity dislodging living (or dead) corals from the steep flanks of the volcanoes on which they lived.

The large hydroid *Lytocarpia myriophyllum* and the sea pen *Virgularia mirabilis* form dense aggregations on detritic bottoms at 140-180 m depth. At about 130 m, the whip coral *Viminella flagellum* is abundant, forming dense monospecific forests on rocky substrates covered with a thin mud veneer (Fig. 8G). At about 190 m, a quite

extensive facies with *F. quadrangularis* was observed on ‘bathyal muds’ (Fig. 8H). Between 100 and 150 m, evidence of hydrothermal vents was detected, consisting of gas emissions associated with white and orange mineralisations.

Nereo Bank

The euphotic-to-disphotic bottoms between 30 and 45 m are dominated by macrophytes. Rocky and soft substrata are covered by extensive and diversified algal populations. A dense population of the kelp *L. rodriguezii*

Table 3. Species of conservation concern, detected during ‘ORBS Banchi 2014-2015’ research surveys, whose conservation or exploitation is regulated by international Directives and Conventions: CITES‡, BERN§, HABITAT¶, SPA/BD††. The species included in the Global, Mediterranean and/or Italian IUCN Red Lists of Threatened Species are also reported. In the last column the Population Trend at Global¹, Mediterranean² and/or Italian³ (International Union for Conservation of Nature, 2015; Italian Committee of International Union for Conservation of Nature, 2016) scale was shown.

TAXA	Directive/ Convention	IUCN Global ¹	IUCN Mediterranean ²	IUCN Italian ³	Population Trend
Arthropoda					
<i>Pachylasmus giganteum</i>	P2, B2	-	-	-	-
<i>Palinurus elephas</i>	B3, P3	-	-	-	-
Cnidaria					
<i>Acanthogorgia hirsuta</i>	-	-	LC	LC	unknown ^{2,3}
<i>Alcyonium acaule</i>	-	-	LC	DD	decreasing ²
<i>Alcyonium coralloides</i>	-	-	LC	LC	stable ^{2,3}
<i>Alcyonium palmatum</i>	-	-	LC	LC	decreasing ² ; unknown ³
<i>Alicia mirabilis</i>	-	-	LC	LC	unknown ² ; stable ³
<i>Amphianthus dohrnii</i>	-	-	DD	-	unknown ^{2,3}
<i>Anemonia viridis</i>	-	-	LC	LC	stable ^{2,3}
<i>Antipathella subpinnata</i>	CB, B3, P2	-	NT	LC	decreasing ²
<i>Antipathes dichotoma</i>	CB, B3, P2, P3	-	NT	LC	decreasing ²
<i>Astroides calycularis</i>	B2, P2, CB	-	LC	LC	stable ²
<i>Bebryce mollis</i>	-	-	DD	DD	unknown ^{2,3}
<i>Callogorgia verticillata</i>	P2	-	NT	NT	decreasing ³
<i>Caryophyllia cyathus</i>	CB	-	DD	DD	unknown ^{2,3}
<i>Cereus pedunculatus</i>	-	-	LC	LC	stable ^{2,3}
<i>Cerianthus membranaceus</i>	-	-	LC	LC	unknown ² ; stable ³
<i>Cladocora caespitosa</i>	CB, P2	E	E	LC	decreasing ^{1,2} ; stable ³
<i>Cladopsammia rolandi</i>	-	-	DD	DD	unknown ^{2,3}
<i>Condylactis aurantiaca</i>	-	LC	LC	DD	unknown ^{1,2,3}
<i>Corallium rubrum</i>	B3, H5, P3	-	E	E	decreasing ^{2,3}
<i>Corynactis viridis</i>	-	-	LC	LC	stable ^{2,3}
<i>Cribrinopsis crassa</i>	-	-	LC	DD	unknown ^{2,3}
<i>Dendrophyllia cornigera</i>	P2, CB	-	E	V	decreasing ^{2,3}
<i>Dendrophyllia ramea</i>	P2, CB	-	V	DD	unknown ^{2,3}
<i>Eunicella cavolinii</i>	-	-	-	LC	stable ³
<i>Eunicella singularis</i>	-	-	NT	V	decreasing ^{2,3}
<i>Funiculina quadrangularis</i>	-	-	V	CE	decreasing ^{2,3}
<i>Leiopathes glaberrima</i>	CB, B3, P2	-	E	E	decreasing ^{2,3}
<i>Leptopsammia pruvoti</i>	CB	-	LC	LC	stable ³
<i>Lytocarpia myriophyllum</i>	-	-	LC	-	unknown ²
<i>Paracyathus pulchellus</i>	-	-	DD	DD	unknown ^{2,3}
<i>Paralcyonium spinulosum</i>	-	-	LC	LC	stable ³
<i>Paramuricea clavata</i>	-	-	V	LC	decreasing ²
<i>Paramuricea macrospina</i>	-	-	DD	LC	unknown ^{2,3}
<i>Parantipathes larix</i>	CB, P2	-	NT	LC	decreasing ²
<i>Parazoanthus axinellae</i>	-	-	LC	LC	stable ^{2,3}
<i>Pennatula rubra</i>	-	-	V	DD	decreasing ² ; unknown ³
<i>Phymanthus pulcher</i>	-	-	DD	DD	unknown ^{2,3}
<i>Pteroeides griseum</i>	-	-	V	DD	decreasing ² ; unknown ³

