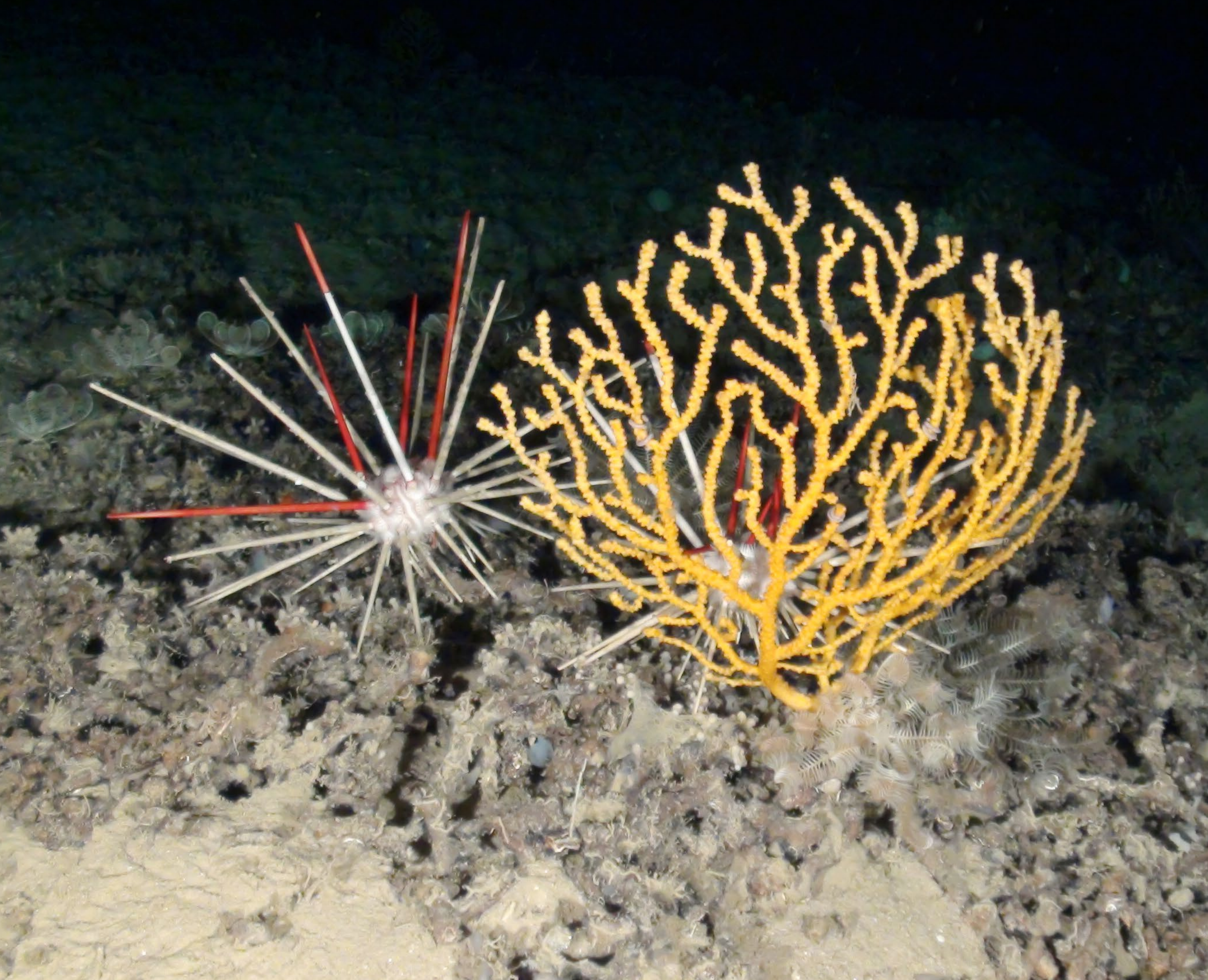
The Mediterranean Biodiversity Centre
SPA/RAC

PROCEEDINGS OF THE 2nd MEDITERRANEAN SYMPOSIUM ON THE CONSERVATION OF DARK HABITATS



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Proceedings of the 2nd Mediterranean Symposium on the conservation of Dark Habitats

FORWARD

Dear Friends and Colleagues,

Following the recommendations of:

- the **Action Plan for the Conservation of Marine Vegetation in the Mediterranean Sea** (adopted by the Contracting Parties to the Barcelona Convention in 1999 and updated in 2012)
- the **Action Plan for the Conservation of Coralligenous and other calcareous bio-concretions of Mediterranean** (adopted by the Contracting Parties to Barcelona Convention in 20018 and updated in 2016)
- the **Action Plan for the conservation of habitats and species associated with seamounts, underwater caves and canyons, aphotic hard beds and chemo-synthetic phenomena in the Mediterranean Sea** (Action Plan for Dark Habitats adopted by the Contracting Parties to the Barcelona Convention in 2013), and
- the **Action Plan concerning Species Introduction and Invasive Species** (Adopted by the Contracting Parties to the Barcelona Convention in 2003 and updated in 2016)

a series of scientific symposia, dedicated to these habitats and NIS, was initiated in 2000 by organising the first Mediterranean Symposium on Marine vegetation. These initiatives aimed essentially to take stock of the recently available scientific data and to promote the cooperation between specialists and key actors working in the Mediterranean.

The Mediterranean Symposia on Marine Key Habitats are an important output, not only of the UNEP/MAP Mid-Term Strategy for the period 2016-2021 (Decision IG.22/1)[1], but also for MedKeyHabitats II Project[2] "Mapping of marine Key habitats and assessing their vulnerability to fishing activities in the Mediterranean" financed by MAVA foundation under its Mediterranean Strategy.

The "Mediterranean Symposia on Marine Key Habitats and NIS" will also provide an opportunity to discuss best practices in the monitoring of marine key habitats and non-indigenous species and provide elements to further improve the Integrated **Monitoring and Assessment Programme of the Mediterranean Sea and Coast and related Assessment Criteria (IMAP)**, of the Ecosystem Approach (EcAp) in the Mediterranean.

The organization of the "Mediterranean Symposia on Marine Key habitats and NIS" together back to back in Antalya from 14 to 18 January, is a joint collaboration among **UNEP/MAP-SPA/RAC** and the **Turkish Ministry of Environment and Urbanization**, as follows :

- 6th Mediterranean Symposium on Marine vegetation (from 14 to 15 January 2018)
- 3rd Mediterranean Symposium on the Conservation of Coralligenous and other Calcareous Bio-Concretions (From 15 to 16 January 2018)
- 2nd Mediterranean Symposium on the Conservation of the Dark Habitats (17 January 2018)
- 1st Mediterranean Symposium on the Non-Indigenous Species (From 17 to18 January 2018)

The Turkish Marine Research Foundation, **TUDAV**, as **SPA/RAC** partner will support the local organization of this event.

This edition will also be a good opportunity to discuss new topics such as monitoring and definition of Good Environmental Status (GES) in the Mediterranean and so strengthen links between scientists and scientific institutions.

Khalil ATTIA
SPA/RAC Director

[1] https://wedocs.unep.org/bitstream/handle/20.500.11822/6071/16ig22_28_22_01_eng.pdf?sequence=1&isAllowed=y
[2] http://www.rac-spa.org/medkeyhabitats2

CONTENTS

PROGRAMME 1

KEYNOTE CONFERENCES.. 3

Ricardo AGUILAR, GARCIA S., PERRY A.L., ALVAREZ H., BLANCO J., BITAR G. 5
THE BATHYMETRIC DISTRIBUTION OF FISH AND OTHER KEY BENTHIC SPECIES AND COMMUNITIES IN LEBANESE SUBMARINE CANYONS

Boris DANIEL, TUNESI L., AQUILINA L., VISSIO A. 13
RAMOGE EXPLORATIONS 2015 AND 2018: A CROSS-BORDER EXPERIENCE OF DEEP OCEANOGRAPHIC EXPLORATIONS

Donat PETRICIOLI, BAKRAN-PETRICIOLI T. 19
STATUS OF KNOWLEDGE ON MARINE CAVE ENVIRONMENTS OF THE CROATIAN ADRIATIC COAST

ORAL COMMUNICATIONS 25

Ricardo AGUILAR, GARCIA S., PERRY A.L., ALVAREZ H., BLANCO J., CHIMIENTI G., MONTESANTO F., MASTROTOTARO F................................. 27
DEEP-SEA HABITATS AND COMMUNITIES IN THE AEOLIAN ISLANDS (NORTH SICILY)

Giovanni CHIMIENTI, BO M., MASTROTOTARO F. 34
JOIN THE DARK SIDE: MEDITERRANEAN COLD-WATER CORALS

Akrem DRIDI, ZRIBI I., Mnasri I., Achouri M.S., Zakhama-Sraieb R................. 41
PRELIMINARY DATA ON THE DISTRIBUTION OF MARINE CAVES ALONG THE TUNISIAN COAST

Antonietta ROSSO, GEROVASILEIOU V., SANFILIPPO R., GUIDO A.................... 47
UNDISCLOSED BRYODIVERSITY OF SUBMARINE CAVES OF THE AEGEAN SEA (EASTERN MEDITERRANEAN)

Juan SEMPERE-VALVERDE, SABINO L. A., ESPINOSA F., GEROVASILEIOU V., SÁNCHEZ-TOCINO L., NAVARRO-BARRANCO C. **53**
LONG-TERM SPATIO-TEMPORAL DYNAMICS OF SESSILE BENTHOS IN A SHALLOW MARINE SUBMERGED CAVE IN THE WESTERN MEDITERRANEAN SEA

Bülent TOPALOĞLU **59**
A PRELIMINARY STUDY ON THE MACROBENTHIC ORGANISMAL COVER IN AN UNDERWATER CAVE IN GÖKÇEADA ISLAND (NORTH AEGEAN SEA, TURKEY)

POSTERS **65**

Anastasia GALANI, DAILIANIS T., SINI M., KATSANEVAKIS S., GEROVASILEIOU V. **67**
CHARACTERIZATION OF BENTHIC COMMUNITIES IN MARINE CAVES OF THE ISLAND-DOMINATED AEGEAN SEA (EASTERN MEDITERRANEAN)

Adriano GUIDO, MASTANDREA A., RUSSO F., ROSSO A., SANFILIPPO R., VOULTSIADOU E., GEROVASILEIOU V. **69**
MICROFACIES OF THE BIOTIC CRUSTS FROM TWO AEGEAN SUBMARINE CAVES (EASTERN MEDITERRANEAN)

RECOMMENDATIONS... **71**

SCIENTIFIC COMMITTEE MEMBERS **72**

ORGANISING COMMITTEE MEMBERS **73**

PROGRAMME

Wednesday 16 January 2019

14:00-14:15 **Opening of the Symposium**

14:15-14:45 Keynote conference: "**The bathymetric distribution of fish and other key benthic species and communities in Lebanese submarine canyons**" by **Ricardo AGUILAR**, GARCIA S., PERRY A.L., ALVAREZ H., BLANCO J., G. BITAR.

14:45-15:15 Keynote conference: "**Ramoge explorations 2015 and 2018: a cross-border experience of deep oceanographic explorations**" by **Boris DANIEL**, TUNESI L., AQUILINA L., VISSIO A.

15:15-15:45 Keynote conference: "**Status of knowledge on marine cave environments of the Croatian Adriatic coast**" by **Donat PETRICIOLI**, BAKRAN-PETRICIOLI T.

Session 1: **Current Knowledge of the deep habitats**
Chair : Ricardo AGUILAR, **Rapporteur** : Antonietta ROSSO

15:45-16:00 "**Deep-sea habitats and communities in the Aeolian Islands (North Sicily)**" by **Ricardo AGUILAR**, GARCIA S., PERRY A.L., ALVAREZ H., BLANCO J. CHIMIENTI G., MONTESANTO F., MASTROTOTARO F.

16:00-16:15 "**Join the dark side: Mediterranean cold-water corals** " by **Giovanni CHIMIENTI,** BO M., MASTROTOTARO F.

16:15-16:30 Discussion

Session 2: **Current Knowledge of undersea caves**
Chair : Antonietta ROSSO, **Rapporteur** : Ricardo AGUILAR

16:30-16:45 **"Preliminary data on the distribution of marine caves along the Tunisian coast"** by **Akrem DRIDI**, ZRIBI I., MNASRI I., ACHOURI M.S., ZAKHAMA-SRAIEB R.

16:45-17:00 "**A preliminary study on the macrobenthic organismal cover in an underwater cave in Gökçeada Island (North Aegean sea, Turkey)**" by **Bülent TOPALOĞLU**

17:00-17:15 "**Undisclosed bryodiversity of submarine caves of the Aegean sea (Eastern Mediterranean)**" by **Antonietta ROSSO**, GEROVASILEIOU V., SANFILIPPO R., GUIDO A.

17:15-17:30 "**Long-term spatio-temporal dynamics of sessile benthos in a shallow marine submerged cave in the Western Mediterranean sea**" by **Juan SEMPERE-VALVERDE**, SABINO L.A., ESPINOSA F., GEROVASILEIOU V., SÁNCHEZ-TOCINO L., NAVARRO-BARRANCO C.

17:30-17:45 Discussion

17:45-18:00 **Poster Session**

18:00-18:15 **Closure of the Symposium**

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KEYNOTE CONFERENCES

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THE BATHYMETRIC DISTRIBUTION OF FISH AND OTHER KEY BENTHIC SPECIES AND COMMUNITIES IN LEBANESE SUBMARINE CANYONS

Abstract
The Lebanese marine environment is characterised by many transversal submarine canyons, along the entire coast, that reach more than 1600 m depth. During 2016, Oceana, in collaboration with the Ministry of Environment of Lebanon (MoE), CNRS, IUCN and SPA/RAC, carried out an expedition in this area to survey five submarine canyon complexes, ranging in depth from 50 to 1000 m. The aim of this research was to describe the key habitats and communities at different depths, as well as the species associated with those ecosystems. Using an ROV, a Van Veen grab, and a CTD to film, sample, and collect oceanographic data, the results provided a list of more than 600 identified taxa. Of these organisms, 95 were fishes, with 84 identified species, and 11 further taxa identified to the genus level. The most common fishes were macrourids, which were widely distributed in all the surveyed canyons, with species such as Nezumia *spp.,* Coelorinchus caelorhincus *and* Hymenocephalus italicus*. Some species of chondrichthyans were also documented, such as the small deep-sea shark* Etmopterus spinax*, the ray* Dipturus oxyrinchus *and the rabbit fish* Chimaera monstrosa*. Other important biological groups and phyla observed were crustaceans (due to their high abundance), echinoderms (because of the presence of some rare species), cnidarians (with the first record of a gorgonian in Lebanese waters), sponges (including hexactinellids), and molluscs (the most biodiverse group with more than 170 species documented).*

Key-words: submarine canyons, fish, deep-sea habitats, bathymetric distribution, marine protected areas

Introduction

The waters of Lebanon host a wide variety of ecosystems, ranging from shallower features such as coralligenous habitats, seagrass meadows and vermetid reefs, to deep-sea ones such as underwater canyons (Bariche, 2010). Lebanese offshore waters are characterised by a narrow continental shelf, which is perpendicularly crossed by various canyon systems that connect coastal zones to deep-sea habitats. These geographic features are important ‘keystone structures’ due to their role in supporting deep-sea communities acting as nursery and shelter habitats, benefiting fisheries, enhancing carbon sequestration, and providing other ecosystem goods and services to human society (Fernandez-Arcaya *et al*., 2017).

Lebanese marine ecosystems face, from a general perspective, similar pressures and threats to the entire Mediterranean. The status of the Lebanese coast has been described as declining due to over-exploitation and pollution from different origins, making the current uses of coastal areas unsustainable (Saab *et al*., 2008). These activities include, among others: marine aggregate (i.e., sand and gravel) extraction, sewage and oil dumping, unsustainable and illegal fisheries, habitat degradation, recreational uses, coastal urbanisation, invasive species, and larger-scale impacts such as the effect of climate change (Lebanese Ministry of Environment & IUCN, 2012).

The Lebanese government has signed or ratified various international conventions and agreements that directly affect the protection of its waters, including, among others, the Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention) and the Convention on Biological Diversity (CBD). As a signatory to these agreements, Lebanon is committed to designate Marine Protected areas (MPAs) for the protection and management of its marine environment and biodiversity. To date, only 2 MPAs have been established in these waters. One general obstacle to MPA designation and management, in Lebanon and elsewhere, is the lack of detailed information about deep marine habitats and species. In the Mediterranean, such information is still relatively deficient, despite advancements in marine research technology and recent efforts to prioritise the study of marine ecosystems. In the Levantine area, the need for marine data is particularly pronounced for the northeastern basins of the Levantine area, in comparison with the central and western basins (Crocetta *et al.,* 2013). This lack of data is even more pronounced when it comes to deep-water ecosystems, which are known to contribute significantly to the total biodiversity of the Mediterranean (Danovaro *et al.*, 2010).

Closing this knowledge gap is the primary aim of the *Deep-sea Lebanon* project (2015-2018) developed by Oceana, in collaboration with IUCN, UNEP-MAP-RAC/SPA, the Lebanese Ministry of Environment, and the Lebanese National Council for Scientific Research (CNRS). The aim of this project is to describe the key habitats and communities at different depths, as well as the species associated with those ecosystems. Providing first-hand information about deep-sea ecosystems to the Lebanese authorities will help to increase the protection of Lebanese waters, and specifically of ecosystems found in deep areas. Ultimately, this increased protection will also contribute to reaching Aichi Target 11 by 2020, and to strengthening the natural marine biodiversity corridor in the Eastern basin.

Materials and methods

A research cruise was carried out in Lebanese waters during a period of nearly four weeks (3–27 October 2016), across a total of five canyons: Tarablus/Batroun, Jounieh, St. George, Beirut escarpment, and Sayniq (Fig. **1**). These areas were selected on the basis of available scientific information and consultation with project partners, covering some of the main underwater canyons and including some areas highlighted as priorities for consideration as potential MPAs.

Exploration of the seabed was principally carried out by a non-intrusive (visual) method, using a Saab Seaeye Falcon DR ROV, equipped with two forward-facing cameras. The bottom was filmed sailing at an average speed of 0.1-0.2 knots, both in high- and low-definition, and simultaneously recording position, depth, course and time. In total, 51 ROV dives were carried out, ranging in depth from 36 to 1050 m. These surveys yielded 71 h 15 min of video of the seabed, and 4601 still images. Samples of key habitat-forming species were also collected (by means of the robotic arm of the ROV) for detailed analyses to confirm preliminary species identifications based on the live video feed.

Sediment and infaunal community composition were examined by collecting samples in soft-bottom areas with a 12 L Van Veen grab. In total, 12 grab samples were collected from a depth range of 76-1015 m and were processed on board. Specimens retained on 0.5 mm and 1 mm mesh sieves were kept for identification.

Following the expedition, analysis of the footage recorded by the ROV was carried out by Oceana scientists. All of the visible species were identified to the finest taxonomic level possible. Specimens collected with the ROV and in grab samples (94 specimens), were also identified to the finest resolution possible. In cases where identification required additional expertise, specimens and/or footage were sent to taxonomic experts for confirmation.

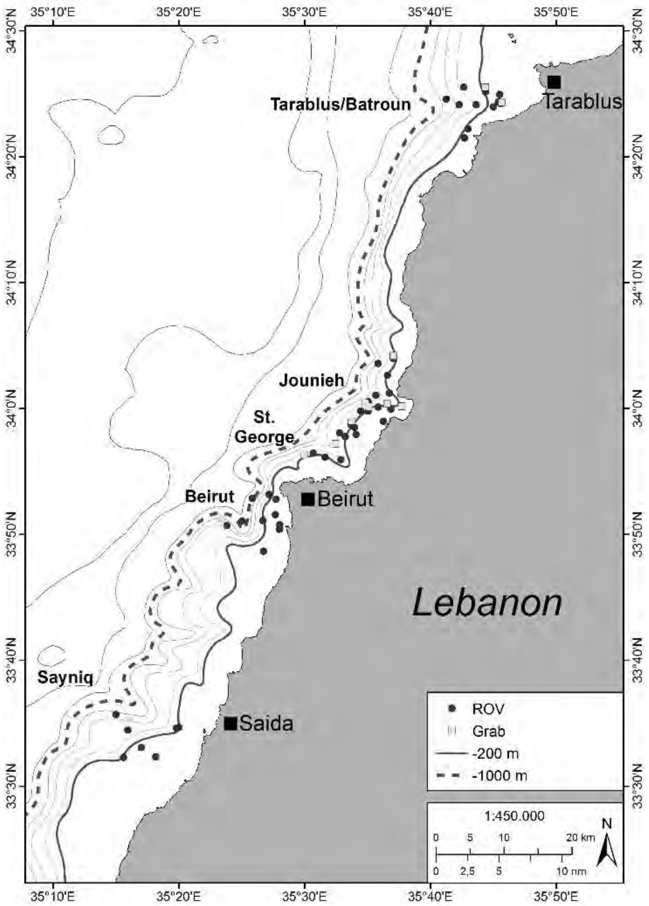

Fig. 1: Survey areas and methods during the expedition.

Results

Key species

In total, 622 taxa were identified both from ROV footage and sediment samples: 358 to the level of species, 118 to genus, and 146 to order or higher. Some biological groups and species documented are of particular relevance, due to their abundance and diversity, such as fishes, crustaceans and molluscs, or their rarity, as they included new records for Lebanon and for the Mediterranean Sea, new species to science, and protected and threatened species (Fig. 2 and Fig. 3).

Fishes were one of the best represented taxonomic group, with 84 identified species (23% of the species identified), 11 further taxa identified to the genus level, and various others still pending identification. Nearly all of the recorded fishes belonged to the class Actinopterygii, with the exception of a small number of individuals of chondrichthyans (i.e., *Chimaera monstrosa*, *Dipturus oxyrinchus* and *Etmopterus spinax*). Of all the fishes documented, 48 species were documented below 200 m depth.

Surveys revealed an abundance of crustaceans, with pandalid shrimps (*Plesionika* spp.) and the deep-water rose shrimp (*Parapeaneus longirostris*) being the most abundant species. The striped soldier shrimp (*Plesionika edwardsii*) was by far the crustacean species with the most widespread distribution and the highest abundance; more than 70% of the documented crustaceans belonged to this species. It was documented from approximately 250 m depth, on both rocky and muddy bathyal substrates. Via the ROV videos recorded during the expedition, it was possible to document the occurrence of a diversity of cephalopods (e.g., *Pteoctopus tetrachirrus*, *Sepia orbignyana*) bivalves (e.g., *Neopycnodonte cochlear*), gastropods (e.g., *Murex forskoehliiI Bolinus brandaris*), and scaphopods (e.g., *Antalis* spp.). Grab samples also provided additional data on bivalves, gastropods, and scaphopods which, due to their size or behaviour (e.g., living within the sediment) would have been impossible to identify via direct visual methods.

Dozens of species identified during these surveys had never previously been recorded from Lebanon. Key species of interest among these first-ever records included the glass sponge *Farrea bowerbanki*, rabbitfish (*Chimaera monstrosa*), velvet-belly lanternshark (*Etmopterus spinax*), and cnidarians such as the gorgonian *Swiftia pallida*, sea pens (e.g., *Pennatula rubra*, *Virgularia mirabilis*, and *Funiculina quadrangularis*), and species of the subclass Hexacorallia, such as *Sideractis glacialis* and tree coral (*D. ramea*). Two sea stars (*Hacelia superba* and *Leptasterias* sp.), had not previously been recorded from the Mediterranean Sea. In addition, three species were discovered that are likely to be new to science: the sponge *Axinella* sp. (Grenier *et al.*, 2017), the sea star *Luidia* sp., and the stony coral cf. *Anomocora* sp. Thirteen species that are considered protected and/or threatened in the Mediterranean Sea were also found in the area (Tab. 1), including: seven species for which strict measures of protection are required under Annex II of the SPA/BD Protocol of the Barcelona Convention (*Centrostephanus longispinus*, *D. ramea, Desmophyllum dianthus*, *Pinna rudis*, *Tonna galea*, *Tursiops truncatus* and *Sarcotragus foetidus*); three species whose exploitation is regulated under Annex III of the SPA/BD Protocol of the Barcelona Convention (*Epinephelus marginatus*, *Spongia officinalis* and *Scyllarus arctus*); two species assessed by IUCN as Endangered in the Mediterranean Sea (*Epinephelus marginatus* and *D. dianthus*), five assessed as Vulnerable (*D. ramea*, *F. quadrangularis*, *Merluccius merluccius*, *Tursiops truncatus*, and *P. rubra*). Two additional species were observed that are considered Near Threatened (*Chimaera monstrosa* and *Dipturus oxyrhincus*).

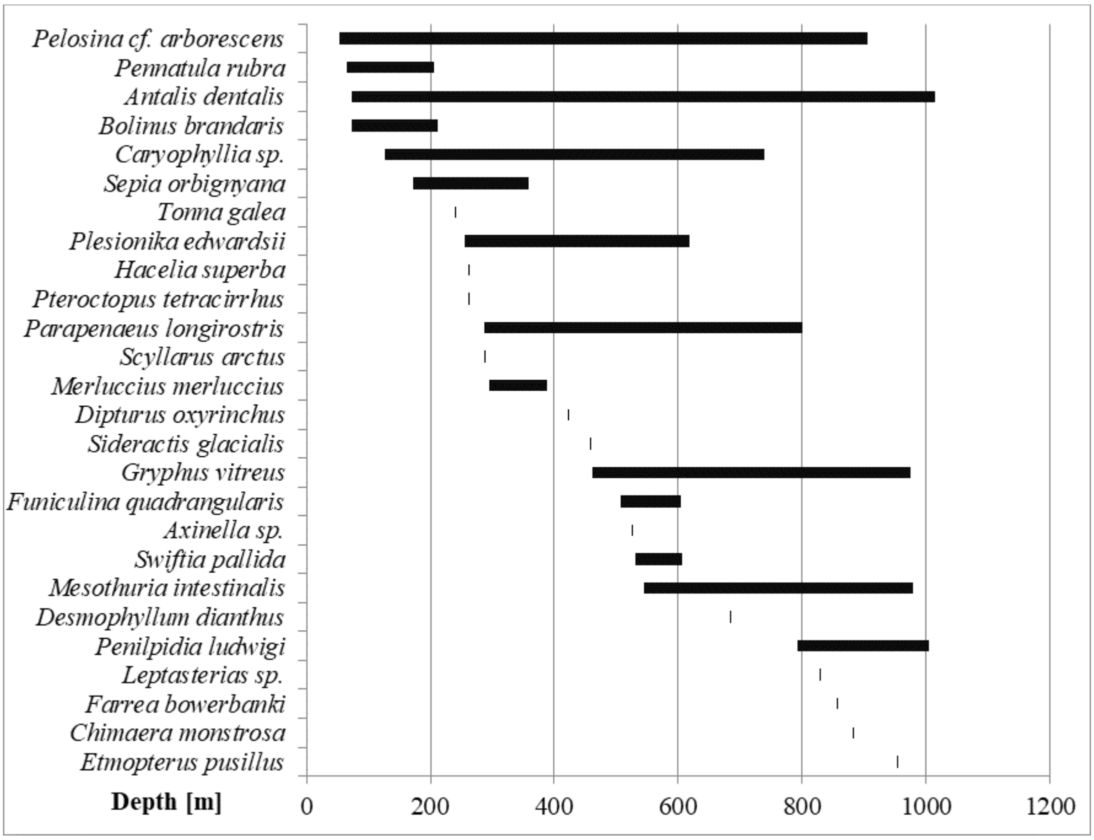

Fig. 2: Bathymetric range of key deep-sea species documented during the expedition. Key species represented in this figure are those observed below 200 m depth.

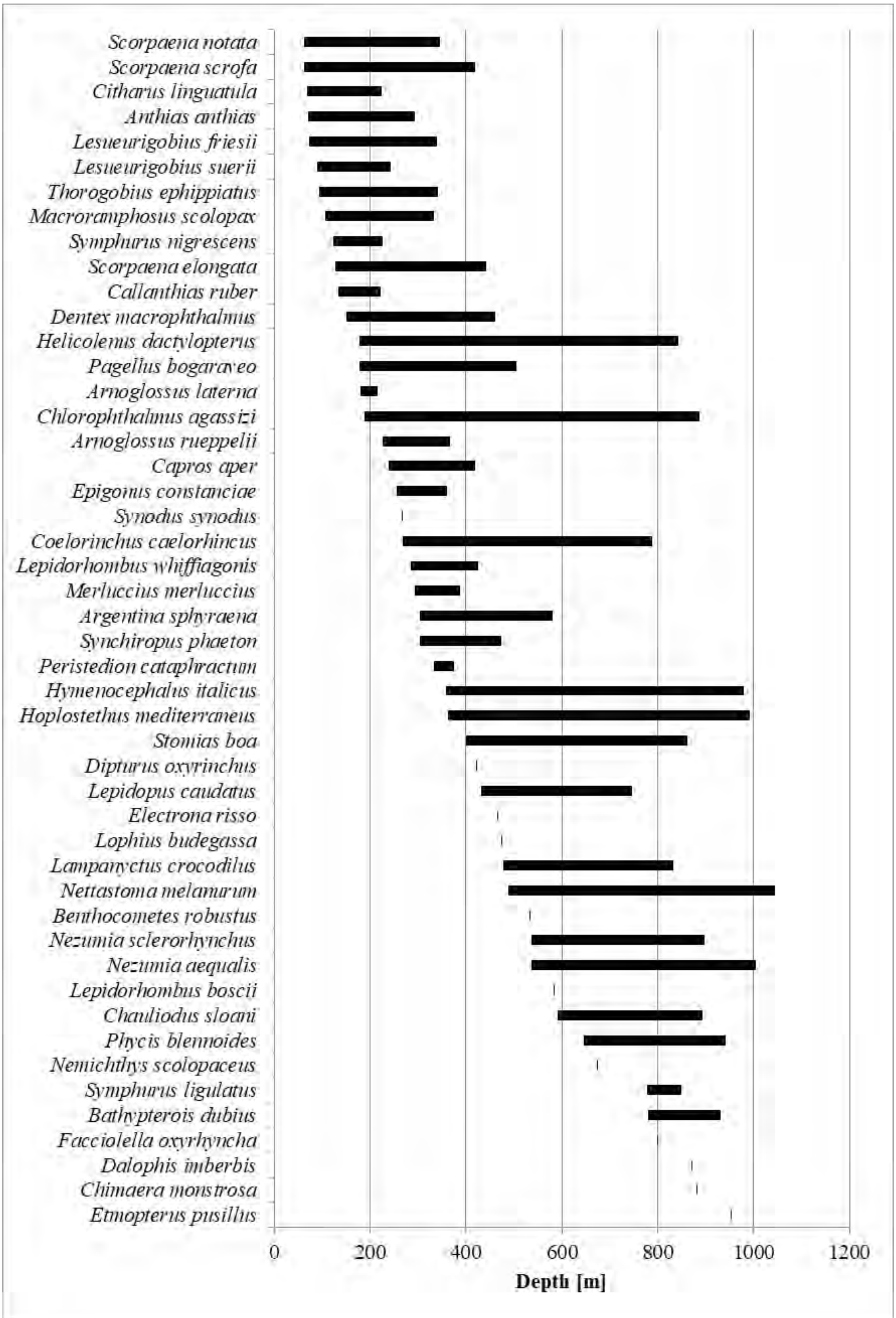

Fig. 3: Bathymetric range of deep-sea fish species documented during the expedition. Fish species represented in this figure are those observed below 200 m depth.

Some of the organisms identified from these surveys are considered non-indigenous; all of them are of Indo-Pacific origin, including mainly fish, but also molluscs and one algal species. Non-indigenous species were present in all five surveyed areas, at a maximum depth of 100 m, although, in general, fewer such species were identified during the expedition than expected. One possible explanation relates to the deep-sea range of the surveyed areas, since Lessepsian species tend to be associated with shallow or pelagic waters.

Tab. 1: Protected and threatened species documented during the expedition. AII: Annex II of the SPA/BD Protocol of the Barcelona Convention; AIII: Annex III of the SPA/BD Protocol of the Barcelona Convention; IUCN: IUCN Red List Threat Status in the Mediterranean X: listed; NT: Near Threatened; EN: Endangered; VU: Vulnerable.

Phylum	Species	AII	AIII	IUCN
Arthropoda	*Scyllarus arctus*		X	
Chordata	*Chimaera monstrosa*			NT
Chordata	*Dipturus oxyrhincus*			NT
Chordata	*Epinephelus marginatus*		X	EN
Chordata	*Merluccius merluccius*			VU
Chordata	*Tursiops truncatus*	X		VU
Cnidaria	*Dendrophyllia ramea*	X		VU
Cnidaria	*Desmophyllum dianthus*	X		EN
Cnidaria	*Funiculina quadrangularis*			VU
Cnidaria	*Pennatula rubra*			VU
Echinodermata	*Centrostephanus longispinus*	X		
Mollusca	*Pinna rudis*	X		
Mollusca	*Tonna galea*	X		
Porifera	*Sarcotragus foetidus*	X		
Porifera	*Spongia officinalis*		X	

Key communities

The habitat types documented, from soft to hard bottoms, harboured key communities of conservation interest, such as coralligenous reefs, rhodolith/maërl beds, fossil reefs, and facies of sponges, cnidarians, gorgonians/sea fans, sea pens, oysters and echinoderms.

Extensive areas of coralligenous habitats were documented extending along the Lebanese coast, on the continental shelf and at the heads of the canyons surveyed, at a depth range of 38-86 m. In these locations, rhodolith beds were also documented, at depths of 46-91 m. A belt of coralligenous habitats was found between approximately 70 m and 90 m depth, which coincided with the edge of the continental shelf and the heads of the submarine canyons, in all surveyed areas. Coralligenous beds were formed by well-developed reefs, which in turn supported a high diversity of species. Also, old coralligenous reefs (87-158 m), were found, formed by dead algae, but providing substrate and refuge for many other species. Both coralligenous and rhodolith beds are considered as vulnerable and essential to hundreds of species, and all Mediterranean states are committed to their conservation, as signatories of the Barcelona Convention.

Rocky bottoms were also found supporting important benthic communities. In areas surrounding canyon heads, rocks were covered with organisms such as corals, sponges, oysters, and brachiopods, while in deep-sea areas, some rocky bottoms were related to ancient fossil reefs built by corals, worms and other organisms. These fossil reefs were documented in two depth ranges: 162-287 m and 699-901 m. In these places, particular species of interest were found, including stony corals (e.g., *D. dianthus* and *Caryophyllia calveri*), glass sponges (*F. bowerbankii*) and gorgonians (*S. pallida*).

Muddy and sandy-muddy bottoms supported vulnerable habitat-forming species, such as sea pens (*P. rubra* and *Virgularia mirabilis*) which were widely distributed in areas where sandy bottom was mixed with mud, from 65 to 206 m depth, while tall sea pens (*F. quadrangularis*), occurred in certain bathyal muddy areas, from 506 to 604 m depth. Some bathyal areas were also dominated by echinoderms, particularly holothurians documented from 544 m to 1004 m depth, such as *Mesothuria intestinalis* and *Penilpidia ludwigi*, and tube worms, tube-dwelling anemones, highly abundant large foraminifers documented at all depths surveyed (*Pelosina* cf. *arborescens*), and brachiopods such as *Gryphus vitreus,* which was documented forming locally important aggregations from 462 to 975 m depth.

Discussion and conclusions

The presence of key benthic species and habitats of conservation interest has been documented in five Lebanese canyons, from shallow to deep waters. More than 600 identified taxa and various habitat types and species aggregations have been recorded and described. These include thirteen protected and threatened species, three possible new species to science (*Anomocora* sp. nov. *Axinella* sp. nov and *Luidia* sp. nov), and new records for Lebanon and the Mediterranean Sea, which all confirm the biodiversity value and need for protection of this deep-water ecosystem.

The data obtained from the 2016 Deep-Sea Lebanon Expedition provided a wealth of information about deep-sea benthic communities along the Lebanese coast. This information establishes a scientific foundation for the development of a plan to manage and protect vulnerable ecosystems, habitats, and species in Lebanese waters, in the face of current and future threats. This plan should be developed in line with the relevant Action Plans developed by UNEP-MAP-RAC/SPA, with measures being developed to protect vulnerable marine ecosystems within fisheries overseen by the General Fisheries Commission for the Mediterranean, and with Lebanon's legal obligations to protect species listed in Annex II of the SPA/BD Protocol of the Barcelona Convention. One critical element of this plan will be the declaration of new MPAs under the framework of a Lebanese network of MPAs. These areas may be designated to protect important geological features (e.g., submarine canyons), habitats, or community types, in order to ensure the coherence and connectivity of marine protection in Lebanese waters, and to help safeguard the natural corridor of the Eastern Mediterranean basin.

Acknowledgments

Oceana is grateful for the generous support of MAVA Fondation pour la Nature, and to all partners of this project, including the Lebanese Ministry of Environment, the Lebanese National Council for Scientific Research (CNRS-L)- as well as its National Centre for Marine Sciences (NCMS)-, UNEP-MAP-SPA/RAC and IUCN, for their full support and collaboration. The authors would also like to thank Dr. Óscar Ocaña, Dr. Alfonso A. Ramos Esplá, Dr. José Templado, Marie Grenier, Dr. Jean Vacelet and Dr. Thierry Pérez for their valuable help with species identification; Dr. Abed El Rahman Hassoun and Ali Badreddine from CNRS-L for having shared the time onboard with us, as well as their extensive knowledge and expertise on these waters. Oceana also thanks the Lebanese Navy Forces, for their support and assistance during the expedition, and the crew of the *Sea Patron*.

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RAMOGE EXPLORATIONS 2015 AND 2018: A CROSS-BORDER EXPERIENCE OF DEEP OCEANOGRAPHIC EXPLORATIONS

Abstract
In the framework of the international agreement RAMOGE, as follow up of the work done in 2014 to identify Ecologically or Biologically Significant Marine Areas (EBSAs) in the RAMOGE area, a first oceanographic exploration campaign was carried out in 2015 by means of the ISPRA research vessel (Italy). The campaign ran from August 16 to 23 between France (Cogolin), Monaco and Italy (San Remo). The main objective of the RAMOGE_Explo_2015 campaign was to explore the depth range 50-400 meters in order to study some relevant sites to establishing an inventory of habitats, protected and commercial species and anthropogenic pressures. To this purpose, six areas of ecological interest have been selected, two per member country. The collected information represented a significant contribution, both in terms of knowledge of biodiversity and the pressures exerted by human activities and have also been used for the development of local management framework documents, such as Marine Protected Areas. Following the same approach, a second campaign, "RAMOGE_Explo_2018", was carried out in summer 2018, thanks to the means of IFREMER (France). The stakes of this new field activity were centered on habitat, species and marine litter in the depth range 2000-3000 m, focusing on seamounts and to verify the presence of a facies of Isidella elongata *recorded in the sixties.*

Key-words: canyon, seamount, human impact, international cooperation

Introduction

Bringing together France, Italy and Monaco since 1976, the RAMOGE agreement was born after an awareness of the pollution of the sea. Its goal is to raise consciousness, develop actions and make recommendations regarding the protection of the marine environment. The RAMOGE area is a part of an Ecologically or Biologically Significant Marine Area (EBSA). EBSAs are identified by the Convention on Biological Diversity (CBD). International agreements and European guidelines encourage the countries to be part of the ecological issues of the deep-sea areas.

As part of its actions, the RAMOGE agreement has organized a preliminary identification of ecological focus areas in 2014. Several deep-sea areas were identified, especially canyon heads and deep rocky outcrops. In 2015, a first scientific exploration mission of the deep-sea, between 50 and 400 depth, was organized to make an inventory of habitats, commercial and protected species, ecosystems and human pressures. Based on these criteria, 6 ecological focus areas were retained, two for each member (Fig. 1): Italy - Arma di Taggia and Bordighera canyons; Monaco - Larvotto canyons and deep rocks; France - Nioulargue Bank and Dramont Canyon (Daniel *et al*., 2016).