continued

Table 3 continued

TAXA	Directive/ Convention	IUCN Global ¹	IUCN Mediterranean ²	IUCN Italian ³	Population Trend
<i>Savalia Savaglia</i>	B2, P2	-	NT	NT	decreasing ^{2,3}
<i>Swiftia pallida</i>	-	-	DD	DD	unknown ^{2,3}
<i>Thalamophyllia gasti</i>	-	-	DD	DD	unknown ^{2,3}
<i>Veretillum cynomorium</i>	-	-	LC	DD	unknown ^{2,3}
<i>Villogorgia bebrycoides</i>	-	-	DD	DD	unknown ^{2,3}
<i>Viminella flagellum</i>	-	-	NT	LC	unknown ^{2,3}
<i>Virgularia mirabilis</i>	-	-	LC	V	unknown ² ; decreasing ³
Echinodermata					
<i>Centrostephanus longispinus</i>	H4, P2, B2	-	-	-	-
<i>Paracentrotus lividus</i>	P3, B3	-	-	-	-
Macrophyta					
“Cystoseira” complex	B1, P2	-	-	-	-
<i>Laminaria rodriguezii</i>	B1, P2	-	-	-	-
<i>Lithothamnion corallioides</i> ^{††}	H5	-	-	-	-
<i>Phymatolithon calcareum</i> ^{††}	H5	-	-	-	-
<i>Posidonia oceanica</i>	B1, P2	LC	LC	-	decreasing ^{1,2}
<i>Sargassum</i> spp.	P2	-	-	-	-
Mollusca					
<i>Octopus vulgaris</i>	-	LC	LC	-	unknown ^{1,2}
Pisces					
<i>Anthias anthias</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Apogon imberbis</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Aulopus filamentosus</i>	-	LC	LC	LC	unknown ^{1,2} ; stable ³
<i>Boops boops</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Callanthias ruber</i>	-	LC	LC	LC	unknown ^{1,2} ; stable ³
<i>Capros aper</i>	-	LC	LC	LC	unknown ^{1,2} ; increasing ³
<i>Chromis chromis</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Conger conger</i>	-	LC	LC	LC	increasing ¹ ; stable ³
<i>Coris julis</i>	-	LC	LC	LC	stable ^{1,3}
<i>Ctenolabrus rupestris</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Dasyatis pastinaca</i>	-	DD	V	DD	decreasing ²
<i>Diplodus vulgaris</i>	-	LC	LC	LC	stable ^{2,3}
<i>Epinephelus caninus</i>	-	DD	DD	DD	unknown ^{1,2,3}
<i>Epinephelus costae</i>	-	DD	DD	V	unknown ^{1,2} ; decreasing ³
<i>Epinephelus marginatus</i>	P3, B3	V	E	E	decreasing ^{1,2} ; increasing ³
<i>Gadella maraldi</i>	-	LC	LC	LC	unknown ^{1,2,3}
<i>Helicolenus dactylopterus</i>	-	LC	LC	LC	unknown ^{1,2,3}
<i>Hyporthodus haifensis</i>	-	DD	DD	DD	unknown ^{1,2,3}
<i>Labrus merula</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Labrus mixtus</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Labrus viridis</i>	-	V	V	LC	decreasing ^{1,2} ; stable ³
<i>Lappanella fasciata</i>	-	LC	-	LC	stable ^{1,3}
<i>Macroramphosus scolopax</i>	-	LC	LC	LC	unknown ^{1,2} ; stable ³
<i>Myliobatis aquila</i>	-	DD	V	LC	decreasing ^{2,3}
<i>Mullus surmuletus</i>	-	LC	LC	LC	stable ^{2,3}
<i>Muraena helena</i>	-	LC	LC	LC	unknown ^{1,2} ; increasing ³