For the RAMOGE_Explo 2018 the stakeholders remained focused on habitats and deep-sea species, with exploration at a depth of about 2500 m and, in addition, observing areas of accumulation of macro-waste.

These campaigns bring elements of knowledge to establish an ecological situational analysis in order for it to be taken into account in public politics (Marine protected areas, MFSD, DHFF/Natura 2000).

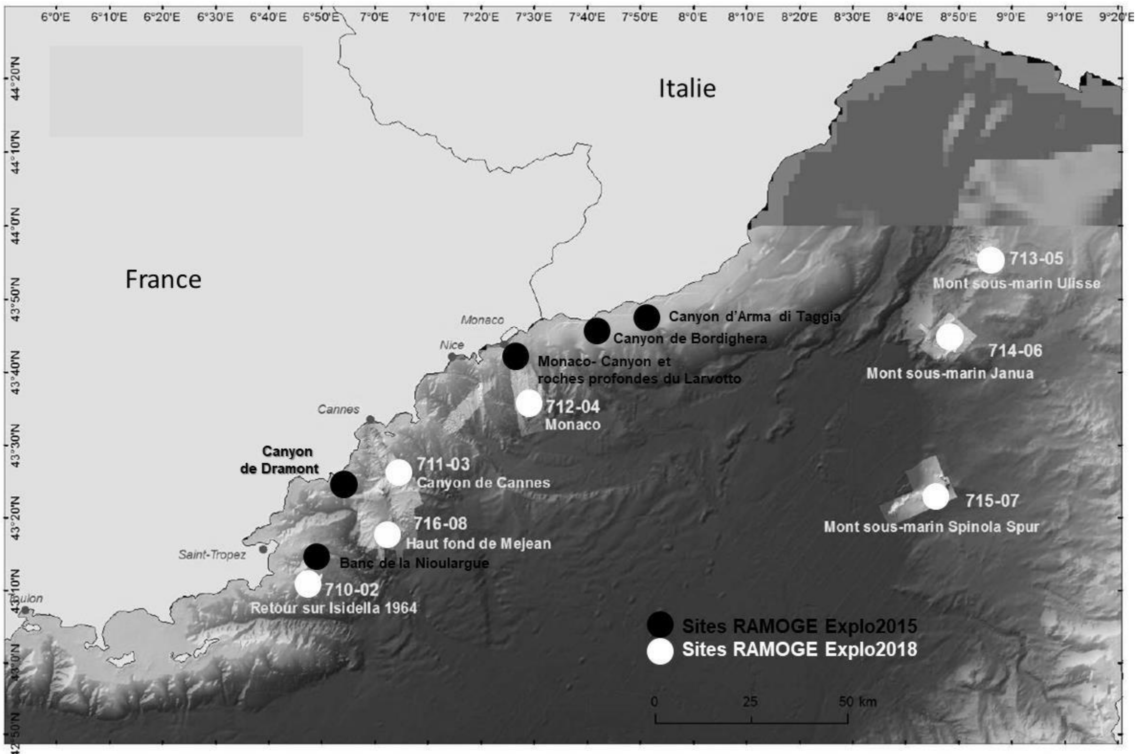

Fig. 1: Map of the areas explored by RAMOGE_Explo 2015 & 2018 (according to Fabri & Daniel, 2018 and Fourt *et al*., 2015).

In the desire to strengthen this cross-border cooperation, several structures got together to prepare and realize these campaigns; in France, the "Agence française pour la biodiversité", "Unité Mixte de Service du Patrimoine naturel", "Groupement d'Intérêt Scientifique Posidonie", IFREMER, and the CPIE of the Lerins Islands ; in Italy, "Istituto Superiore per la Protezione e la Ricerca Ambientale" (ISPRA), the University of Genoa and as for Monaco, the Direction of the Environement and the Scientific Center of Monaco.

Materials and methods

The first RAMOGE oceanographic exploration campaign in 2015, ran from August 16 to 23 between France (Cogolin), Monaco and Italy (San Remo), using the scientific equipment of ISPRA (Italy) (Fig. 2). Explorations were conducted thanks to the 23 m vessel "R/V Astrea" which had on board for this occasion, the ROV "Polluce III", allowing exploration down to 500 m (Fig. 2).
In 2018, the second campaign ran from September 17 to 25, in the waters of the three countries. (Fig. 1) using the nautical means of the French oceanographic fleet: 83 m vessel "N/O Atalante" which had on board the ROV "Victor" which can go down to 6000 m depth (Fig. 2).

Fig. 2: a) Oceanographic vessel "R/V Astrea" used during the 2015 campaign; b) ROV "Pollux III" used during the 2015 campaign; c) Oceanographic vessel "N/O Atalante" used during the 2018 campaign; d) ROV Victor 6000 used during the 2018 campaign (Photos by B. Daniel/AFB).

For each ROV dives, the exploration of ecological focus areas was conducted in the same way. The description of the marine environment relied mainly on visual data (photos and videos) obtained from unmanned submarines. The identification of the species of the megafauna was visual, usually using samples from the campaigns.
Bathymetry and audio images were obtained through a multibeam sounder. Analysed prior to the dives, a bathymetric survey allowed to target efficiently the explorations.

Results
In the 2015 campaign, more than 21 km were explored in a depth range between 52 and 462 m: 0.5 km (Canyon of Monaco) and almost 10 km of the coast (East of Nioulargue Bank), deep-sea rocks (Nioulargue Bank and Larvotto), as well as canyon heads in their upper part (canyons of Dramont, Monaco, Bordighera and Arma di Taggia). These sites were largely dominated by species from circalittoral zones. Rocky and bathyal muddy areas were also explored in the canyons. A total of 122 species were observed and identified. The Nioulargue Bank and the Larvotto rocks exhibited a variety of seascapes. The former consists of a rocky outcrop covered with a rich detrital and dotted with rocky outcrops colonized by gorgonians, black corals and some sponges. The rocks of Larvotto emerge from a soft, muddy or sandy-muddy medium. They are oases of life for the sessile species, dominated by sponges, black corals and gorgonians. In the shallower rocky areas of the Dramont and Bordighera canyons, similar seascapes were observed: rocky outcrops mainly covered by gorgonians, such as *Paramuricea clavata* and *Eunicella cavolini*, but also *E. verrucosa*, especially in the canyon of Bordighera and on the rocks of Larvotto.

The yellow coral *Dendrophyllia cornigera* was observed at all sites, but it was particularly present in the Bordighera Canyon, sometimes with such a high density that it should be considered a facies.
At the Nioulargue Bank, the discovery of two colonies of the deep-sea coral *Madrepora oculata* could indicate the presence of a settlement of these cold-water corals, in even deeper environments. With regard to the visible anthropogenic pressures, we observed in particular those related to lost fishing gear (Bordighera Canyon, Nioulargue and Bank) and those due to repeated anchoring (deep Larvotto rocks). Stand-up faunal stands can be severely damaged by fishing activities, causing mechanical damage and increasing sedimentation rates (Ferrigno *et al*., 2018).
Seven sites were explored during the 2018 campaign, ranging between 396 and 2194 m in depth: two sites in Cannes and Monaco, a deep rocky plateau in Méjean and three seamounts (Tab. 1).

Tab. 1: Sites explored during the RAMOGE_Explo 2018 campaign- (dates and depth intervals are indicated for each site).

Sites	Dates	Maximum depth (m)	Minimum depth (m_
Return to *Isidella* 1964	18/09/2018	1070	800
Cannes Canyon	19/09/2018	1445	945
Monaco Canyon	20/09/2018	2194	1292
Ulysse Seamount	21/09/2018	1234	399
Janua Seamount	22/09/2018	1118	790
Spinola spur Seamount	23/09/2018	2124	2001
Méjean Highland	24/09/2018	917	396

Data from the 2018 campaign have not yet been processed. A considerable amount of data has been acquired (almost 2 terabytes of video recordings and photographic material) (Fig. 3). These data are expected to produce information on the: (i) signaling and georeference of known species, (ii) new bathymetric distribution of signaling; (iii) frequency of species observation (i.e. rare, frequent); (iv) environment and context assemblages; (v) possibly behavior; (vi) sites of significant biodiversity; (vii) sites visibly impacted by humans with the presence of macro-waste.
The first observations of the 2018 campaign make it possible to sketch the following general remarks:

a) The field of *Isidella elongata* observed in 1964 was not found. This may be due to inaccurate historical data and possibly to exploration not compatible with its presence (800 m). Observations during the MedSeacan exploration campaign located *I. elongata* between 600 and 100 m on the French continental coasts.
b) The exploration of the Cannes Canyon was dedicated to the search for macro-waste. It is a silted canyon with almost no signs of bioturbation.
c) The Monaco Canyon has muddy parts with large areas of accumulation of macro-waste, drop-offs of heterogeneous composition: rocks, marls, visual identification of the sea pen *Protoptilum carpenteri* (taxonomic identification is in progress), which was previously found in the Balearic Islands by Mastrototaro *et al*. (2014).

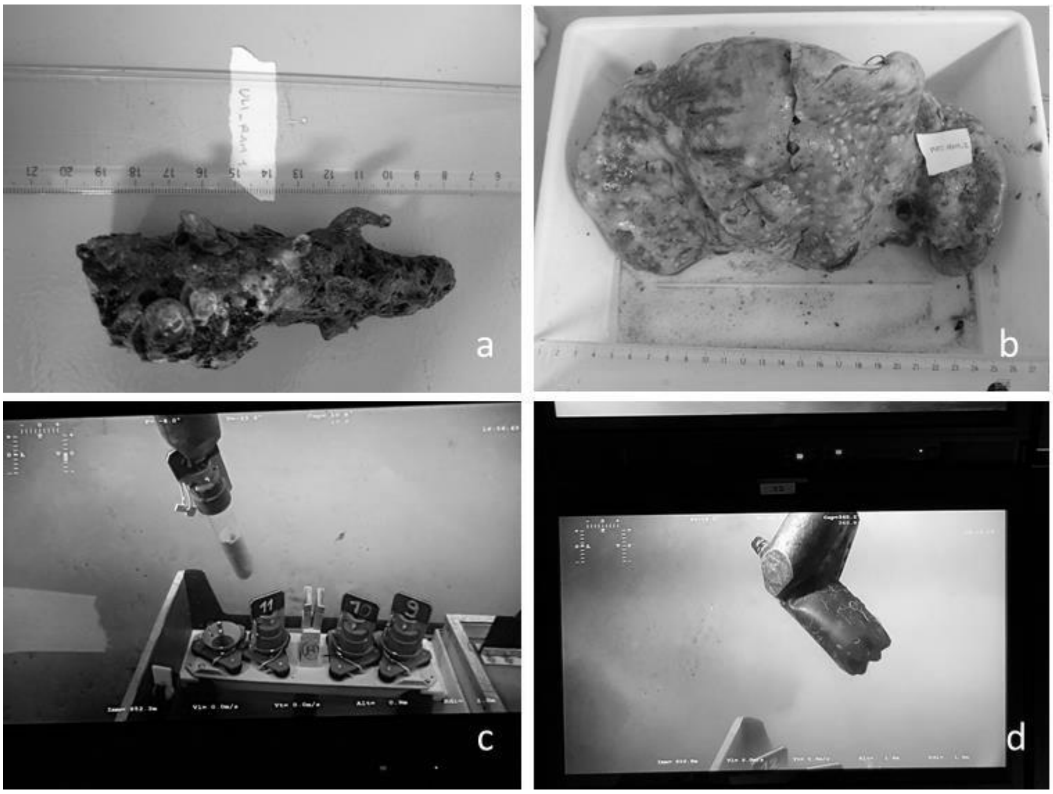

Fig. 3: Taxonomic identification in progress: a) dead corals and undetermined fossil structure from a depth of 729 m, Ulysse Seamount; b) massive sponge, 767 m, Méjean Highlands; c) Core drilling with ROV Victor; d) Macro-waste removal with ROV Victor (Photos by Marzia Bo/Univ. of Genoa & Eric Tambutte/Monaco Scientific Center).

d) The rich observations from Ulysses Seamount justified the interest of this site in terms of biodiversity: rich diversity of anthozoans and fish, high density of *Callogorgia verticillata*.
e) The Janua Seamount also hosts interesting anthozoan diversity. Many *Farrea* sp. sponges were observed. The presence of pieces of fossil wood on the slopes and the top of the seamount questioned scientists on the geological history of the site (Fig. 3).
f) Low biodiversity on the Spinola Seamount, but an interesting geological aspect with extensive thanotocoenoses (characterization in progress).
g) The Mejean Shoal has revealed a higher density of massive sponges than other dives on rocky areas. The top of this shoal presents important signs of bioturbation, sponges of the genus *Leiodermatium* (also observed in 2008), which should make it possible to differentiate *Leiodermatium pfeifferae* of *L. lynceus* (Fourt *et al*., 2017).

Discussion

The knowledge obtained on deep Mediterranean ecosystems from the RAMOGE deep-sea exploration campaigns carried out in 2015 and 2018, illustrates the fruitful collaboration between the scientific teams of the three countries (Italy, Monaco and France). Monitoring the health status of these deep environments is fundamental to assessing the effects of human activities and thus constitutes an essential element of

adaptive management, namely the ability to adjust, refine human activities and thus optimize their preservation effectiveness.
The RAMOGE experiment, with the collaboration of the scientific components of the three signatory countries of the Agreement, aims to be an example of international collaboration for the definition of standardized activities for the study and monitoring of deep habitats. The exchanges between the members of the crew aboard the ship were rich and revealed the importance of working together. It is clear that the three countries share, at different intensities, the same environmental issues.

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STATUS OF KNOWLEDGE ON MARINE CAVE ENVIRONMENTS OF THE CROATIAN ADRIATIC COAST

Abstract
There are more than a thousand semi- and entirely submerged caves, underwater passages and cold-water pits along the eastern karstic coast of the Adriatic Sea which belongs to the Republic of Croatia. They are inhabited by, up to now, poorly investigated, fragile and long-living communities of semi-dark caves, completely dark caves and cold-water pits with bathyal elements. Marine caves are endangered marine habitats according to the NATURA 2000 classification (submerged and partly submerged marine caves, code 8330). Most caves are located within the Ecological Network of the Republic of Croatia (NATURA 2000 Network). Although Croatian coasts are considered among the most studied Mediterranean areas concerning geology and biodiversity of marine and anchialine caves, comprehensive and quantitative studies were only done on a small number of Croatian caves. There is an urgent need for systematic research and monitoring of marine caves in Croatia. Threats to which marine caves are subjected today are numerous. A considerable number of Croatia's marine caves face an upcoming or rising danger of damage to their living communities and/or their geomorphological features due to intense commercial use (SCUBA diving, nautical, and individual tourism). Our experience suggests that it is currently impossible to control the vast and often remote areas encompassing submerged caves in Croatia. Therefore, some of Croatia's most valuable caves are possibly exposed to over exploitation and poor management or no management at all. Croatia's submerged karst deserves particular consideration and valorisation.

Key-words: Marine caves, protection, touristic exploitation, Croatia

Introduction

The eastern coast of the Adriatic Sea, covered by marine carbonate sediments which emerged as carbonate bedrock in the Alpine orogeny, was highly subjected to karstification. During the last sea transgression, a considerable part of the karstified area was submerged. Numerous karstic features that were originally formed under subaerial conditions, like caves and pits, dolines, karstic springs, etc. are now under the sea. By 2010 only 235 submerged caves were officially recorded in Croatia (Surić *et al*., 2010), but it was clear that, on the basis of knowledge about recent subaerial caves and pits (Gottstein, 2010), it was likely that there are thousands of marine caves, pits and caverns to be discovered. According to Giakoumi *et al*. (2013) 708 marine caves have been recorded so far in the whole Adriatic Sea.

Marine cave geomorphology, depth and submarine freshwater discharge form the environmental surroundings that influence the distribution of living organisms inside caves and result in their uniqueness (Bakran-Petricioli *et al*., 2007; Radolović *et al*., 2015). Fragile and long-living communities of semi-dark caves, completely dark caves and cold-water pits with bathyal elements inhabit these, up to now, poorly investigated habitats. Marine caves belong to endangered marine habitats according to the NATURA

2000 classification (submerged and partly submerged marine caves, code 8330). According the European Red List of Habitats (assessment for Mediterranean marine habitats by Gubbay *et al.*, 2016) “Communities of Mediterranean mediolittoral caves and overhangs” (EUNIS code A1.44) are listed as Data Deficient (DD) while “Communities of Mediterranean circalittoral caves and overhangs” (EUNIS code A4.71) are listed as Least Concern (LC) according to the broad distribution range criterion. Nevertheless, it can be assumed that the habitat quality might have decreased over the last several decades. Most marine caves in Croatia are within the Ecological Network of the Republic of Croatia (NATURA 2000 Network). Marine cave communities and organisms are subjected to numerous threats, the most important of which are: mechanical damage caused by unregulated diving activities, physical damage and siltation due to coastal development, marine pollution, extractive human activities, water temperature rise, and potentially non-indigenous species (Aguilar *et al.*, 2017 and references therein).

Materials and methods

The aim of this work was to provide an overview of existing knowledge about marine caves of the Croatian coasts in the Adriatic Sea. In this study, the term “marine caves” encompasses all kinds of submerged karstic phenomena recorded along the eastern Adriatic coast (i.e. caves, pits, caverns, big vruljas, marine parts of anchialine caves, semi- and entirely submerged objects). A considerable amount of data were collected by the authors during extensive field expeditions which took place in the Adriatic Sea from 1992 to date, focusing on benthic organisms and communities (part of it has already been published). Furthermore, a detailed literature survey was performed, both on scientific and grey literature sources and the Croatian legislative framework. We also consulted a number of professional and recreational divers as well as divers leading touristic dive centres about their experience with diving in caves in Croatia.

Results

Our review showed that biological research in Croatian marine caves started approximately sixty years ago (Abel, 1959; Rützler, 1965; Riedl, 1966). In the past decades, researchers from different European countries (*e.g.* Austria, France, Italy) as well as from Croatia have studied several taxonomic groups in a number of Croatian caves (Rützler & Sarà, 1962; Starmühlner, 1968; Griessinger, 1971; Zibrowius & Grieshaber, 1975; Zibrowius, 1976; Fransen, 1991; Logan, 2003; Kršinić, 2005; Pisera & Vacelet, 2011; Rastorgueff *et al.*, 2014).

Localized faunistic research in submarine caves with the focus on photo-documentation took place at the end of the seventies, (Legac & Legac, 1979; caves along the Islands of Rab and Grgur). However, most of the findings from marine caves were obtained during more general faunistic research on certain areas (e.g. Kovačić, 1997, on the cryptobenthic fish in Kvarner area; Novosel *et al.*, 2002, on the benthos of the Velebit Channel; Kružić, 2002; 2007, on the anthozoan fauna of Mljet National Park and Telašćica Nature Park, respectively; Zavodnik *et al.*, 2005, on the benthos of the Senj Archipelago). During the last two decades detailed biocoenotic studies of only a few particular marine caves were undertaken in the Croatian part of the Adriatic (Grubelić *et al.*, 1998, for the submarine cave in the central Adriatic; Arko-Pijevac *et al.*, 2001, for the cave on Vrbnik Island; Faresi *et al.*, 2006, for the Columbera cave on Istrian Peninsula; Radolović *et al.*, 2015, for the Y-Cave on Dugi Otok Island).

Due to their complex geomorphology many Croatian caves, especially those in the coastal zone, harbour various types of communities. For example, the pronounced impact of freshwater discharge often results in the development of an anchialine biocoenosis in close contact with marine cave biocoenoses. This is the case for the semi-submerged Živa Voda pit on Hvar Island, where an anchialine community overlies the community of completely dark caves (Bakran-Petricioli *et al*., 2007; Novosel *et al*., 2007).
A close connection between caves on land and those in the sea can be demonstrated in vruljas (submarine temporary freshwater springs), especially those pit-like vruljas at the foothills of Croatian mountains Velebit and Biokovo. When inactive, they harbour a marine community in a permanent pioneer stage, and when active, the flowing freshwater might flush organisms from the karstic underground into the sea (preliminary work by Petricioli *et al*., 1994).
Marine caves with a descending character, which therefore trap cold winter water inside and harbour bathyal organisms, were found in Croatia over a decade ago (Bakran-Petricioli *et al*., 2007; Novosel *et al*., 2007). Dense populations of the small hexactinellid sponge *Oopsacas minuta* Topsent, 1927 were discovered in the cold marine part in a number of marine caves along the eastern Adriatic coast (marine caves at Hvar, Lastovo, Iški Mrtovnjak and Fraškerić Islands). So far, the finding of a dense population of the carnivorous demosponge *Lycopodina hypogea* (Vacelet & Boury-Esnault, 1996) on the south-western part of Telašćica Nature Park, in a narrow pit at Garmenjak Island at 24 m of depth, is the only Adriatic record of this species (Bakran-Petricioli *et al*., 2007). Long-term temperature measurements confirmed that cold sea water is present in the studied descending caves throughout the year.
Considering species diversity in Croatian marine caves, Radolović *et al*. (2015) found that the diversity of poriferan species in the Y-Cave on Dugi Otok Island in the central Adriatic (56 sponges out of 139 taxa recorded in the cave) ranks among the ten highest when compared to other studied Mediterranean caves (Gerovasileiou & Voultsiadou, 2012). So far, a total of 77 sponge species were found in seven marine caves along the eastern Adriatic coast (Bakran-Petricioli *et al*., 2012).
The sensitivity of marine cave biota to elevated sea temperatures due to climate change has already been documented for mysids of genus *Hemimysis* that inhabit dark Croatian caves (Chevaldonné & Lejeusne, 2003).
In addition, we have observed marine litter in the most remote parts of many marine caves. Notable examples include a truck tyre in the submarine pit Zmajevo Uho in Rogoznica (29 m depth); numerous PET bottles in the submarine pit in Kravljačica cove, Kornat Island, Kornati National Park (20 m depth); numerous plastic bags, pieces of fishing nets and PET bottles in the submerged pit at Borovnik Island, Kornati National Park, (2 m depth); empty plastic milk containers in the submerged pit at Iški Mrtenjak Island (23 m depth); two anchors in the submerged pit Poganica, Šolta Island (30 m depth).
Numerous touristic agencies offer excursions to semi-submerged caves (e.g. Golubinka Cave on Dugi Otok Island, Medviđa Cave on Biševo Island, caves on Lokrum Island) during the touristic season. Usually, the excursions are daily trips by fast boats or sea kayaks. Individual touristic visits to semi-submerged caves are also numerous, and the number of visits and visitors is growing constantly.
A number of SCUBA diving centres offer sea cave diving on a regular basis. Some of the most visited marine caves are Lučica pit on Brač Island, Katedrala cave on Island Premuda, as well as caves and tunnels near Brbišćica Cove on Dugi Otok.

There is also a rising interest for the so called "adrenalin tourism and adventurism", often connected with diving in sea caves. Sometimes such activities are performed by unskilled individuals and a few human deaths and serious injuries have already been noted (e.g. submerged pit Poganica on Šolta Island).

Discussion and conclusions

The Croatian coast is considered one of the most studied Mediterranean areas concerning geology and biodiversity of marine and anchialine caves (Aguilar et al., 2017). However, comprehensive and quantitative studies were done only on a small number of Croatian caves. So far, no systematic research and monitoring of marine caves in Croatia have been undertaken.

It is generally accepted that the species number reported in marine caves of a given area is related to sampling effort and scientific expertise (Gerovasileiou *et al*., 2015). Nevertheless, nowadays in Croatia there is a significant lack of experts, available funds and technology, as well as relevant authorities' determination to support such demanding research.

Methods for studying and monitoring marine caves were recently summarised in the "Draft Guidelines for Inventorying and Monitoring of Dark Habitats" by Aguilar *et al*. (2017) who suggested that future monitoring schemes for marine caves should mainly consider common indicators related to biodiversity. Therefore, there is an urgent need to adopt and/or use/develop appropriate methods for Croatian marine caves.

On the other hand, there is an obvious rising pressure for the commercial use of marine caves (SCUBA diving, nautical, and individual tourism). The consequence is an upcoming or rising danger of damage to living communities and/or devastation of geomorphological features in those caves due to heavy visitation. Thus, there is a high possibility that some important, scientifically valuable organisms, communities or even geomorphological features in Croatian marine caves will be lost even before they could be discovered and scientifically described.

According to Croatian regulations, in order to visit a submerged cave, divers (especially researchers) need to obtain an official permit from the Croatian Ministry of Environment Protection and Energy. Some of Croatia's most visited marine caves are in commercial use although they are part of the NATURA 2000 Ecological Network. However, there is no concession for diving issued or monitoring of diving activities performed. To our knowledge concessions are only issued for Modra Špilja (Blue Cave) on Biševo Island and Zelena Špilja (Green Cave) on Ravnik Island near Vis Island. Recently, the preparation of a project to develop a code of visiting and to determine the visitor carrying capacity for Modra Špilja has started in Split-Dalmatia County. Our experience suggests that it is currently impossible to control the vast and often remote areas encompassing submerged caves in Croatia. To conclude, the uniqueness of Croatia's submerged karst deserves particular consideration.

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ORAL COMMUNICATIONS

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DEEP-SEA HABITATS AND COMMUNITIES IN THE AEOLIAN ISLANDS (NORTH SICILY)

Abstract
*During May-June 2018, Oceana carried out a research expedition in the volcanic archipelago of the Aeolian Islands, to the north of Sicily, to document benthic communities and species down to a depth of 1000 metres. A total of 51 ROV dives were carried out, across six survey areas with differing geological and bathymetric characteristics, including a seamount, continental shelf, sharp slopes, and flat deep-sea beds. Community types observed ranged from seagrass meadows in the shallowest areas surveyed, to coralligenous and maërl beds on the continental shelf, and facies of hexactinellid sponges (*Farrea bowerbanki*) on the deepest rocky slopes studied. Detritic bottoms hosted aggregations of oysters (*Neophycnodonte *spp.) and tube anemones, while muddy bottoms were characterised by various communities of sponges (*Thenea muricata, Aaptos aaptos, *and* Cladorhiza abyssicola*), carnivorous sea squirts (*Dicopia antirrhinum*), and extensive colonies of bamboo corals (*Isidella elongata*), among many other species. On rocky bottoms, both soft and stony corals were common, including* Bebryce mollis, Swiftia dubia, Villogorgia bebrycoides, Callogorgia verticillata, Viminella flagellum, Caryophyllia *spp.,* Dendrophyllia cornigera, *and* Thalamophyllia gasti. *Gardens of the black corals* Antipathes dichotoma, Antipathella subpinnata, Leiopathes glaberrima *and* Parantipathes larix *were also documented, together with sponge aggregations (*Pachastrella monilifera, Haliclona *spp. and* Podospongia loveni*). A total of close to 600 taxa have been observed, including rare, threatened and protected ones, some of which had never been recorded before from the study area.*

Key-words: Sponges, corals, exploration, ROV, Mediterranean Sea.

Introduction

The Aeolian Islands is a volcanic Archipelago of the north of Sicily (Southern Tyrrhenian Sea, Central Mediterranean Sea), dating from 1.3 my and formed by a group of seven main islands, surrounded by submarine seamounts and banks arising between 1,000–1,500 m b.s.l. from a continental crust of 15–20 km of thickness (Favalli *et al.,* 2005; Ventura *et al*., 1999).

This area was identified by the Italian government as being worthy of protection in 1982, under Ministerial Decree 979 (Ministero Dell'Ambiente, 1982). In August 2016, the Italian Ministry of the Environment committed ISPRA, the Italian National Institute for Environmental Protection and Research, to start the environmental studies to acquire part of the necessary information to support creating a new Marine Protected Area (MPA) in the Aeolian Islands. The formal process is underway, and the Italian authorities will develop a proposal for protection, based on all the available information. Oceana was invited by Blue Marine and by the Aeolian Islands Preservation Fund to contribute to this broader effort, by carrying out surveys of deep-sea areas around the Aeolians, from which the information available is scarce.

Six areas of the Archipelago were surveyed during a one-month expedition in order to collect information about the main habitats and communities of the circalittoral and bathyal zones, including coral forests, sponge aggregations, and oyster beds, as well as about the occurrence, distribution and abundance of deep-sea species.

Materials and methods

From May to June 2018, Oceana carried out an expedition around the Aeolian Islands to identify key habitats and communities down to 1,000 m by means of Remotely Operated Vehicle (ROV). The ROV used was a SAAB Seaeye Falcon DR equipped with an HDV (High Definition Video) camera of 480 TVL (Television Lines) with Minimum Scene Illumination of 2.0 lux (F1.4), a ½″ CCD (Charge-Coupled Device) pick-up device, an image sensor, spherical ½ of 3.8-mm and wide-angle lenses (Mastrototaro *et al*., 2017). The ROV also hosted a depth sensor, a sonar, a compass, and laser beams providing a 10-cm scale.

ROV transects were carried out with an average speed of 0.2–0.3 knots and a wide path view averaging approximately 1.80 m. The position was continuously recorded using a LinkQuest Tracklink USBL Transponder with up to 0.25° accuracy.

All the species observed were identified to the finest taxonomic resolution possible. Mega- and macro-fauna were identified mainly with a visual approach. When necessary, some samples were collected using the robotic arm of the ROV in order to identify specific taxa.

Results

The ROV filmed a total of 76h11m of seabed, along a total linear distance of 52,316 m, surveying a total area of ca. 91,344 m^2. Of that area, 65,318 m^2 were below 200 m depth. Close of 600 taxa were identified from the ROV footage, 450 of which to the species level.

The dominant species and the most important habitat builders were cnidarians and sponges, although some other species of foraminifera, echinoderms and molluscs were also abundant across a wide bathymetric range.

The most relevant taxa observed are reported below, and their depth range of occurrence is presented in Tab. 1.

- Cnidaria: Scleractinia

The most common and widely distributed Scleractinia observed were the solitary corals of the genus *Caryophyllia*, especially *C. calveri*, in almost all areas featuring rocky bottoms. These corals were between 250 and 600 m depth, also in areas with high levels of sedimentation.

The yellow coral *Dendrophyllia cornigera* was observed both on rocky and muddy bottoms, from 96 to 615 m depth, with the highest abundance between 150 and 500 m depth. Dead colonies of this species were frequently mixed with living ones and they represented an important substrate used from several other benthic species.

The solitary pink coral *Thalamophyllia gastii* was found on rocks and overhangs at 282 m depth, with local aggregations of hundreds of specimens, while the solitary white coral *Desmophyllum dianthus* was observed at 748–790 m depth, often mixed with other solitary corals.

- Cnidaria: Antipatharia

The so-called black corals *Antipathella subpinnata*, *Leiopathes glaberrima, Parantipathes larix* and *Antipathes dichotoma* were observed on rocky bottoms along a wide bathymetric range. In particular, *A. subpinnata* and *A. dichotoma* showed a wider range, from the circalittoral zone (83 and 129 m depth, respectively) to the bathyal zone (612 and 696 m depth, respectively). Several colonies of *A. subpinnata* hosted shark eggcases laid on their branches.

- Cnidaria: Alcyonacea

This taxon includes both rocky bottom species (as most of the Mediterranean gorgonians) and muddy bottom species (such as the bamboo coral *Isidella elongata*).
In particular, *I. elongata* was found in several muddy bottom areas around the Aeolian Islands, particularly north of Lipari, where a dense aggregation of this species was present below 800 m.
On hard substrata, the two most common alcyonaceans were *Swiftia dubia* and *Bebryce mollis*, showing similar bathymetric distribution of 120–786 and 137–793 m depth, respectively.
In the transition area between the circalittoral and the upper bathyal, some colonies of *Acanthogorgia hirsuta* were observed. Other alcyonaceans recorded were *Chironephthya mediterranea*, *Nidalia studeri*, *Muriceides lepida* and *Villogorgia bebrycoides.*

- Cnidaria: others

It is worthy to mention the finding of the hexacorals *Savalia savaglia* and *Sideractis glacialis*, as well as some unidentified Actinostolidae and several Ceriantharia at different bathymetric levels.
Among hydrozoans, *Lytocarpia myriophyllum* was found to form important facies on soft shallow bottoms from 196 to 212 m depth. All the pennatulaceans found were in bottoms shallower than 200 m depth.

- Porifera: Demospongiae

The most important sponge aggregations in the bathyal zone of the Aeolian Islands were those of Tetractinellida, on both hard and soft bottoms. *Pachastrella monilifera* was the species with the widest bathymetric distribution, from the circalittoral (i.e., 168 m depth) to the deepest point surveyed (i.e., 986 m depth). This species formed mixed aggregations with *Poecillastra compressa* only along the lower limit of the circalittoral zone.
The mushroom-shaped sponge *Thenea muricata* was observed with a wide bathymetric distribution (i.e., 250–837 m depth) either on muddy bottoms and on rocks heavily covered by sediments. *Aaptos aaptos* showed a similar bathymetric distribution to *T. muricata*, but it occurred mainly on rocky bottoms covered by sediments.
Other relevant demosponges were *Haliclona (Soestella) mucosa*, *Podospongia loveni* and the carnivorous sponge *Cladorhiza abyssicola*. While *H. mucosa* was dominant in the transition area between the circalittoral and bathyal rocks (81–263 m depth), *P. loveni* and *C. abyssicola* were common in the deepest areas, on rocky and muddy substrata, respectively.

- Porifera: Hexactinellida

The only glass sponge found was *Farrea bowerbanki*. This species was observed on the deepest hard bottoms with a sharper gradient, and it was sometimes mixed with *Podospongia loveni.*

- Mollusca: Bivalvia

The bivalves *Neopycnodonte cochlear* and *N. zibrowii* were both observed in the study area. In particular, *N. cochlear* was present from 65 to 482 m depth, with most of the specimens observed in the circalittoral zone. On the contrary, the deep-sea oyster *N. zibrowii* was observed in relatively shallow waters, at 223–359 m depth, with only isolated specimens.

- Giant Foraminifera

Pelosina cfr. *arborescens* was the most common species of this taxon, with a wide bathymetric range of 42–958 m depth.

- Chordata: Ascidiacea

The carnivorous sea squirt *Dicopia antirrhinum* was found on muddy bottoms in several areas, from 568–812 m depth. In particular, Secca del Capo was the area with the highest number of sightings.

Tab. 1: Bathymetric distribution of key habitat species in the Aeolian Islands.

Phylum	Class	Order	Species	Depth range (m)
Foraminifera	Monothalamea	Astrorhizida	*Pelosina* cfr. *arborescens* Pearcey, 1914	42–958
Porifera	Hexactinellida	Sceptrulophora	*Farrea bowerbanki* Boury-Esnault, Vacelet & Chevaldonné, 2017	855–986
	Demospongiae	Tetractinellida	*Pachastrella moniliera* Schmidt, 1868	168–986
			Thenea muricata (Bowerbank, 1858)	250–837
		Suberitida	*Aaptos aaptos* (Schmidt, 1864)	252–983
		Poecilosclerida	*Cladorhiza abyssicola* Sars, 1872	380–967
			Podospongia loveni Barboza du Bocage, 1869	283–986
		Haplosclerida	*Haliclona (Soestella) mucosa* (Griessinger, 1971)	81–263
Cnidaria	Hydrozoa	Leptothecata	*Lytocarpia myriophyllum* (Linnaeus, 1758)	196–212
	Anthozoa	Alcyonacea	*Acanthogorgia hirsuta* Gray, 1857	113–282
			Isidella elongata (Esper, 1788)	311–921
			Bebryce mollis Philippi, 1842	137–793
			Muriceides lepida Carpine & Grasshoff, 1975	181–811
			Swiftia dubia (Thomson, 1929)	120–786
			Villogorgia bebrycoides (Koch, 1887)	174–235
			Chironephthya mediterranea López-González, Grinyó & Gili, 2014	146–252
			Nidalia studeri (Koch, 1891)	153–793
		Antipatharia	*Antipathes dichotoma* (Pallas, 1766)	129–696
			Leiopathes glaberrima (Esper, 1788)	274–344
			Antipathella subpinnata (Ellis & Solander, 1786)	83–612
			Parantipathes larix (Esper, 1788)	129–349
		Corallimorpharia	*Sideractis glacialis* Danielssen, 1890	168–791
		Scleractinia	*Caryophyllia (Caryophyllia) calveri* Duncan, 1873	138–898
			Desmophyllum dianthus (Esper, 1794)	748–790
			Thalamophyllia gasti (Döderlein, 1913)	282
			Dendrophyllia cornigera (Lamarck, 1816)	96–615
		Zoantharia	*Savalia savaglia* (Bertoloni, 1819)	274–744
Mollusca	Bivalvia	Ostreida	*Neopycnodonte cochlear* (Poli, 1795)	65–482
			Neopycnodonte zibrowii Gofas, Salas & Taviani, 2009	223–359
Annelida	Polychaeta	Sabellida	*Vermiliopsis monodiscus* Zibrowius, 1968	226–649
Echinodermata	Holothuroidea	Elasipodida	*Penilpidia ludwigi* (von Marenzeller, 1893)	812–946
	Echinoidea	Cidaroida	*Cidaris cidaris* (Linnaeus, 1758)	41–791
Chordata	Ascidiacea	Phlebobranchia	*Dicopia antirrhinum* Monniot C., 1972	568–812

- Echinodermata

Among the echinoderms observed, two species were noteworthy to be mentioned concerning Aeolians waters, due to their wide bathymetric distribution and their abundance. The echinoid *Cidaris cidaris* was recorded from the widest bathymetric distribution (41–791 m depth), and from different types of substrata. On deep bathyal muds, the sea cucumber *Penilpidia ludwigi* resulted relatively common from 800 m depth. Moreover, close to Filicudi Island, at 414 m depth, the starfish *Zoroaster fulgens* has been probably observed for the first time in the Mediterranean Sea.

- Annelida

Vermetids and serpulids were observed in different areas. From the ROV videos it was possible to identify only the serpulid *Vermiliopsis monodiscus*, observed from 226 to 649 m depth.

- Charismatic features

As a result of the volcanic environment of the Aeolian Islands, in some areas, gas seepage and bacterial activity have created crustose and foam-like structures on the seabed. These structures were mainly found in the bathyal zone, down to depth of 925 m, although some bacterial activity and crustose structures were also observed in very shallow waters, from 55 m depth.

Although bacterial activity in some of these structures appears to prevent other species from settling on them, some of the apparently older, large crustose structures seemed to be acting as new reefs. Some species showed a certain attempt of colonization of such structures, including hydroids, corals, corallimorpharians, polychaetes and sponges.

Discussion and conclusions

Research on deep-sea areas is providing new information on the presence and distribution of peculiar marine species and habitats of great scientific interest. The deep-sea habitats observed, such as the coral forests or the sponge grounds, are often affected by human activities causing mechanical impacts (e.g., fishery) or significant changes of the environmental conditions (e.g., climate changes, organic pollution, littering) (Chimienti *et al*., 2018a). In fact, some of the species found in the Aeolian Archipelago are highly vulnerable to anthropogenic impacts, being considered Critically Endangered according to the IUCN Red List (Otero *et al.,* 2017), like the bamboo coral *Isidella elongata* and other habitat-forming anthozoans (Mastrototaro *et al*., 2017; Chimienti *et al*., 2018b) Some of these animal forests (*sensu* Rossi *et al.*, 2017), represents Essential Fish Habitats, being spawning and nursery areas for several fish species, as showed by the presence of shark eggcases on the colonies of *A. subpinnata*. For these reasons, our results are of primary importance for conservation activities aiming for the protection of the so-called Vulnerable Marine Ecosystems (FAO, 2009) and to support a proposal for the establishment of an MPA that embrace the deep-sea habitats of the Aeolian Archipelago. Rare or uncommon species, such as the ascidian *D. antirrhinum*, the elasipodid *P. ludwigi* and the bivalve *N. zibrowii* have been observed in the study area, adding some records for the update of their distribution. Some of them, such as *D. antirrhinum* and *P. ludwigi* are probably most common than what known so far, having been usually unnoticed to date due to their small size, their deep-sea distribution, and the difficult identification in sediment samples because of their small gelatinous body (Mecho *et al*., 2014a, 2014b). On the contrary, *N. zibrowii* is relatively easy to identify but information about its distribution are still scarce (Beuck *et al*., 2016). This species, mainly observed deeper than 500 m so far, seems to occupy a shallower bathymetric range in the Aeolian Archipelago. Rare species can be considered the alcyonacean *C. mediterranea* and the starfish *Z. fulgens*. While *C. mediterranea* has been found only recently in the basin, *Z. fulgens* is considered an Atlantic species mainly found in the Western Atlantic and occasionally in the North-East Atlantic (Clark & Downey, 1992), but never observed before in the Mediterranean Sea.