continued

Table 3 continued

TAXA	Directive/ Convention	IUCN Global ¹	IUCN Mediterranean ²	IUCN Italian ³	Population Trend
<i>Pagellus bogaraveo</i>	-	NT	LC	LC	decreasing ^{1,3} ; increasing ³
<i>Parablennius rouxi</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Phycis phycis</i>	-	LC	LC	LC	unknown ^{1,2} ; increasing ³
<i>Scorpaena elongata</i>	-	LC	LC	LC	unknown ^{1,2} ; stable ³
<i>Scorpaena maderensis</i>	-	LC	LC	LC	unknown ^{1,2} ; stable ³
<i>Scorpaena notata</i>	-	LC	LC	LC	unknown ^{1,2} ; stable ³
<i>Scorpaenodes arenai</i>	-	DD	DD	LC	unknown ^{1,2} ; stable ³
<i>Seriola dumerili</i>	-	LC	LC	LC	stable ^{2,3}
<i>Serranus cabrilla</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Serranus scriba</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Sparus aurata</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Spicara maena</i>	-	LC	LC	LC	decreasing ² ; stable ³
<i>Spicara smaris</i>	-	LC	LC	LC	decreasing ² ; stable ³
<i>Spondyliosoma cantharus</i>	-	LC	LC	LC	stable ^{2,3}
<i>Symphodus doderleini</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Symphodus mediterraneus</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Symphodus melanocercus</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Symphodus ocellatus</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Symphodus roissali</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Symphodus tinca</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Thalassoma pavo</i>	-	LC	LC	LC	stable ^{1,2,3}
<i>Trachurus trachurus</i>	-	V	LC	LC	stable ^{1,2,3}
<i>Zeus faber</i>	-	DD	LC	LC	stable ^{1,3}
Porifera					
<i>Axinella damicornis</i>	-	-	-	LC	unknown ³
<i>Axinella polypoides</i>	B2, P2	-	-	E	unknown ³
<i>Agelas oroides</i>	-	-	-	LC	unknown ³
<i>Dysidea avara</i>	-	-	-	LC	unknown ³
<i>Pachastrella monilifera</i>	-	-	-	V	unknown ³
<i>Chondrosia reniformis</i>	-	-	-	LC	unknown ³
<i>Cliona celata</i>	-	-	-	LC	unknown ³
<i>Ircinia variabilis</i>	-	-	-	LC	unknown ³
<i>Petrosia ficiformis</i>	-	-	-	V	unknown ³
<i>Poecillastra compressa</i>	-	-	-	V	unknown ³
<i>Spongia lamella</i>	B3, P3	-	-	E	unknown ³

‡CB: CITES, Convention on International Trade in Endangered Species of Wild Fauna and Flora (C). Annex: B-Species that are not necessarily now threatened with extinction but that may become so unless trade is closely controlled.

§B1, B2, B3: BERN, "Convention on the Conservation of European Wildlife and Natural Habitats(B). Annex: 1-Strictly protected flora species; 2-Strictly protected fauna species; 3-Protected fauna species.

¶H4, H5: HABITAT 42/93 CEE Directive (H). Annex: 4-Animal and plant species of community interest in need of strict protection; 5-Animal and plant species of community interest whose taking in the wild and exploitation may be subject to management measures.

††P2, P3: SPA/BD, Protocol Concerning Specially Protected Areas and Biological Diversity of the Barcelona Convention (P). Annex: 2-List of endangered or threatened species; 3-List of species whose exploitation is regulated

IUCN: CE: Critically Endangered; E: Endangered; V: Vulnerable; NT: Near threatened; LC: Least Concern; DD: Data Deficient.

(Fig. 9A) is widespread, accompanied by other brown algae such as *Dictyopteria* cfr. *polypodioides*, *Dictyota* spp., *Sargassum* sp. and species of the ‘*Cystoseira*’ complex, as well as by red algae such as *Lophocladia lallemandii* and *Osmundaria volubilis*. At 30–60 m depth, gently sloping rocky bottoms host the ‘coralligenous biocoenosis’ (Fig. 3D). At about 30 m, the ‘facies with *Eunicella singularis*’ is widespread, characterised by the abundance of this gorgonian in flourishing macrophyte communities (Fig. 9C). At 40–50 m, a highly diversified ‘coralligenous biocoenosis’ is frequently spotted on vertical rocky walls, dominated by the encrusting sponge *Hexadella racovitzai*, the tubular sponge *Haliclona* sp., and the erect ascidians *Aplidium* cfr. *proliferum* and *Aplidium* cfr. *tabarquensis* (Fig. 9D). These rocky habitats offer numerous refuges to fish and decapod crustaceans of high commercial value. *Epinephelus marginatus*, assessed as an endangered species in the Global and Mediterranean IUCN Red Lists (IUCN, 2015; Italian Committee of IUCN, 2016; Table 3) has been observed, together with *Palinurus elephas* (Fig. 9E), whose exploitation is regulated (Table 3). At 30–60 m depth, on soft bottoms the ‘coastal detritic bottom biocoenosis’ (Fig. 3C) is represented by the ‘maërl facies’ and the ‘association with rhodoliths’ (Table 3 and Fig. 3E). Locally dense populations of the soft coral *Veretillum cynomorium* (Fig. 9F) occur. In this bathymetric range, ecotones between ‘coastal detritic bottom’ biocoenosis and ‘coralligenous’ (Fig. 3D), bioconstructions are also conspicuous on this bank. Rocks frequently host sponge–cnidarian assemblages dominated by *Alcyonium acaule*,

Eunicella singularis and the candelabrum-shaped sponge *Raspailia viminalis* (Fig. 9G). In restricted infralittoral and circalittoral zones, the ‘semi-dark caves biocoenosis’ (Fig. 3F) was recognised as well. At about 50 m depth, a school of more than 30 individuals of the common eagle ray *Myliobatis aquila* was observed (Fig. 9H).

Pantelleria Vecchia Bank

The euphotic bottoms are dominated by flourishing *P. oceanica* seagrasses (Fig. 4E and Fig. 10A) on both rocky and soft bottoms, interspersed with diversified algal populations, mainly of *Sargassum* sp. (Fig. 10B), *Flabellia petiolata*, *Osmundaria volubilis*, and species of the ‘*Cystoseira*’ complex, which also thrive on substrates of the disphotic zone. The ‘biocoenosis of semi-dark caves’ is present, mainly on the sciaphilous subvertical hard substrates, as well as in enclaves of the infralittoral zone (Fig. 4G). As on the other banks, the ‘facies with *P. axinellae*’ was detected. Extensive ecotones between the ‘association with rhodoliths’ and ‘coralligenous’ were detected, chiefly around bioconstructions (Fig. 4D, 4F and Fig. 10C). The ‘coralligenous’ was detected mainly on vertical rocky walls but also in enclaves in the infralittoral zone. This habitat is markedly diversified, dominated by different species, among which are *Leptopsammia pruvoti* and *Astroides calycularis* (Fig. 10D–E). On the Pantelleria Vecchia Bank, the group of protected species or whose exploitation is regulated is represented by *Posidonia oceanica*, *Astroides calycularis*, *Axinella polypoides*, *Leptopsammia pruvoti* and *Centrostephanus longispinus* (Fig. 10F). The endangered dusky grouper *Epinephelus marginatus* (Fig. 10G) and the vulnerable common eagle ray *Myliobatis aquila* were also detected.

Table 4. Mediterranean endemic species detected on the Graham, Nereo and Pantelleria Vecchia banks through ROV visual assessment and ROV grabber sample †.

Taxonomic group	Mediterranean endemic species
Macrophytes	<i>Laminaria rodriguezii</i> <i>Posidonia oceanica</i>
Cnidaria	<i>Cladopsammia rolandi</i> <i>Condylactis aurantiaca</i> <i>Eunicella cavolinii</i>
Bryozoa	<i>Adeonella calveti</i> <i>Bertorsonidra prenanti</i> † <i>Cellepora adriatica</i> † <i>Coronellina fagei</i> † <i>Distansescharella seguenzai</i> † <i>Gregarinidra gregaria</i> † <i>Hippopleurifera pulchra</i> † <i>‘Microecia’ occulta</i> † <i>Patinella mediterranea</i> † <i>Rhynchozoon pseudodigitatum</i> † <i>Stephanoteca arrogata</i> † <i>Stephanoteca monoecensis</i> † <i>Tubulipora hemiphragmata</i> †
Tunicata	<i>Halocynthia papillosa</i>

Discussion

The present study evaluated, for the first time, the biodiversity of the Graham, Nereo and Pantelleria Vecchia Banks located in the Strait of Sicily. The numerous banks in the area, and most of the shallower ones located in the euphotic zone (0–100 m), provide habitats for a large variety of species together with unique ecosystems, many of which are still to be discovered and described (Clark *et al.*, 2006), as demonstrated by the newly reported *Cladocora coespitosa*–*Treptacantha ballesterosii* habitat (Pons-Fita *et al.*, 2020). This also applies to the ‘*Corallium rubrum* facies’ observed on the Graham Bank, which would need a formal description prior to its possible inclusion in lists of marine habitats.

The use of ROV technology on the Graham, Nereo and Pantelleria Vecchia Banks allowed the recording of an unexpectedly high richness of species (identified by taxonomists at different levels: species, genus, family, phylum) and habitats of conservation concern otherwise unattainable by traditional sampling methods. In fact, ROVs equipped with high-definition digital cameras are able to operate in natural and artificial complex habitats,