Besides the coastal habitats, usually being a strong attraction for touristic frequentation and a possible sustainable fruition of an MPA (e.g., Chimienti *et al*., 2017), the establishment of the Aeolian Islands MPA would protect the lush deep-sea communities here presented, providing a consistent contribution for the conservation of the deep Mediterranean fauna. Appropriate management measures and controls will be needed, together with the proper regulation of human activities and consistent zoning of the MPA, according to the distribution of the main marine habitats and communities thriving around the archipelago, in order to safeguard these fragile ecosystems from current and future threats.

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JOIN THE DARK SIDE: MEDITERRANEAN COLD-WATER CORALS

Abstract

Cold-water corals (CWCs) are among the main habitat formers of the deep Mediterranean Sea, hosting a lush diversity of species and playing a crucial ecological role. The term CWC sensu lato *groups taxa of cnidarians with a more or less pronounced frame-building ability with forest-forming organisms both on hard and soft bottoms. CWC species and their occurrence in the Mediterranean Sea are here reviewed and discussed from a biogeographic point of view, considering the geographical areas of occurrence and the bathymetric ranges of distribution. Due to the interaction between particular topography and a combination of cold, oxygenated and trophic-carrying water masses, CWCs communities develop in a mosaic-like situation along the main paths that such currents follow within the basin. This would help to have a comprehensive knowledge about features and processes governing CWC habitats in the Mediterranean Sea, for proper management strategies needed in the near future.*

Key-words: Distribution, habitat, exploration, deep-sea, Mediterranean Sea.

Introduction

The dark side of the Mediterranean Sea is broadly represented by the seabed below the continental slope, from 150-200 m depth, not just because of the lack of sunlight, but considering that the majority of the basin's deep bottoms are still not (or scantly) explored. In the same way, little is known about the species inhabiting such seabed, some of them considered rare and only recently observed for the first time or re-described (e.g., Chimienti *et al*., 2018a; Mastrototaro *et al*., 2015, 2016). Cold-water corals (CWCs) are among the main habitat formers of the deep Mediterranean Sea, constituting peculiar bioconstructions and coral forests that host a lush diversity of species and play a crucial role in the marine ecology of the basin (Chimienti *et al*., 2018b; Ingrosso *et al*., 2018; Freiwald *et al*., 2009; Rossi *et al*., 2017).

Mediterranean CWCs are cold-affinity azooxanthellate cnidarians that can be present below 200 m depth with large aggregations of colonies acting as habitat formers. In some places, CWCs can develop as highly structured communities over wide areas, representing the so-called coral provinces (Taviani *et al*., 2017). Nowadays, under the name of CWC are grouped both stony corals (i.e., Scleractinia) building up bioconstructions that persist after their death, as well as forest-forming anthozoans (i.e., Antipatharia, Alcyonacea and Pennatulacea) whose aggregations can improve the structural heterogeneity on both hard and soft bottoms.

This study reviews the known distribution of some of the most common and large-sized Mediterranean CWCs. On hard bottoms, we focused on the so-called white corals *Desmophyllum dianthus* (Esper, 1794), *Lophelia pertusa* (Linnaeus, 1758) and *Madrepora oculata* Linnaeus, 1758, on the yellow coral *Dendrophyllia cornigera* (Lamarck, 1816), on the black corals *Antipathes dichotoma* Pallas, 1766, *Leiopathes* *glaberrima* (Esper, 1788) and *Parantipathes larix* (Esper, 1788), as well as on the alcyonaceans *Callogorgia verticillata* (Pallas, 1766) and *Viminella flagellum* (Johnson, 1863). On soft bottoms, we focused on the alcyonacean *Isidella elongata* (Esper, 1788), and on the pennatulaceans *Funiculina quadrangularis* (Pallas, 1766) and *Kophobelemnon stelliferum* (Müller, 1776) (Chimienti *et al*., 2018b). Their distribution has been reviewed considering geographical areas of occurrence and bathymetric ranges of distribution, in order to provide an update about the actual biogeography of these deep-sea habitat formers in the basin, as well as to understand the future perspective in the study of deep-sea communities and habitats.

Materials and methods

A review of the scientific literature about Mediterranean CWCs was carried out to organize all the available information concerning the 12 main coral species considered, their geographical distribution and their bathymetric range of occurrence within the basin. A total of 207 papers were selected and analyzed, among which research papers, conference proceedings and project reports. The literature considered dated back from the first record of CWCs in the Mediterranean Sea (Steindachner, 1891) to the recent literature published until 2018 (Chimienti *et al*., 2018b and references therein).

All the published records of living CWCs on hard bottoms were considered valid, including the old ones, due to the stability of this environment and to the relatively low removal impacts related to the fishery. On the contrary, records of soft-bottom CWCs older than 15 years were not considered, because of the sensitivity of these communities to fishing pressures. Therefore, non-recent data of CWCs on muddy bottom, usually collected with trawl nets or dredges, need to be verified considering the ongoing decline of these communities, as for the gardens of *I. elongata* and the fields of *F. quadrangularis*, reported as very common in the past but currently very rare within the whole Mediterranean Sea (Bo *et al*., 2015; Mastrototaro *et al*., 2017).

Results

The analysis of the literature highlighted how the Mediterranean Sea now appears to be speckled with records of living CWCs (Fig. 1). Only along African coasts, historically less explored, information on CWC presence and distribution is scarce, except for the Alboran Sea where a CWC province is present (Chimienti *et al*., 2018b; 2018c; Hebbeln *et al*., 2009).

Rocky-bottom CWCs showed a widespread distribution throughout the basin, with numerous findings mainly occurring in the last twenty years, when Remotely Operated Vehicles (ROVs) and other deep-sea exploration tools have been widely used. The two colonial white corals *M. oculata* and *L. pertusa* have been found mainly in the canyons and slopes along the coasts of Spain, France, Italy, Morocco and, for some species, also Croatia and Greece (Fig. 1). In particular, *M. oculata* seems to be more common than *L. pertusa*, and dominant in shallower areas (e.g., within 500 m depth), despite the two species show almost the same bathymetric range of distribution on a basin scale. In fact, *M. oculata* has been found from 118 m depth (Chella Bank, Alboran Sea) to 1100 m depth (Santa Maria di Leuca CWC province, Ionian Sea) (Lo Iacono *et al*., 2012; Mastrototaro *et al*., 2010), while *L. pertusa* from 180 m depth (Gulf of Lions CWC Province, Balearic Sea) to 1100 m depth (Santa Maria di Leuca CWC province) (Gori *et al*., 2013; Mastrototaro *et al*., 2010). A similar distribution has been observed for the solitary coral *D. dianthus* (Fig. 1), recorded from the westernmost Gibraltar Strait to the easternmost coasts of Cyprus and Lebanon, with a bathymetric range from 246 m depth

(Gulf of Lions CWC Province) to 1136 m depth (Northeast Menorca, Balearic Sea) (Gori *et al*., 2013; Montagna *et al*., 2006).

The yellow coral *D. cornigera* can be locally common, but rarely forms large monospecific aggregations. It is usually shallower than white corals, and it has been recorded from 80 m depth (Mantice Shoal, Ligurian Sea) to 733 m depth (Linosa Through, Sicily Channel) (Bo *et al*., 2014; Freiwald *et al*., 2011).

The deep sea-fan *C. verticillata* is present on the rocky seabed of many sites and coral provinces, from the Alboran to the Aegean seas (Fig. 1), where it can form mixed gardens with other CWC species, creating an extremely heterogeneous and three-dimensional habitat (Angeletti *et al*., 2014). The shallower Mediterranean record of *C. verticillata* is at 90 m depth (St Eufemia Gulf, Tyrrhenian Sea), while the deepest is at 1000 m depth (South Malta CWC province, Sicily Channel) (Bo *et al*., 2012; Evans *et al*., 2016). On the contrary, the whip-like gorgonian *V. flagellum* has been currently found only in the western basin, with relatively few records from the Alboran Sea to the Sicily Channel (Fig. 1). This species seems to prefer deep circalittoral hard substrata, from 90 to 200 m depth, although it has been found down to 500 m depth (Eastern Alboran CWC province) (de la Torriente *et al*., 2018).

Black corals have been found mostly found in the Sicily Channel, Sardinia Channel, South Adriatic Sea, Aegean Sea and Alboran Sea (Fig. 1), from the shelf edge to bathyal depths. In particular, *A. dichotoma* has been found from 90 m depth (St Eufemia Gulf) to 640 m depth (Santa Maria di Leuca CWC province) (Bo *et al*., 2012; Mastrototaro *et al*., 2010), similarly to *P. larix*, recorded from 90 m depth (St Eufemia Gulf) to 458 m depth (Eastern Alboran CWC province) (Bo *et al*., 2012; Hebbeln *et al*., 2009). On the contrary, *L. glaberrima* showed a wider bathymetric distribution, from 120 m depth (South-West Sardinia, Sardinia Channel) to 1000 m depth (off Montenegro, Adriatic Sea) (Bo *et al*., 2015; D'Onghia *et al*., 2016). In general, with the exception of some areas of the Alboran and the Balearic Seas, *P. larix* seems to be less common at the greater depths, where *A. dichotoma* and *L. glaberrima* are commonly reported for several sites, often in association with other CWCs (Chimienti *et al*., 2018b).

On soft bottoms, the bamboo coral *I. elongata* has been recorded on the compact muddy bottoms from 115 m depth (Southwest Sardinia) to 1656 m depth (South Catalonia, Balearic Sea) (Bo *et al*., 2015; Maynou & Cartes, 2012). This candelabrum-shaped alcyonacean is still present in few areas (Fig. 1), with dense aggregations thriving in places more or less accidentally protected from fishing pressures. This is the case, for example, of the populations recently found in shallow water refuges Southwest Sardinia (Bo *et al*., 2015), and in the Balearic Sea, where the presence of submarine cables does not allow fishing activities (Mastrototaro *et al*., 2017).

Similarly to *I. elongata*, also the sea pen fields are still present only in areas where the fishing pressure is generally low, such as CWC provinces where the presence of coral frameworks discourages trawl fishing activities (Mastrototaro *et al*., 2015). However, few populations of sea pens have been reported on the deep muddy bottoms of the Mediterranean Sea (Fig. 1). In particular, *F. quadrangularis* can be considered present mainly in the western basin, from 70 m depth (St Eufemia Gulf) to 616 m depth (Mallorca Channel, Balearic Sea) (Bo *et al*., 2012; Mastrototaro *et al*., 2017). Even more rare is *K. stelliferum*, found only in few areas from 70 m depth (St Eufemia Gulf) to 629 m depth (Eastern Alboran CWC province) (Bo *et al*., 2012; Hebbeln *et al*., 2009).

Discussion and conclusions

As highlighted, among others, by Freiwald *et al*. (2009), Taviani *et al*. (2017) and Chimienti *et al*. (2018b), the occurrence and distribution of Mediterranean CWCs seems

to be strictly related to the main path of Levantine Intermediate Waters (LIW) and Deep Waters providing oxygen and food transport for the CWC communities. Some knowledge gaps could be filled, in the near future, by following the LIW main path on continental margins, seamounts and canyons, in order to have a comprehensive knowledge about CWC distribution. This would represent a needed background to understand CWC biogeography, calling for the investigation of factors and impacts governing CWC onset and demise (Chimienti *et al*., 2018c).
Joining the dark side means, for researchers and explorers, trying to understand features and processes governing the presence of these Vulnerable Marine Ecosystems (*sensu* FAO, 2009). It is also an invitation to decision makers for the conservation of these habitats with effective policies, passing through a better regulation of fishing practices, a proper management of the Deep-Sea Fishery Restricted Areas and their implementation to protect peculiar areas characterized by lush CWC communities. These deep "coral oases" could be the key to understand and guarantee the connectivity among the different CWC communities in the basin, acting as potential ecological corridors. Considering the variety of ecosystem goods and services provided by CWC habitats (e.g., Foley *et al*., 2010), whose importance has been recognized worldwide, knowing the distribution and understanding patterns and trends that shape their presence in the basin would support the development of a proper conservation plan on a Mediterranean-scale.

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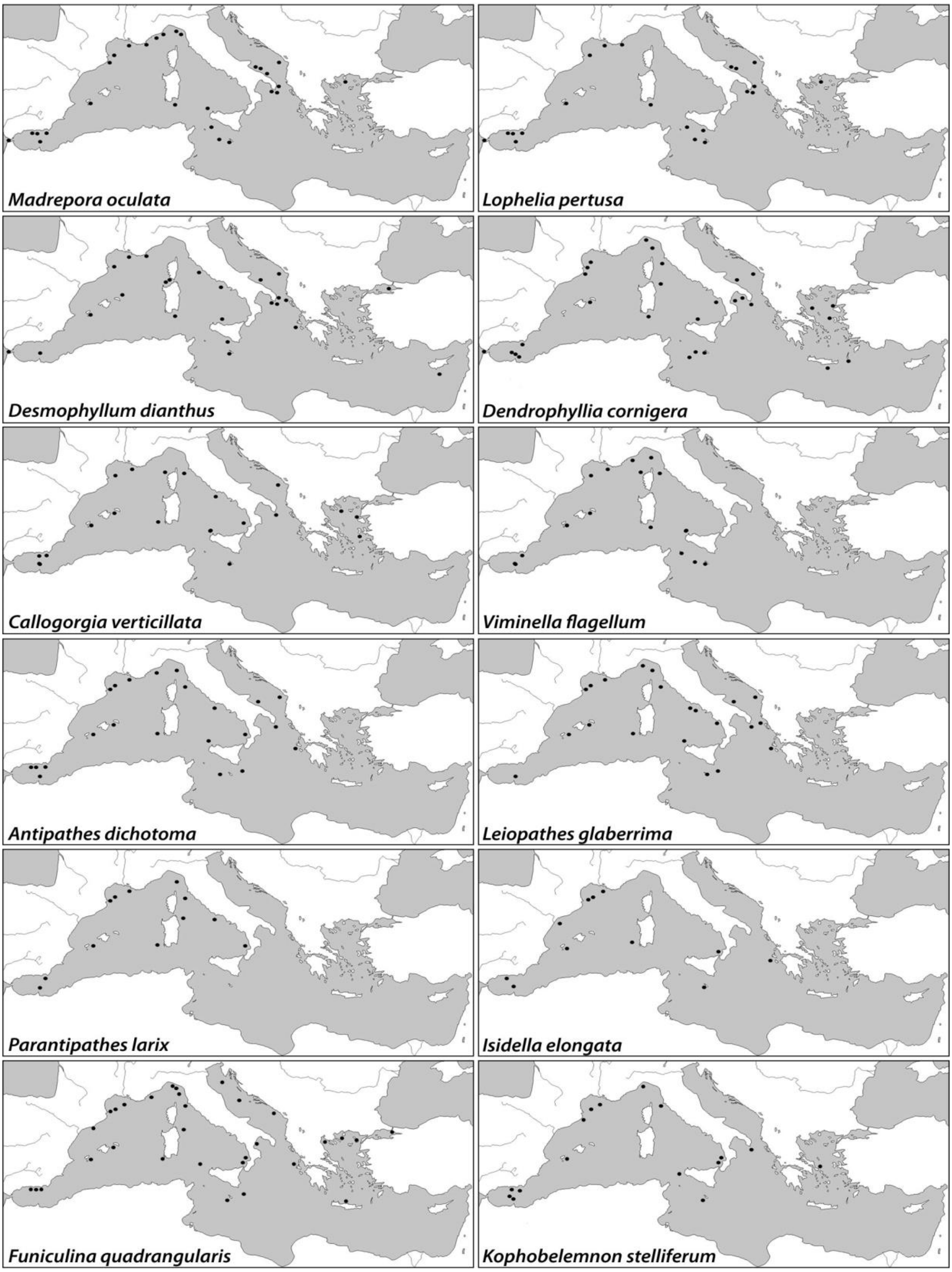

Fig. 1: Geographic distribution of the Mediterranean cold-water coral sites studied to date.

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PRELIMINARY DATA ON THE DISTRIBUTION OF MARINE CAVES ALONG THE TUNISIAN COAST

Abstract
According to the EU Habitats Directive (92/43/EEC), marine caves are considered habitats of high priority in the Mediterranean Sea. These ecosystems are of great scientific interest for the study of marine life, since they are well known for their rich and unique biodiversity. Nevertheless, Tunisian marine caves were almost left out from any scientific study. This is proved by the scarcity of any bibliographic information from national documents or/and scientific publications about these key habitats. The aim of this study was to provide a first database on marine caves along the Tunisian coast. We combined information published in scientific and 'grey' literature, including presentations at scientific meetings, university theses, websites as well as personal observations. In addition, we conducted a questionnaire survey, with a compilation of 20 questions, to collect information about the location, morphology, depth and uses of marine caves in Tunisia. This survey was addressed to fishermen, recreational and professional divers, scientific divers, and local people who can provide reliable data about marine caves. A total of 32 marine caves and tunnels were identified. Most of those habitats were located in the northern coasts of Tunisia. A map of the distribution and characteristics of each marine cave was compiled. This preliminary database will be a useful tool in future studies on the biodiversity of marine caves in Tunisia.

Key-words: Marine caves, bibliographic information, questionnaire, cartographical database, Tunisia

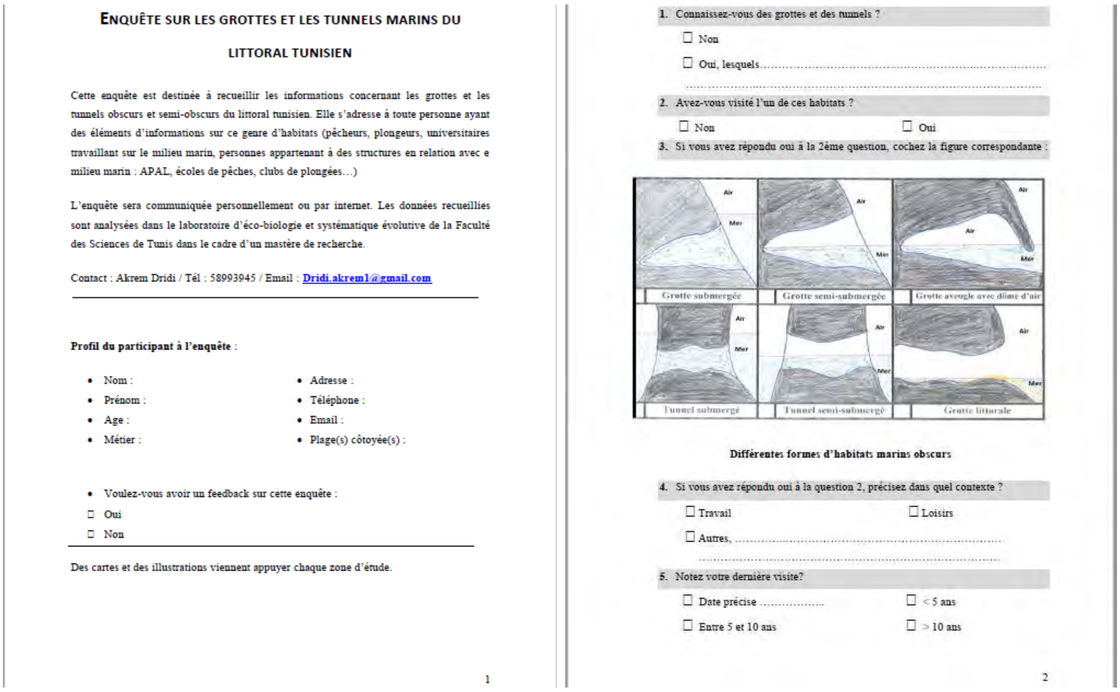
Introduction

In the Mediterranean, marine caves are widely considered as one of the most widespread features of its coastline. The study of their biodiversity and morphology is becoming of great interest to the scientific community, as these habitats are well known for their potential to harbour a mosaic of species, thus an immensely important biodiversity. Riedl (1966) defined marine caves as a cavity, of various origins, partially or entirely submerged, characterised by (1) a ratio, between the internal global volume and the surface of the entrance, exceeding 1; and (2) smaller entrance width than the internal width of the cavity. The Tunisian coastline has been the subject of many studies and research projects, yet caves are rarely mentioned in literature even though they are protected by the EU Habitats Directive (92/43/EEC) and have been included in two action plans of the UNEP-MAP-RAC/SPA (2015). Information about marine cave communities of Tunisia is still not documented as they are only known to recreational scuba divers, fishermen and some locals (Cicogna, 2003). A small number of scientific publications report on the location and biodiversity of Tunisian marine caves, yet they did not focus exclusively on this particular habitat (Harmelin *et al*., 1985; Gerovasileiou & Voultsiadou, 2012). The aim of this work was to establish for the first time a preliminary database about marine caves of Tunisia**.**

Materials and methods

In order to compile a first list of marine caves from the coasts of Tunisia, all available scientific publications about this habitat were reviewed. Information about the location, cave depth and identified taxa were assembled in a database.