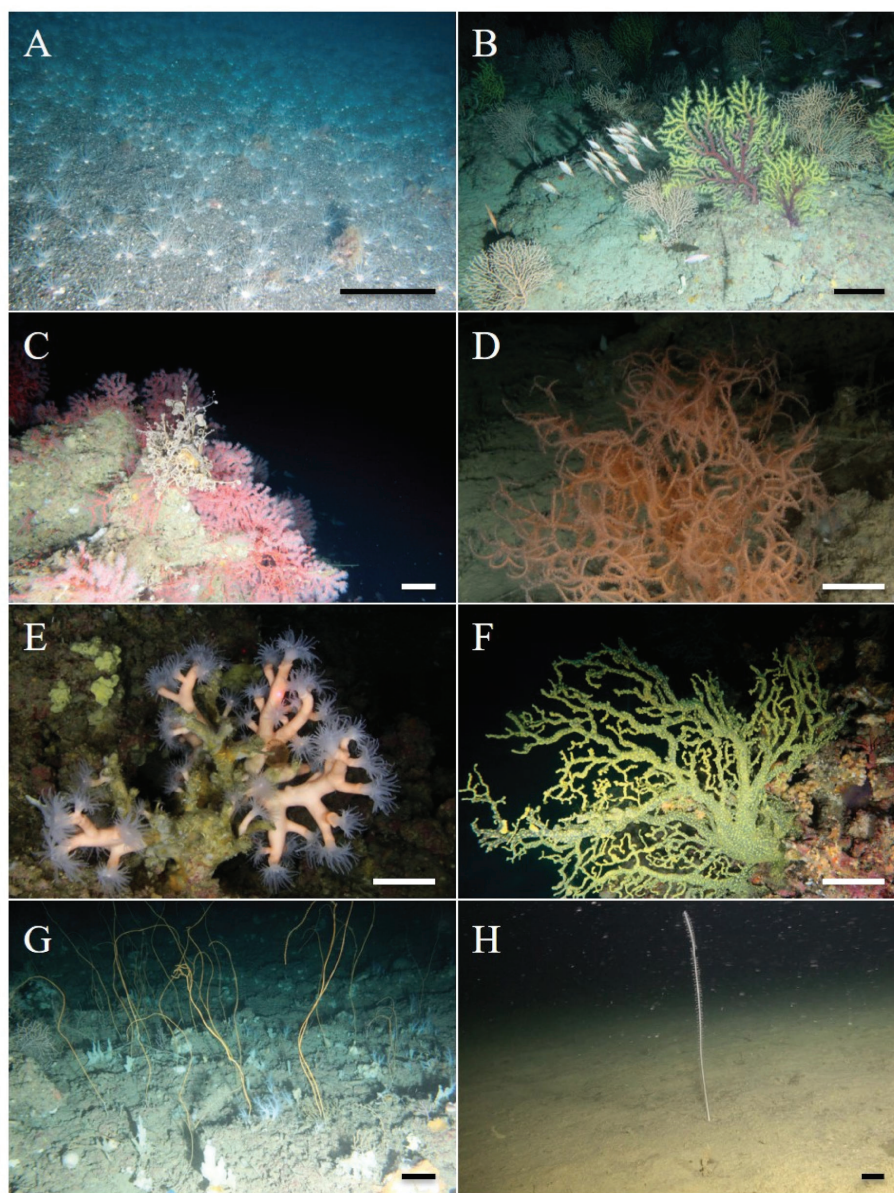


Fig. 8: ROV images of some habitats and species identified on the Graham Bank. A) Dense population of *Ceriantharia* sp. on a gently sloping detritic bottom (Ferdinandea Bank: -30 m); B) Deep coral garden (-140 m), dominated by the gorgonians *Eunicella cavolinii* and *Paramuricea clavata*, hosting different schools of fish, among which are *Macroramphosus scolopax* and *Callanthias ruber*; C) A dense monospecific deep coral garden (-110 m) composed of *Corallium rubrum* hosting the ophiuroid *Astrospartus mediterraneus*; D) A large colony of the antipatharian *Leiopathes glaberrima* on a slightly silted rocky substrate (-140 m); E) Colony of the scleractinian *Dendrophyllia ramea* (-100 m); F) colony of *Savalia savaglia* (-80 m); G) Deep megabenthic community thriving on a highly silted hardground covered by a *Viminella flagellum* forest, massive sponges and the alcyonacean *Chironomophthya mediterranea*. Scattered colonies of *Bebryce mollis* and *Eunicella cavolinii* are also visible; H) A specimen of the tall sea pen, *Funiculina quadrangularis*, on mud (-190 m). Scale bars 10 cm.

even at depths where diving is logistically limited (Consoli *et al.*, 2016, 2018); moreover, being non-invasive, they can also be used to investigate sensitive habitats (Consoli *et al.*, 2015, 2018; Sinopoli *et al.*, 2015).

Using this technological approach, an extensive number of associations and facies of conservation concern were observed on all three banks, mainly on rocky substrates that dominate from a few metres down to 250 m depth. In the studied area, the occurrence of hard bottoms, often of volcanic origin, and also at depths usually covered with soft substrates, promotes a diversification and richness of habitats and species in the area.

ROV explorations also allowed the observation of some rare or poorly known fish species, such as *Scorpaenodes arenai*, *Gadella maraldi*, *Hyporthodus haifensis* and *Myliobatis aquila* (Battaglia *et al.*, 2015). Also, the occurrence of the whip-like gorgonian *Viminella flagellum* is worthy of note because it forms dense monospecific forests or 'deep coral gardens' on the Graham Bank. This species, previously known from near the Gibraltar Strait and the Balearic Sea, has recently been reported in rocky habitats at 100-250 m depth from the Ligurian Sea to the Strait of Sicily (Angiolillo *et al.*, 2014).

The Graham Bank hosts the largest variety of habitats

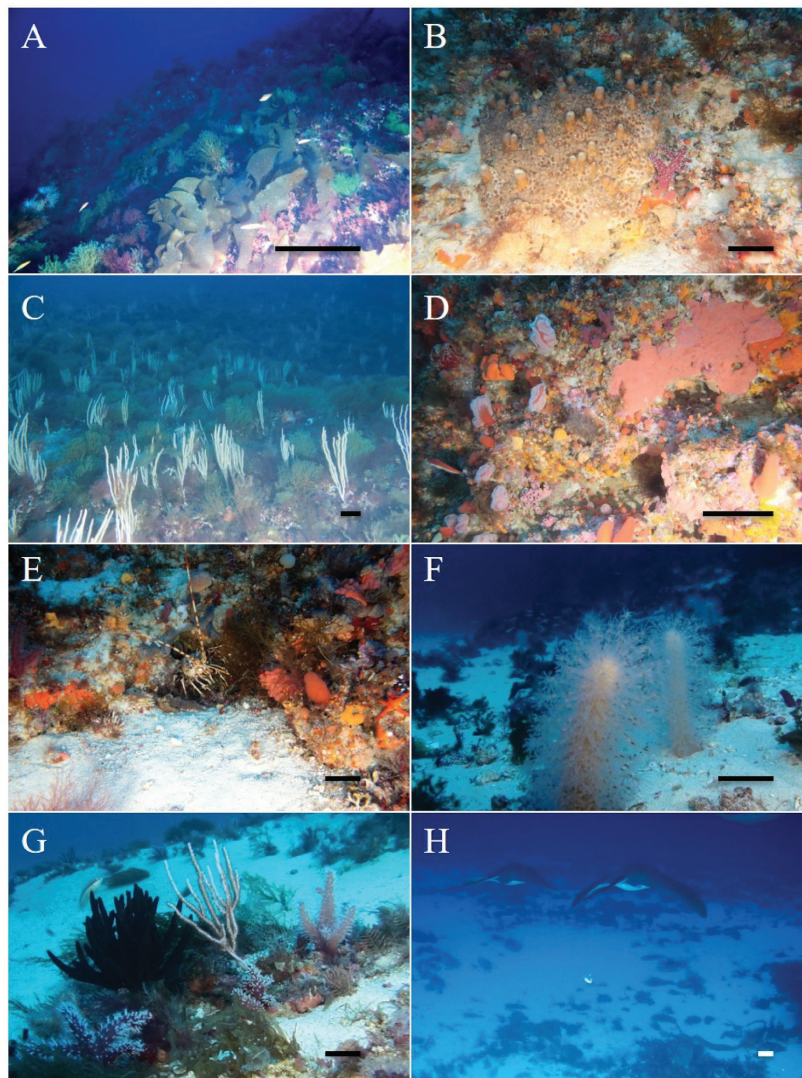


Fig. 9: ROV images of some habitats and species identified on the Nereo Bank. A) Dense algal population dominated by *Laminaria rodriguezii* (–40 m); B) Gently sloping coralligenous bottom composed of sponges such as *Cliona celata*, cnidarians such as *Alcyonium acaule*, and numerous ascidians and bryozoans (–50 m); C) Gently sloping coralligenous bottom dominated by *Eunicella singularis* scattered in a dense algal population (–30 m); D) Highly diversified vertical coralligenous community dominated by the encrusting sponge *Hexadella racovitza*, the tubular *Haliclona* sp. and the erect ascidians *Aplidium* cfr. *proliferum* and *Aplidium* cfr. *tabarquensis* (–40 m); E) A specimen of *Palinurus elephas* emerging from a coralligenous concretion (–50 m); F) Coastal detritic bottom dominated by the finger-shaped sea pen *Veretillum cynomorium* (–50 m); G) Sponge–cnidarian assemblage dominated by *Alcyonium acaule*, *Eunicella singularis* and the candelabrum-shaped sponge *Raspailia viminalis* (–50–60 m); H) Specimens of *Myliobatis aquila* (–40 m). Scale bars 10 cm.

and species of conservation concern, likely to be due to its wider bathymetric range from the infralittoral to the upper bathyal zone. The high RLI value indicated that the Cnidaria and Pisces in these biocoenoses are generally not in ‘danger’ of extinction. Nevertheless, most species found in the ‘shelf-edge rock’ and in the ‘bathyal mud’ habitats are included in the Threatened categories in the IUCN Red List: they were represented by cnidarians such as gorgonians, antipatharians and pennatulaceans. Moreover, many of the cnidarian species found in bank areas and for which data about conservation state are available (Global, Mediterranean and/or Italian Red Lists), are Near Threatened with extinction and show a decreasing Population Trend. Furthermore, the abundant marine litter present in the area, composed mostly of lost

or abandoned fishing gear, represents a serious threat to bank ecosystems by entangling and damaging the sessile fauna, especially corals (Octocorallia and Hexacorallia; Consoli *et al.*, 2018).