Furthermore, data on marine caves were collected by means of a questionnaire survey through personal interviews, performed from May to September 2018. The questionnaires (Fig. 1) included 9 questions about the profile of person interviewed and 20 questions concerning marine cave features, based on the Draft Guidelines for Inventorying and Monitoring of Dark Habitats (UNEP-MAP-RAC/SPA, 2017) and the World Register of marine Cave Species (Gerovasileiou *et al.*, 2016), such as depth, submersion level, morphology, dimensions of the entrance(s), total length, etc. Each interview lasted about 15 to 25 minutes. The questionnaire was addressed to fishermen, recreational and professional divers, researchers working on marine habitats, the Tunisian Agency for the Protection and Development of the Coast (APAL) and local people who could provide reliable data about marine caves.



ENQUÊTE SUR LES GROTTES ET LES TUNNELS MARINS DU LITTORAL TUNISIEN

Cette enquête est destinée à recueillir les informations concernant les grottes et les tunnels obscurs et semi-obscurs du littoral tunisien. Elle s'adresse à toute personne ayant des éléments d'informations sur ce genre d'habitats (pêcheurs, plongeurs, universitaires travaillant sur le milieu marin, personnes appartenant à des structures en relation avec e milieu marin : APAL, écoles de pêches, clubs de plongées…)

L'enquête sera communiquée personnellement ou par internet. Les données recueillies sont analysées dans le laboratoire d'éco-biologie et systématique évolutive de la Faculté des Sciences de Tunis dans le cadre d'un mastère de recherche.

Contact : Akrem Dridi / Tél : 58993945 / Email : Dridi.akrem1@gmail.com

Profil du participant à l'enquête :

- Nom :
- Prénom :
- Age :
- Métier :
- Adresse :
- Téléphone :
- Email :
- Plage(s) côtoyée(s) :

- Voulez-vous avoir un feedback sur cette enquête :

☐ Oui
☐ Non

Des cartes et des illustrations viennent appuyer chaque zone d'étude.

1

1. Connaissez-vous des grottes et des tunnels ?

☐ Non
☐ Oui, lesquels……………………………………

2. Avez-vous visité l'un de ces habitats ?

☐ Non ☐ Oui

3. Si vous avez répondu oui à la 2ème question, cochez la figure correspondante :

Différentes formes d'habitats marins obscurs

4. Si vous avez répondu oui à la question 2, précisez dans quel contexte ?

☐ Travail ☐ Loisirs
☐ Autres, ……………………………………

5. Notez votre dernière visite?

☐ Date précise ……………… ☐ < 5 ans
☐ Entre 5 et 10 ans ☐ > 10 ans

2

Fig. 1: The first and second pages of the questionnaires used in the survey about Tunisian marine caves.

Results

A total of 32 marine caves and similar formations were identified, specifically 28 caves, 2 tunnels and 2 faults. Most of these (87.5%) are located on the northern coast of Tunisia, where most of the rocky shores are concentrated. Six of these caves have been described for their biodiversity, with a total of 53 identified taxa belonging to 6 groups: 4 Macroalgae, 33 Porifera, 6 Cnidaria, 5 Bryozoa, 2 Echinodermata and 3 Ascidiacea (Tab. 1).

Tab. 1: Information about Tunisian marine caves from the existing scientific literature.

Morphology / Depth	**Location / Reference**	**Identified taxa**
Tunnel / 25 m	Northern coast, Tabarka / Ben Mustapha *et al*. (2002)	**Macroalgae:** *Mesophyllum expansum*, *Halimeda tuna* and *Flabellia petiolata* **Porifera:** *Oscarella lobularis*, *Crambe crambe*, *Hamigera hamigera*, *Agelas oroides*, *Dysidea tupha*, *Sarcotragus foetidus* and *Plakina* sp. **Cnidaria:** *Eunicella cavolini* and *E. singularis, Pennaria disticha* (reported as *Halocordyle disticha*) and *Halecium halecinum* **Bryozoa:** *Myriapora truncata* and *Reteporella grimaldii* (reported as *Sertella septentrionalis*) **Echinodermata**: *Paracentrotus lividus* and *Holothuria poli* **Ascidiacea:** *Aplidium conicum*
Tunnel / 21 m	Northern coast, Cani island / Ben Mustapha *et al.* (2002)	**Porifera:** *Plakina* sp., *Spirastrella cunctatrix*, *Crambe crambe*, *Hemimycale columella*, *Phorbas tenacior*, *Oscarella lobularis*, *Petrosia ficiformis*, *Chalinula* sp., *Spongia officinalis*, *Sarcotragus* sp., *Dysidea tupha* and *Dysidea fragilis*
Caves (unspecified number) / 30 m	Northern coast, West off Cathedral Rock in Zembra Island / Ben Mustapha *et al*. (2002)	**Porifera:** Agelasida, Poecilosclerida and Haplosclerida genera, Dendroceratida, *Pleraplysilla* spp., *Dendrilla* spp. and *Petrobiona massiliana*
Cave / 6 m	Northern coast, Lantrocho Cave, Zembra island / Harmelin (2006)	**Bryozoa:** *Puellina mikelae*
Cave / 20 m	Northern coast, Cathedrale Cave, Zembra island / Harmelin (2006)	**Bryozoa:** *Puellina mikelae*
Cave / 14-33 m	Eastern coast, Salakta / Ben Mustapha *et al.* (2003)	**Porifera:** *Spongia zimocca*, *Ircinia oros* and *Sarcotragus fasciculatus*

Tab. 2 (Continue)

Morphology / Depth	Location / Reference	Identified taxa
Fault / 28-35 m	Northern coast, Zembra and Zembretta islands / Ben Mustapha *et al.* (2002)	**Macroalgae:** *Dictyota dichotoma*, *Flabellia petiolata* and *Halimeda tuna* **Porifera:** *Axinella cannabina*, *A. damicornis*, *A. polypoides*, *Agelas* sp., *Petrosia ficiformis*, *Spongia officinalis*, *Hippospongia communis*, *Sarcotragus foetidus*, *Sarcotragus* sp., *Ircinia* sp., *Cacospongia mollior*, *Mycale* sp., *Hemimycale columella*, *Myxilla* sp., *Phorbas* sp., *Clathria* sp. and *Crambe* sp. **Cnidaria:** *Eunicella singularis*, *E. cavoloni*, *Leptogorgia sarmentosa* and *Eudendrium racemosum* **Bryozoa:** *Myriapora truncata*, *Pentapora fascialis* and *Reteporella* sp. **Ascidiacea:** *Aplidium* sp. and *Clavelina* sp.
16 Semi-submerged caves	Northern coast, Galite and Galiton islands / Mo *et al.* (2001)	Not available

During this study, a total of 22 interviews were performed. Among the participants there were 4 professional scuba divers, 3 recreational divers, and 15 fishermen. Results of the survey allowed to gather information about eight not previously mentioned marine caves. Obtained data were confirmed by fieldwork for the semi-submerged caves: 3 in Cap Zebib and 2 in Cap Hmem (Tab. 2).

Tab. 3: Information about Tunisian marine caves collected from the questionnaire survey and field data.

Morphology	Depth (m)	Location	GPS coordinates
Fault	9-15	Eastern coast, Sidi Bou Ali	Not available
Cave	9-13	Eastern coast, Beni Khiar	Not available
Cave	17-20	Eastern coast, Maamoura	Not available
Cave	25	Northern coast, Tabarka	Not available
Semi-submerged cave	Not available	Northern coast, Haouaria	Not available
Semi-submerged cave	1-3	Northern coast, Cap Zebib	37°15’45.3” N/ 10°03’22.8” E
Semi-submerged cave	1-5	North coastern, Cap Zebib	37°15’46.3” N/ 10°02’56.5” E
Semi-submerged cave	1-5	North coastern, Cap Zebib	37°15’46.3” N/ 10°02’56.5” E
Semi-submerged cave	0-1.5	Northern coast, Cap Hmem	37°20’09.3” N/ 09°41’10.2” E

A map of the distribution of marine caves along the coasts of Tunisia was compiled based on the data collected from the bibliography and the questionnaire survey (Fig. 2).

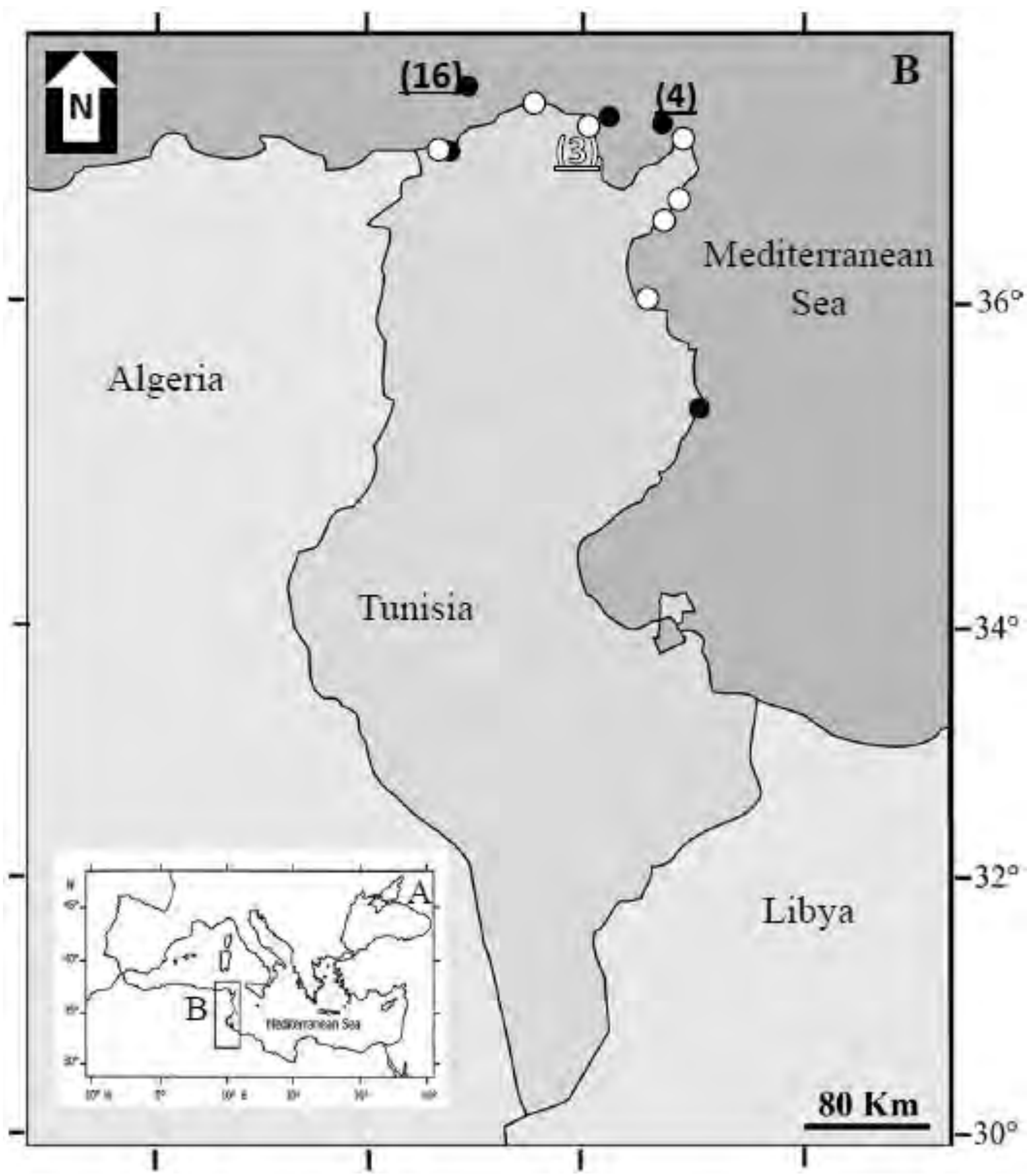


Fig. 2: Distribution of marine caves along the Tunisian coast. Black circles indicate data derived from literature. White circles indicate data obtained from the questionnaire survey. In sites where multiple caves were reported, the cave number is indicated in brackets.

Discussion and conclusions

The dominance of sponges (33 from 53 taxa identified) proves that these habitats represent a biodiversity hotspot for this group, this was reported in the work of Gerovasileiou & Voultsiadou (2012). After processing all the gathered information, an initial database, that will be helpful for other researchers, was developed. The numerous sources, the imprecision or absence of GPS coordinates as well as the existence of multiple names for some caves were the main constraints of this work, in agreement to the work of Gerovasileiou & Voultsiadou (2014). Field checks are required in order to cross-check these findings. Further studies must be conducted with the help of locals in order to increase knowledge about these habitats.

Acknowledgments
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UNDISCLOSED BRYODIVERSITY OF SUBMARINE CAVES OF THE AEGEAN SEA (EASTERN MEDITERRANEAN)

Abstract
Bryozoan diversity from the eastern Mediterranean basin is still poorly known, especially in dark cave and deep-water habitats. Examination of samples collected from two submarine caves in Lesvos Island, Aegean Sea, revealed 74 bryozoan taxa. Most taxa (67) occurred with living and dead colonies, whereas 7 were exclusively recorded with dead colonies. Cheilostomes (59 species) outnumbered cyclostomes (14 species) and ctenostomes (1 species). Unilaminar-multilaminar encrusters prevailed; runners, spots and erect colonies were subordinate to rare. Most taxa, but 6, were already known from present-day Mediterranean. These are Palmiskenea *sp. 1,* Schizomavella *sp. 1,* Fenestrulina *sp. 1,* Rhynchozoon *sp. 1,* Setosella *sp. 1, and Onychocellidae sp. 1. The last two taxa are new species, whose description is under way. The former four taxa could be either new or non-indigenous species. Assessments about their status, however, require comparison with several species distributed worldwide. Indeed, except for the genera* Palmiskenea *(known with 7 species, 2 from the Mediterranean),* Fenestrulina*,* Schizomavella*, and* Rhynchozoon*, are very rich in species in the world ocean (70, 71 and 88 species, respectively) and in the Mediterranean Sea (4, 22, and 6, respectively). To date, only one species of the above genera,* R. larreyi*, has been recorded as non-indigenous in the eastern Mediterranean Sea (Lebanon). The finding of 6 new taxa in two neighbouring sites supports that a considerable number of species await to be discovered from understudied sectors and habitats of the Mediterranean Sea, and especially from dark habitats. Knowledge of this diversity is crucial for monitoring and conservation initiatives.*

Key-words: Submarine caves, Aegean Sea, biodiversity, bryozoans, new species

Introduction
Bryozoan diversity from the eastern Mediterranean Sea, and particularly from dark cave and deep-water habitats, remains understudied (Rosso & Di Martino, 2016). However, submarine caves harbour a remarkable percentage of the total Mediterranean bryozoan diversity (Gerovasileiou & Voultsiadou, 2015; Rosso & Di Martino, 2016), despite their low spatial coverage when compared to other habitat types (Giakoumi *et al.*, 2013). To date, only a small number of caves from the eastern Mediterranean have been studied for their bryozoan diversity, specifically from the coasts of Lebanon (Harmelin, 2014; Harmelin *et al.*, 2016), Cyprus (Guido *et al.*, 2018) and Greece (Rosso *et al.*, 2018). Marine caves often host a distinctive species composition (Harmelin, 1997; Rosso *et al.*, 2013) and thus, dedicated research in the eastern Mediterranean Sea could increase our knowledge on the regional bryozoan diversity. This study focuses on new elements and features of bryozoan assemblages from two Aegean caves, namely Agios Vasilios (AV) and Fara (F) Caves.

Materials and Methods

The AV and F caves are located on Lesvos Island, North Aegean Sea, Greece (Fig. 1), at a depth-range of 11-18 and 24-40 m, respectively. These caves have been thoroughly described regarding their topography and structure of sessile benthos (Gerovasileiou *et al*., 2013; 2017), as well as for the composition of individual assemblages (i.e. sponges by Gerovasileiou & Voultsiadou, 2016; serpulids by Sanfilippo *et al*., 2017; bryozoans by Rosso *et al*., 2018). A total of thirty samples (20 x 20 cm scraped quadrats) were collected with SCUBA diving from representative sectors (i.e. entrance, semi-dark and inner dark zones) along the walls and ceilings of the two caves. Bryozoan colonies were sorted and examined under a stereomicroscope and a low-vacuum scanning electron microscope Tescan VEGA 2 LMU at the microscopy laboratory of the University of Catania, using back-scattered electrons on unbleached, uncoated specimens.

Results

A total of 74 bryozoan taxa were found in the two caves. Most taxa (67) occurred with living (and some of them also with dead) colonies, whereas 7 taxa exclusively with dead colonies. Most species were rare and only a few (specifically *Annectocyma major, Corbulella maderensis*, *Onychocella marioni*, *Cribrilaria radiata*, *C. innominata*, *Hippopodina ambita*, *Hippomenella mucronelliformis*, *Hippaliosina depressa*, *Celleporina canariensis* and *Rhynchozoon neapolitanum*) were represented by numerous and/or large sized colonies and constituted the bulk of the assemblages (see Rosso *et al.*, 2018).

Cheilostomes were represented by 22 families and 59 species, largely outnumbering cyclostomes, which were present with 7 families and 14 species. Ctenostomes occurred with only 1 species. Several families (12) were represented by a single species and further 12 included only 2 or 3 species. In contrast, 6 cheilostome families accounted for 45% of the total diversity. These families are Calloporidae, Cribrilinidae and Bitectiporidae, each with 6 species, and Smittinidae, Escharinidae and Phidoloporidae, each with 5 species. Most of these species occurred with common unilaminar to multilaminar encrusting colonies; some formed elevated “nodular” structures, and a few others grew as runners and spots. Erect taxa and colonies were extremely rare.

Tab. 1: List of taxa identified at supra-specific rank from the two studied caves of Lesvos Island. Bold numbers indicate dead colonies.