The results of this study provide a fundamental baseline for addressing more in-depth studies on macrophytes, which appear to be very abundant and diversified on these banks. In particular, further research should be focused on the species belonging to the ‘*Cystoseira*’ complex, and *Sargassum* sp., *Laminaria rodriguezii* and *Posidonia oceanica* populations. Porifera need further investigation as well, owing to their high diversity, mainly in coralligenous and semi-dark cave habitats. Numerous specimens of *Pachastrella monilifera* and *Pocillastra compressa* were found on the Graham Bank between 100

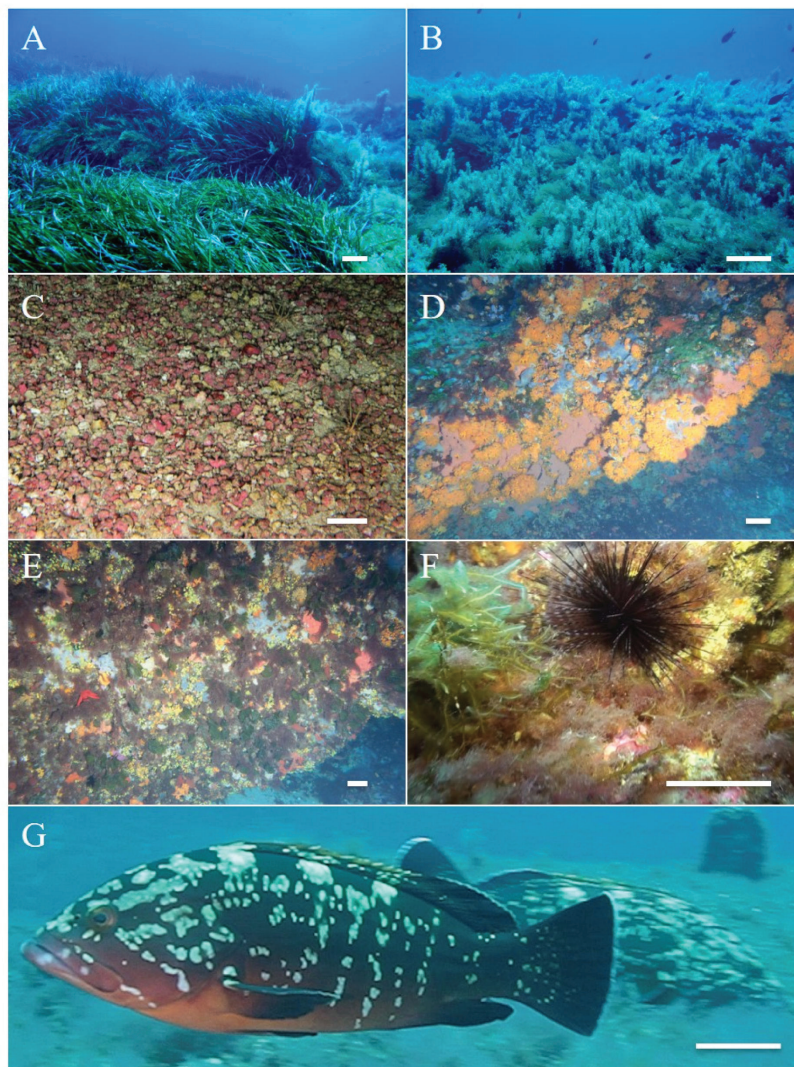


Fig. 10: ROV images of some habitats and species identified on the Pantelleria Vecchia bank. A) *Posidonia oceanica* seagrass flourishing on rocky outcrops (–20 m); B) Algal population dominated by *Sargassum* sp. densely covering the euphotic bottoms along with *Posidonia oceanica* seagrass (–20–30 m); C) Coastal detritic bottom with rhodoliths and cidarid sea urchins (–50 m); D) Vertical surface hosting a coralligenous community dominated by *Astroides calycularis*. Wide patches of the encrusting sponges *Hexadella racovitzai* are also visible (–35 m). E) Vertical-to-overhanging surface hosting a coralligenous community dominated by *Leptopsammia pruvoti* (–35 m); F) The protected urchin *Centrostephanus longispinus* (–30 m); G) Two adults of the endangered dusky grouper *Epinephelus marginatus* (–15 m). Scale bars 10 cm.

and 180 metres depth on rocky substrates. A recent study (Bo *et al.*, 2012b) reported the first record of the so-called deep sponge grounds, composed mainly of these two astrophorids, on some seamounts in the Mediterranean Sea. It would be interesting to investigate the occurrence of these sponge assemblages on the Graham Bank. Moreover, it would be important to elucidate better the large diversity of the banks' sponges from the taxonomic point of view, as numerous other un-identifiable sponge species were found to form important aggregations. Cnidarians such as *Chironophthya* cfr. *mediterranea*, *Aiptasia* sp., and *Thalamophyllia gasti* deserve further analysis, due to their rarity and their ability to contribute to the structural complexity of the coral gardens. Dense population of *Ceriantharia* sp. (probably *Arachnantus oligopodus*) observed on the Graham Bank need a deep taxonomic review. This species, an enigmatic cerianthid, was recently found in the Ligurian Sea and Central Tyrrhenian Sea

in similar habitats and with comparable high densities (Marzia Bo, personal observation).

The IUCN Red Lists and the international conventions and directives represented a baseline for this study; however, despite the different lists of protected species consulted, it was possible to make only limited considerations on the state of conservation of the identified species. In fact, some taxonomic groups, such as Macrophyta, Bryozoa, Tunicata and Porifera are scarcely or not considered in these lists. This could be for different reasons, such as the low commercial value, the microscopic dimensions (especially Bryozoa) and the difficulty of collection and identification.

As stated by Moser *et al.* (2016), remarkable discrepancies in species conservation status assessment exist between the IUCN Red Lists and the international conventions and directives (Habitats Directive, Bern Convention, SPA/BD Protocol, CITES). This was confirmed

by our results; in fact, out of 115 taxa of conservation concern observed on the banks of the Strait of Sicily, 108 are listed in the IUCN lists, 22 in the SPA/BD protocols, 16 in the Bern Convention, 10 in the CITES and only four are included in the Habitats Directive. Moreover, very few species that are threatened with extinction or are endangered or vulnerable according to the IUCN Red Lists are listed in the Habitat Directive.

Not surprisingly, the IUCN Red Lists, although not legally binding for European States (unlike the Directives and Conventions), represent the most important instruments for evaluating the extinction risk of species worldwide (Moser *et al.*, 2016); they also contain most complete lists of species. In spite of this, the conservation policies in the EU are largely focused on the Habitats Directive, which is really not exhaustive.

It follows that at European scale an exhaustive and legally binding instrument to protect species of conservation concern is still lacking, and its preparation, approval and issue are highly recommended as the starting point to suggest measures to be undertaken for their protection.

The ecological and biological data here reported are complementary to those reported by Altobelli *et al.* (2017); these authors carried out an ecological evaluation of the Mediterranean banks. Data acquired to date allow to state that these three banks are of high ecological and biological value. However, they are endangered by human activities: mainly fishing, which presently represents the main source of marine litter, and oil and gas extraction, whose increase is foreseen in the near future. In general, research has shown the uniqueness of these offshore shallow environments, which can represent a network of biodiversity hot spots at a Mediterranean scale, that should be managed through binding, regionally based and supranational collaborative management measures (Altobelli *et al.*, 2017; Consoli *et al.*, 2018).

The whole Strait of Sicily has been recently considered as a relevant area of conservation concern (CBD-COP 12 Decisions, 2014). In fact, it has been included in the 12 priority conservation areas likely to contain candidate sites for SPAMIs and included in the EBSA by the Contracting Parties of the Convention on Biological Diversity for their high naturalistic importance. The results acquired could be useful for the delimitation of a future SPAMI or a network of MPAs (including the investigated banks and others located in the same area) and the identification of zones within them with different area-based management measures. An example of this approach is suggested by the Man and the Biosphere (MAB) Programme for the designation of UNESCO biosphere reserves (UNESCO, 2013). In such reserves the core area is devoted to long-term protection with specific conservation objectives; in the buffer zone only activities compatible with the conservation objectives can take place; in the transition area sustainable resource management practices are promoted and developed.

In order to protect these banks, the future challenges are to promote further scientific research, strengthen international political collaboration and foster the involvement of local stakeholders and populations, as recom-

mended in the Annex I of SPA/BD Protocol, reporting the criteria for the choice of protected marine and coastal areas that could be included in the SPAMI list.

Acknowledgements

This paper is dedicated to Giovanni Bortoluzzi who attended, with passion, commitment and professionalism, to the 'ORBS Banchi 2014-2015' research surveys, and who unexpectedly passed away in October 2015. We thank Pietro Battaglia, Silvana Campagnuolo, Luca Castriota, Manuela Falautano, and Mauro Sinopoli for participating to the 'ORBS Banchi 2014-2015' research surveys. Alfio Viola (University of Catania) is acknowledged for SEM assistance. Paper financially supported by Linea di intervento 3.2.1.2 of POR FESR Sicilia 2007-2013 aimed to assess the marine biodiversity in Sicily. Additional funds were provided by the University of Catania through "Piano per la Ricerca 2016-2018" to A. Rosso, n. 22722132118 and "PiaCeRi-Piano Incentivi per la Ricerca di Ateneo 2020-22 linea di intervento 2". This is the contribution n. 472 of the Catania Palaeontological Research Group.

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Supplementary data

The following supplementary information is available online for the article:

Appendix S1: List of taxa detected on the Graham (Gr), Nereo (Ne) and Pantelleria Vecchia (Pa) banks through ROV visual assessment and ROV grabber sample.