Cave	Fara				Agios Vasilios	
Cave sector	Coralligenous	Semi-Dark	Transition	Dark	Semi-Dark	Dark
Species						
Cyclostomatida sp. 1				1	1	
Lichenoporidae sp. 1				1 + **2**	1 + **1**	
Setosella sp. 1			10 + **6**	17 + **9**		2 + **2**
Onychocellidae sp. 1				2 + **3**		
Palmiskenea sp. 1						4
Schizomavella sp. 1						2
Fenestrulina sp. 1					2 + **1**	1
Rhynchozoon sp. 1				2		
Total number of colonies	41 + **4**	114 + **14**	95 + **39**	111 + **63**	263 + **76**	342 + **119**

Biodiversity and taxonomic composition were remarkably different between the two caves. A total of 67 taxa were found within the AV Cave whereas 35 occurred in F Cave with only 28 taxa shared by the two caves.

Eight taxa were identified at supra-specific rank (Tab. 1). These taxa (Fig. 1, Tab. 1) include two cyclostomes, i.e. Cyclostomatida sp. 1, probably belonging to the families Oncousoeciidae, and Lichenoporidae sp. 1. Undetermined cheilostomes are more numerous and include four taxa of ascophoran-grade, namely *Palmiskenea* sp. 1, *Schizomavella* sp. 1, *Fenestrulina* sp. 1, and *Rhynchozoon* sp. 1, and another two taxa (*Setosella* sp. 1 and Onychocellidae sp. 1) belonging to the Flustrina suborder. The above taxa were subordinate to rare within the total assemblage, and each ecological zone, except for *Setosella* sp. 1. A general increase was observed in both the number of these species and their colony abundance from the Semi-Dark to the Dark cave zones.

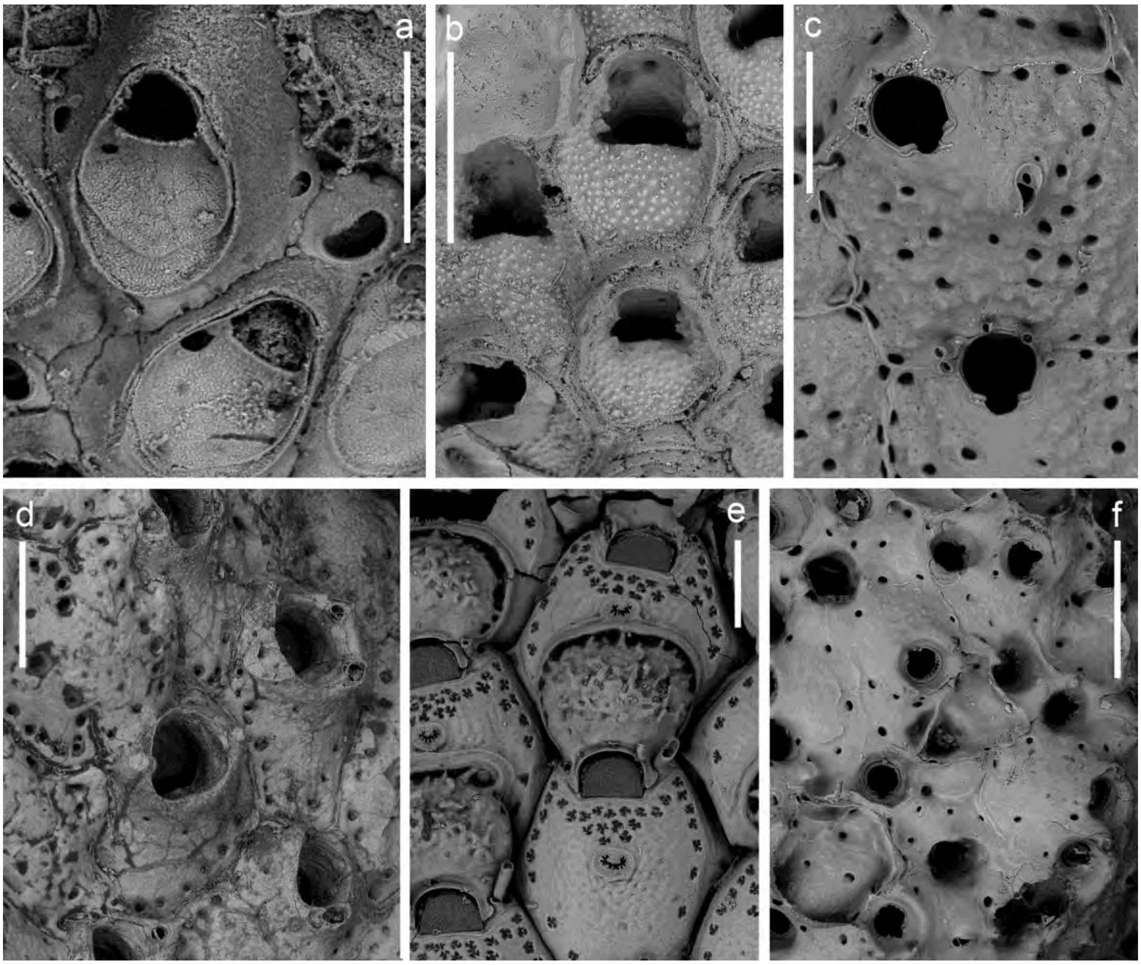

Fig. 1: Bryozoans from Agios Vasilios and Fara submarine caves in Lesvos Island, eastern Mediterranean Sea. a) *Setosella* sp. 1; b) Onychocellidae sp. 1; c) *Schizomavella* sp. 1; d) *Palmiskenea* sp. 1; e) *Fenestrulina* sp. 1; f) *Rhynchozoon* sp. 1. Scale bars: 200 mm for a, c and e; 500 mm for b, d and f.

Discussion and conclusions

The total number of species (74) found in the two studied caves represents only 13% of the total bryozoan diversity so far reported for the Mediterranean Sea (Rosso & Di Martino, 2016) but slightly higher than 33% of the species richness known for

Mediterranean submarine caves (Gerovasileiou & Voultsiadou, 2014; Rosso & Di Martino, 2016; A.R. and V.G., unpublished data). However, percentages of the three bryozoan orders vary remarkably, with species found in the two studied caves representing 18, 2 and 14% of the Mediterranean species richness for cyclostomes, ctenostomes and cheilostomes, respectively (based on data from Rosso & Di Martino, 2016). Percentages raise to 38, 10 and 35%, respectively when focusing on the "bryodiversity" of Mediterranean submarine caves alone. These figures highlight that ctenostomes are comparably less represented than other order-rank taxa in the Lesvos caves. Further investigations are needed to elucidate if this represents an eco-regional mark, a particular feature of the studied caves or even a temporal aspect of the bryozoan associations in such caves.

Although obtained from only two caves, the documented total bryozoan diversity from the Lesvos caves is comparable to, and even slightly higher than that known from submarine caves in other biogeographic regions of the eastern (Ionian) and western (Tyrrhenian and Balearic) Mediterranean (see Rosso *et al*., 2018 and references therein). It is, however, lower in comparison to the 116 species reported from the well-studied caves of the Marseille area (e.g. Harmelin, 1969; 1997).

The vast majority of species found in the studied caves have already been reported from the Mediterranean (Rosso & Di Martino, 2016) where they are typical elements of cave habitats (see Rosso *et al*., 2013b). In addition, taxonomic analysis allowed to identify: 1) new species records for the marine cave habitat, 2) new records for the eastern Mediterranean cave biota; 3) new additions to the Aegean fauna; and 4) species that are new and/or possibly represent Non Indigenous Bryozoans (NIB) for the Mediterranean Sea. More specifically:

1) The cheilostomes *Puellina (G.) orientalis orientalis* Harmelin, 1988, *Parellisina curvirostris curvirostris* (Hincks, 1862), *Cradoscrupocellaria* cf. *bertholletti* (Audouin, 1826), *M. circumcincta*, *Smittoidea ophidiana* (Waters, 1879), *Diporula verrucosa* (Peach, 1868), and *Porella concinna concinna* (Busk, 1854) are reported for the first time from cave habitats although they are widely distributed in the Mediterranean Sea. Furthermore, the recently described species *Schizomavella (Schizomavella) tubulata*, as well as *Smittipora disjuncta* (Canu and Bassler, 1930) and *A. monodon*, seemingly absent from the Western Mediterranean but widely occurring in its eastern sector, are here reported for the first time from cave habitats.
2) The cheilostomes *Callopora dumerilii dumerilii* (Audouin, 1826), *Schizomavella (S.) asymetrica* (Calvet, 1927) and *Smittoidea reticulata* (MacGillivray, 1842), as well as the ctenostome *Bantariella verticillata* (Heller, 1867) had been previously recorded only in caves of specific western Mediterranean regions (Rosso *et al*., 2018 and references therein).
3) Six cheilostomes, namely *Mollia circumcincta* (Heller, 1867), *Prenantia ligulata* (Manzoni, 1870), *Microporella appendiculata* (Heller, 1867), *Celleporina canariensis* Aristegui, 1989, *Hippellozoon mediterraneum* (Waters, 1895), and *Schizomavella (Schizomavella) tubulata* Reverter Gil, Souto, Novosel and Tilbrook, 2015, were not reported previously from the Greek seas (Gerovasileiou & Rosso, 2016) and they represent new additions for the bryozoan fauna of this marine area. The finding of the latter species in the Lesvos caves is the second record, after its erection from material originating from the Adriatic Sea (Reverter Gil *et al*., 2015).
4) With 6-8 new species, this group accounts for a large diversity (8-11%) within the studied caves. The two cyclostomes, reported as Cyclostomatida sp. 1 and Lichenoporidae sp. 1,

probably add to already known species. Indeed, they presumably correspond to taxa already found in caves from the Ionian coast of Sicily but still undescribed (Rosso *et al*., 2013a, b), owing to the need of detailed comparison of SEM (Scanning Electron Microscopy) photos. In contrast, *Setosella* sp. 1 (Fig. 1a) and Onychocellidae sp. 1 (Fig. b) are new species, and their description is currently under way. The first taxon has very small, hardly detectable spot-like colonies, but zooidal features that can be distinguishable at high magnification even at stereomicroscope. It is the easternmost representative of a group of species colonising submarine caves within the genus, that seems particularly adapted for the colonisation of dark habitats (Rosso *et al*., in prep). Onychocellidae sp. 1 (Fig. 1b) has comparably wider and more obvious colonies, but can be easily mistaken with the superficially similar *Onychocella marioni* (Jullien, 1882), a co-occurring species that is often abundant. However, close observation of zooidal skeletons, including produced lateral denticles, points to a different taxon and even prevents the attribution to the genus *Onychocella* (Jullien, 1882). The taxa *Schizomavella* sp. 1 (Fig. 1c), *Palmiskenea* sp. 1 (Fig. 1d), *Fenestrulina* sp. 1 (Fig. 1e) and *Rhynchozoon* sp. 1 (Fig. 1f), could be either new species or NIB. Assessments about their status, however, require intensive efforts implying comparison (including fine morphological characters essential for identification) with several species distributed worldwide (Bock & Gordon, bryozoan.net, accessed 23.5.2018). Indeed, except for *Palmiskenea*, known with only 7 species (2 of which from the Mediterranean) the remaining genera, namely *Fenestrulina*, *Schizomavella*, and *Rhynchozoon*, include 70, 71 and 88 species, respectively. All of them have representatives in the Mediterranean, with a fairly relevant number reached by *Schizomavella* (22 species), whereas fewer species are known for *Fenestrulina* (4 species) and for *Rhynchozoon* (6 species). This last genus is presently the only one including a NIB species, i.e. *R. larreyi* (Audouin, 1826) from Lebanese waters (Harmelin, 2014).

The finding of several rare and previously undescribed cheilostome taxa in only two closely located sites supports the claim made by Rosso & Di Martino (2016) that a considerable number of species await to be discovered from little known habitats from understudied sectors of the Mediterranean Sea, and especially from dark habitats of the Eastern Mediterranean.

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LONG-TERM SPATIO-TEMPORAL DYNAMICS OF SESSILE BENTHOS IN A SHALLOW MARINE SUBMERGED CAVE IN THE WESTERN MEDITERRANEAN SEA

Abstract
Submarine caves are considered priority habitats according to the Barcelona Convention and the EU Habitat Directive, yet they have received relatively low research effort when compared to other Mediterranean coastal habitats. This paper provides information about the long-term spatio-temporal observations of sessile benthos along the exterior-interior axis of Cerro-Gordo marine cave (Granada, Spain) from 2007 to 2016. Using feeding strategies and morphological descriptors, significant temporal variations of sessile community were recorded in both external and internal sectors, in spite of the higher confinement of the inner parts of the cave. In the inner cave sector, the use of feeding strategies revealed community variability through time and between opposite cave walls. On the other hand, the use of morphological descriptors proved to better depict variability in the outer cave sector, where the community was more heterogeneous. These results provide valuable information that could be included in future monitoring programs of these endangered and protected habitats.

Key-words: Marine Cave, Sessile Benthos, Morphological Descriptor, Feeding Strategies

Introduction
Submarine caves are considered as key habitats and are included in the European Community Habitat Directive 92/43/EEC (habitat type 8330) and the "Dark Habitats Action Plan" (UNEP-MAP-RAC/SPA, 2015) for the conservation of sensitive species and habitats. They are important biodiversity hotspots which harbour rich biodiversity in coastal rocky areas (Gerovasileiou & Voultsiadou, 2012). In addition, these unique ecosystems are vulnerable and act as ecological islands, hosting communities sensitive to fragmentation as well as relict species and communities which are often similar to those found in abyssal systems (Boury-Esnault *et al*., 1993). The physicochemical conditions within submerged marine caves are easily disturbed by natural and anthropic alterations at global (e.g. climate change or water acidification) and regional/local scales (e.g. storms, coastal pollution, shoreline modifications or diving activities - Chevaldonné & Lejeusne, 2003; Parravicini *et al*., 2010; Di Franco *et al*., 2010). These alterations may affect benthic community at functional level (i.e. species morphology and feeding strategies - Guarnieri *et al*., 2012; Nepote *et al*., 2017; Montefalcone *et al*., 2018).
Given the variety of source of impacts and biotic responses, as well as the natural spatial heterogeneity and inaccessibility of these habitats, the effectiveness of efficient monitoring programs is often limited by the scarcity of information concerning the natural temporal changes present in these complex and variable systems (Magurran *et al*., 2010). Medium/long-term time series observations (years-decades) are essential tools in order to address these issues. The present study investigates the benthic community variability

within a nine-year period in a shallow blind-ending submerged cave of the Western Mediterranean Sea (Cerro-Gordo cave, Alboran Sea).

Materials and methods

The cave of Cerro-Gordo is located in the North Coast of the Alboran Sea, within the limits of Maro-Cerro Gordo Natural Park, in Granada, Spain (Fig. 1A). Benthic community was studied in the outer Semi-Dark (SD) and inner Dark (D) sectors of the cave (Fig. 1B). Within each sector, four 20 x 20 cm quadrats were randomly photographed at 5 m intervals on both walls of the cave, at a depth range of 6-8 m. Sampling took place in August of the years: 2007, 2010 and 2016 (D) and 2008, 2011 and 2016 (SD). Benthic community coverage was obtained by overlaying 50 random points on each photoquadrat using photoQuad software (Trygonis & Sini, 2012). All taxa were assigned to two functional descriptors: Morphological descriptor (Md) and Feeding Strategies (FS), whose indicators were selected considering previous studies (Parravicini *et al.*, 2010; Guarnieri *et al.*, 2012; Gerovasileiou *et al.*, 2017; Nepote *et al.*, 2017 - see indicators in Results section). Orthogonal and fixed factors Year (three levels: 2007/2008, 2010/2011 and 2016) and Wall (two levels: Left and Right Wall, looking from the entrance of the cave) were tested separately for SD and D sectors. For each sector, multivariate PERMANOVA and SIMPER analyses were carried out using Md and FS datasets. Statistical analyses were carried out using PRIMER-E v6 + PERMANOVA (Anderson *et al.*, 2008; Clarke & Gorley, 2006).

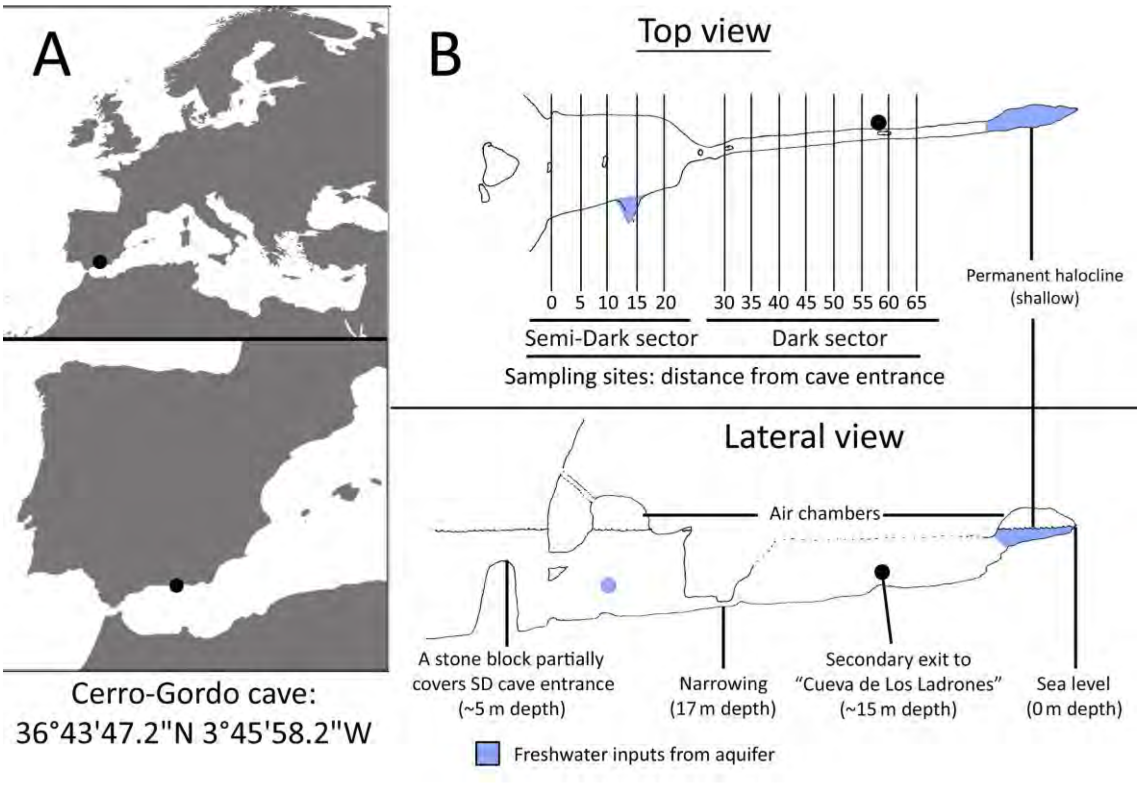
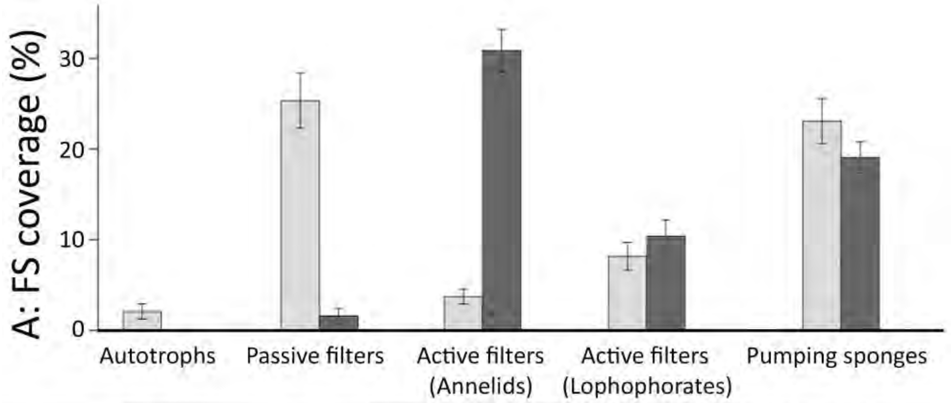


Fig. 1: A) Location of Cerro-Gordo cave (Alboran Sea). B) Cave topography. Up: Top view. Down: Lateral view. The presence of a marked narrowing divides the cave in an outer Semi-Dark (SD) and an inner Dark (D) sector. Position of sampling sites is referenced in meters to the entrance of each sector (cave entrance for SD and cave narrowing for D). The Dark sector is connected by a narrow tunnel to the open sea; this secondary opening (Cueva de los Ladrones) is very close to the primary entrance.

Results

Mean biotic coverage was similar in both Semi-Dark (SD: 62.40%) and Dark (D: 61.94%) sectors. However, the coverage of the used Md and FS variables differed between the two sectors (Fig. 2A and 3A).



B: Feeding strategies (FS) Year & Wall PERMANOVA

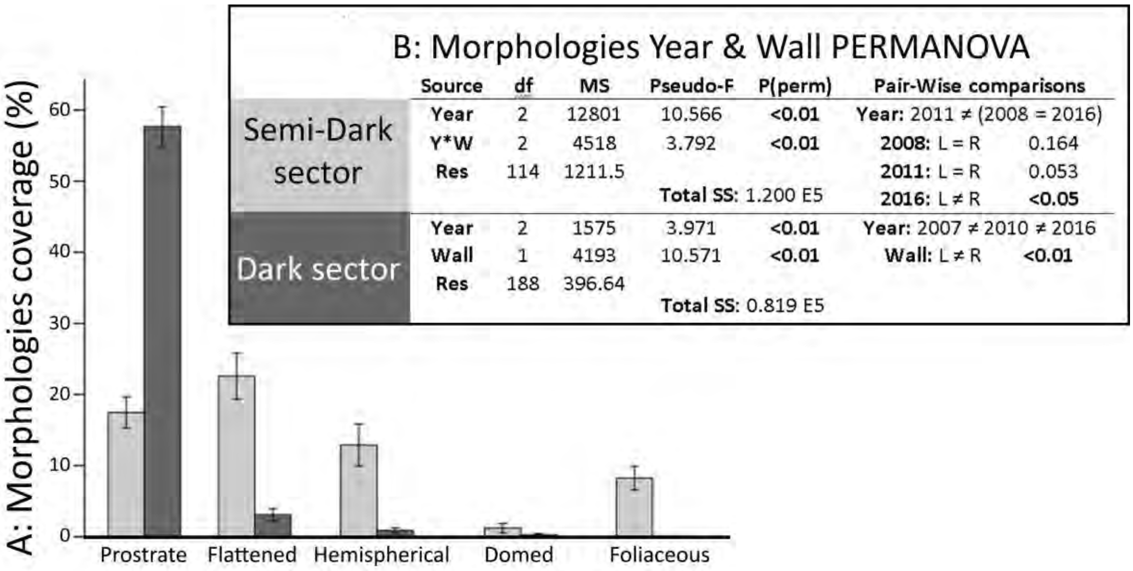
	Source	df	MS	Pseudo-F	P(perm)	Pair-Wise comparisons
Semi-Dark sector	**Year**	2	1735	3.079	**<0.01**	**Year:** (2011 ≠ 2008) = 2016
	Res	117	563.49			
				Total SS: 0.694 E5		
Dark sector	**Year**	2	5431.8	16.085	**<0.01**	**Year:** 2007 ≠ 2010 ≠ 2016
	Wall	1	8962	26.555	**<0.01**	**Wall:** L ≠ R **<0.01**
	Res	188	337.49			
				Total SS: 0.833 E5		

Fig. 2: Feeding strategies (FS) results A) FS mean coverage and 95% confidence interval bars in outer Semi-dark (light grey) and inner Dark (dark grey) sectors. B) Results of the factorial PERMANOVAs (factors: Wall and Year) and Pair-Wise comparisons carried out using FS in Semi-dark and Dark sectors. Only significant factors and interactions were included.

Temporal variation occurred in both cave sectors when grouping species coverage by feeding strategies (see Fig. 2B). In SD, the increase of passive filters (cnidarians) and the decrease of active pumping sponges contributed up to 67% of the accumulated dissimilarities between 2008 and 2011 (SIMPER). In D sector, lophophorates were responsible for 42% of multivariate dissimilarity between walls (higher coverage on the right wall) and active filter feeders grouped up to 60% of dissimilarities among years (temporal increase of lophophorates and annelids).

When grouping species coverage by morphologies, up to 78% of dissimilarities among years in SD sector (see Fig. 3B) were caused by variations of prostrate sheets, flattened mounds and hemispherical mounds (SIMPER results). On the other hand, prostrate sheets, which were ubiquitous in the inner cave sector (Fig. 2A) contributed up to 80% of dissimilarities among years and walls in D.

Morphological descriptor (Md) pooled higher variation than feeding strategies (FS) in the outer (SD) sector, while both FS and Md pooled similar variation in D sector (see total sums of squares –SS– in Figs 2B and 3B). Note that FS and Md are different ways of grouping the same data, which allow comparisons by the amount of variation grouped by each descriptor (SS) and also by the distribution of this variation among factors and residuals (mean square sums –MS) (see Anderson *et al.*, 2005; 2008).



	Source	df	MS	Pseudo-F	P(perm)	Pair-Wise comparisons	
Semi-Dark sector	Year	2	12801	10.566	<0.01	Year: 2011 ≠ (2008 = 2016)	
	Y*W	2	4518	3.792	<0.01	2008: L = R	0.164
	Res	114	1211.5			2011: L = R	0.053
				Total SS: 1.200 E5		2016: L ≠ R	<0.05
Dark sector	Year	2	1575	3.971	<0.01	Year: 2007 ≠ 2010 ≠ 2016	
	Wall	1	4193	10.571	<0.01	Wall: L ≠ R	<0.01
	Res	188	396.64				
				Total SS: 0.819 E5			

Fig. 3: Morphological descriptor (Md) results. A) Mean coverage and 95% confidence interval bars in Semi-dark (light grey) and Dark (dark grey) sectors. B) Results of the factorial PERMANOVAs (factors: Wall and Year) and Pair-Wise comparisons carried out using Md in Semi-dark and Dark sectors. Only significant factors and interactions were included.

Discussion

Benthic community patterns with the use of Feeding Strategies (FS) and Morphological (Md) descriptors within Cerro Gordo cave were similar to those described for other Mediterranean marine submerged caves (see Rastorguef *et al*., 2015 and references therein). The predominance of prostrate life-forms in the inner parts of the cave has been suggested as an adaptation to a resource-restricted environment (Okamura *et al*., 2001). The presence of fine sediment in the bottom of D sector (see Navarro-Barranco *et al*., 2012) suggests that the tunnel connecting “Cerro-Gordo” to “Cueva de los Ladrones” does not significantly increase water motion. Yet, temporal variation in Cerro-Gordo cave benthic community was relatively similar in the outer and inner sectors, which could indicate the presence of water flow because of this secondary opening.
Cerro-Gordo cave was found to experience greater temporal changes than those usually expected for isolated ecosystems such as submerged marine caves. It is possible that frequent SCUBA diving activities within both cave sectors could have produced punctual turbidity events which could in turn cause sponge mortalities (see Di Franco *et al.*, 2010 and Nepote *et al*., 2017), and resuspension of large-size particles which may favour lophophorates and annelids (Riisgård & Larsen, 2000; Mancenido & Gourvennec, 2007). High-temperature peaks and storms in the study area became more frequent from 2012 onwards (Puertos del Estado, 2018), possibly influencing community functional dynamics. The deleterious effect of thermal rise in Mediterranean marine caves affects mainly massive sponges (Chevaldonné & Lejeusne, 2003; Parravicini *et al*., 2010; Montefalcone *et al*., 2018). It is also possible that D sector receives organic matter from percolation through small rock cracks and fissures. Such inputs may have a significant effect in highly oligotrophic ecosystems such as caves (Rastorgueff *et al*., 2015 and references therein).
In the outer SD sector, high non-linear temporal variation in the coverage of the anthozoans *Astroides calycularis* and *Parazoanthus axinellae* were the main contributors to the patterns observed. This may have modified cave community functioning and affected epibenthic assemblages (Martí *et al*., 2004; Navarro-Barranco *et al*., 2014; 2016). Finally, spatial

differences within D sector for the cave wall communities are probably related to their inclination. The latter allows higher sediment deposition over left wall surfaces, leading to a reduction of *Novocrania anomala* brachiopod assemblages, which are known to inhabit mud-free surfaces (Rosso *et al*., 2015).

The results of this study support the effectiveness of both FS and Md descriptors for monitoring marine caves, as suggested by previous studies (Guarnieri *et al*., 2012; Nepote *et al*., 2017; Montefalcone *et al*., 2018). Nevertheless, morphological descriptors were more efficient for identifying variation in the outer cave sector while the use of feeding strategies was more suitable in the inner cave sector where prostrate sheet forms dominate.

Conclusions

The spatio-temporal variation in Cerro-Gordo cave reflects complex context- and scale-dependent processes in marine caves with complex topographies (Harmelin 1969; Bussotti *et al*., 2006; Radolović *et al*., 2015; Montefalcone *et al*., 2018). Sessile benthic community in Cerro-Gordo cave was found to be sensitive to external perturbations in accordance to studies in other Mediterranean marine caves (Chevaldonné & Lejeusne, 2003; Parravicini *et al*., 2010; Rastorgueff *et al*., 2015). These results provide valuable information for future monitoring programs for these fragile protected habitats.

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A PRELIMINARY STUDY ON THE MACROBENTHIC ORGANISMAL COVER IN AN UNDERWATER CAVE IN GÖKÇEADA ISLAND (NORTH AEGEAN SEA, TURKEY)

Abstract
In this preliminary survey, the spatial variability of biotic cover was studied in an underwater cave. The studied cave is located in the Marine Park (MPA) of Gökçeada Island at 10 m depth. Sampling took place in May 2018. A total of 150 underwater photographs were taken from the external, entrance and internal zones of the cave. Each photograph was divided in 100 cells in order to determine the cover of the main taxonomic groups. Macroalgae covered the largest percentage of the surface area outside of the cave (95.5%), followed by sponges at the entrance of the cave (78.2%) and internal zones of the cave (75.1%). Other groups had much lower cover percentage, specifically Polychaeta (2.7%), Anthozoa (stony corals) (0.5%), Echinodermata (0.2%), and Cirripedia. In the outer part of the cave the substrate was completely occupied (95.5% by Algae) while the biotic coverage was 94.6% in the cave entrance (78.2% by sponges) and 81.7% inside the cave (sponges covered 78.2% and 75.1% of the substrate, respectively). The results of this preliminary work showed that the studied underwater cave is an important habitat for sponges, in terms of substrate cover, and provide a baseline for future studies in marine caves of Turkey.

Key-words: Underwater cave, sponges, Gökçeada Island, Aegean Sea, Photoquadrat

Introduction

Marine caves constitute an important semi-closed subsystem in the marine littoral ecosystem (Gili *et al.*, 1986). On the other hand, the benthic communities are usually impoverished from the open sea to dark caves (Fichez, 1991). Two biocoenoses were described in Mediterranean marine caves: a semi-dark and a dark cave biocoenosis, towards the entrance and the inner cave zones, respectively (Peres & Picard, 1964). Oxygen supply and sedimentation are important factors for biomass and biodiversity in caves, with the latter factor being particularly important for filter feeding organisms (Gili *et al*., 1986).

Studies on submerged caves in the Turkish coasts are extremely limited and usually focus on the occurrence of a single species or a taxonomic group (e.g. Bilecenoğlu & Taşkavak, 1999; Kıraç & Savaş, 1996; Güçlüsoy & Savaş, 2003). The present study examined the main benthic groups in a small underwater cave located in the Marine Park of Gökçeada Island (North Aegean Sea, Turkey). The aim of this preliminary study was to highlight the dominant benthic groups in terms of coverage and the main differences between the inner and outer zones of the cave.

Materials and methods

Sampling was carried out in a small underwater cave, located at a depth of 10 m, on the northern coast of Gökçeada Island (North Aegean Sea, Turkey, coordinates: 40°14'8.97" N; 25°53'56.49" E, Fig. 1). The cave is located in the area which is under protection as a marine park since 1999. Six sampling points were selected; three points concerning the cave (the front, entrance and inner parts) and three external points for comparison (the upper side of rocks outside the cave, the passage to the cave which is a kind of tunnel to the cave entrance, and a "shelter" which is a vertical concave wall in the vicinity of the cave).

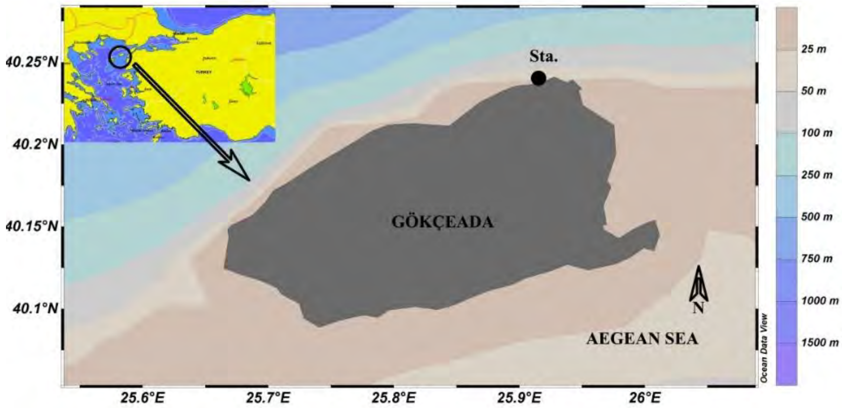
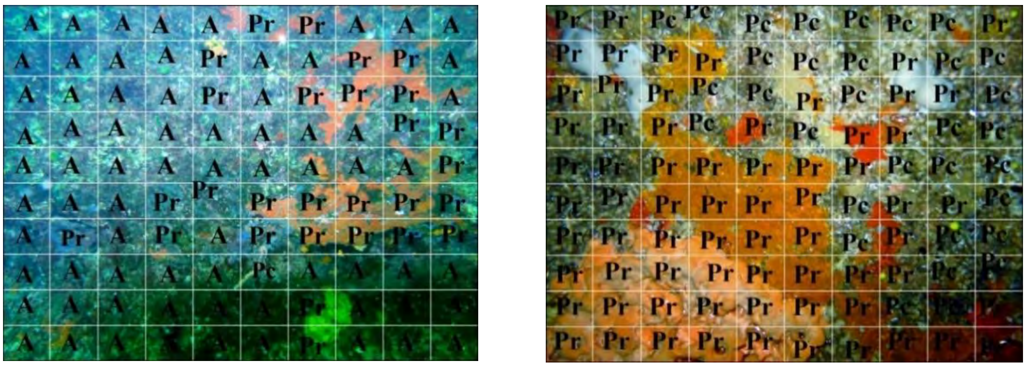


Fig. 1: Location of the studied marine cave in Gökçeada Island, North Aegean Sea, Turkey.

Photoquadrat analysis was used in order to calculate the percentage of cover per benthic group, based on Holme & McIntyre (1984), Foster *et al.* (1991), and the method modified for digital camera according to Peach *et al.* (2003). A total of 150 underwater photographs (30 from the front of the cave, 19 from the entrance, 34 from the inner cave zone, 20 from the upper side of rocks, 17 from the passage, and 30 from the "shelter") were taken with a Canon G15 camera with underwater housing. All photographs were taken with 14 mm lens and at about 1 m distance, thus the sampling area shown in each photograph was approximately 1 m^2. Each photograph taken was divided into one hundred (10 x 10) cells. The number of cells with a particular group (taxon) observed was counted (Fig. 2). This was regarded as a percentage of coverage. Then, arithmetic mean of the count for each group at a sampling point was calculated. In cells with more than one groups, only the group with the greatest coverage was counted.



(a) **(b)**

Fig. 2: Underwater photos taken from the front (a) and inner part (b) of the studied cave divided in 100 cells. Letters indicate the major coverage of the group of organisms (A: Algae, Pr: Porifera, Pc: Polychaeta).

Results

Macroalgae had the highest cover percentage on the upper side of rocks (95.5%) and at the front of cave (64.9%). On the other hand, sponges were the dominant group at the entrance and the inner part of the cave (78.2 and 75.1, respectively), as well as in the shadowy passage, outside the cave (48.3%). The total biotic coverage at the cave entrance was 94.6% (78.2% covered by sponges) and 81.7% at the inner part of the cave (75.1% covered by sponges) (see Tab. 1). Algae had highest coverage in the study area (46.6%), considering all studied points, followed by sponges (40.35%). The other groups identified were Polychaeta (2.7%), Anthozoa (stony corals), Echinodermata, and Cirripedia (all less than 1%).

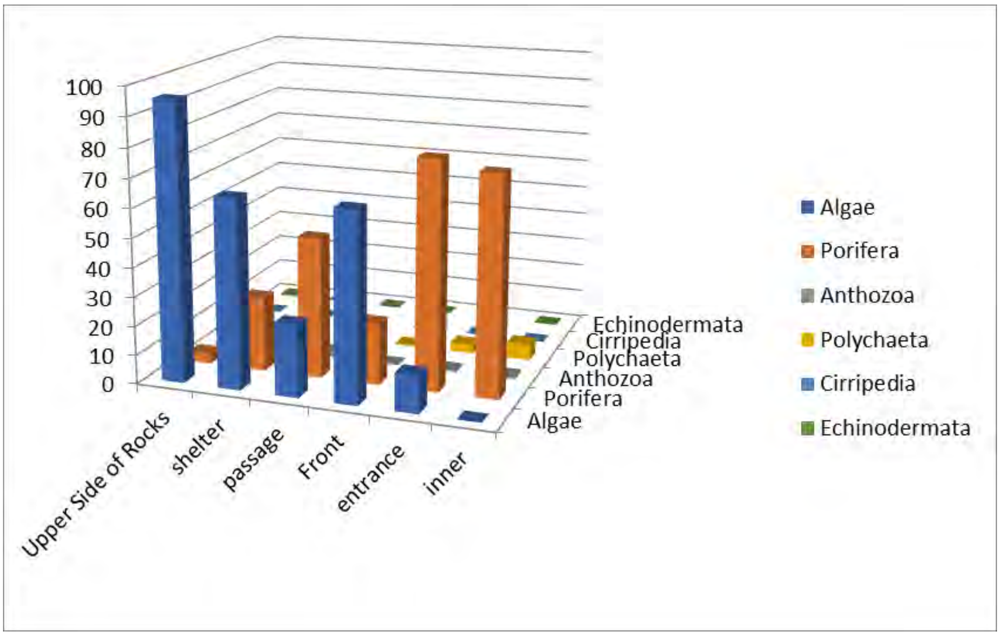


Fig. 3: Percent cover of benthic groups per sampling point.

Tab. 1: Coverage (%) of the major benthic groups for each sampling site.

	External area			Cave			
	Upper side of rocks	**Shelter**	**Passage**	**Front**	**Entrance**	**Inner part**	**Coverage (%)**
Algae	95.5	65.1	25	64.9	13	-	**46.6**
Porifera	3.5	25.7	48.3	21.2	78.2	75.1	**40.35**
Anthozoa	-	0.1	1.8	-	0.5	0.8	**0.5**
Polychaeta	0.1	1.6	7.1	0.3	3.1	5.6	**2.7**
Cirripedia	-	0.2	0.1	-	-	-	**0.1**

Echinodermata	0.4	0.4	0.2	0.1	0.1	0.2	**0.2**
Total biotic coverage	100	93.1	82.5	90	94.9	81.7	
Number of groups observed	5	6	6	5	5	4	

Discussion and conclusions

According to Cinelli *et al.* (1979), light is one of the most important environmental factors for cave communities together with water movements. Therefore, the dominance of Algae in the external and outer well-lit zones and sponges in the cave interior were expected. As a result of this preliminary study, it is understood that underwater caves are important habitats especially for sponges. Some eggs of octopus were observed during the fieldwork, which shows that this habitat is important also as an egg-spawning site for other benthic species. Marine cave fauna of the eastern Mediterranean Sea is understudied compared with that of the western basin (Gerovasileiou & Voultsiadou, 2012). Most relevant studies in the eastern basin have taken place in the Aegean coasts of Greece (Gerovasileiou *et al*., 2015a; 2015b; 2016a; 2016b; Gerovasileiou & Voultsiadou, 2016; Dimarchopoulou *et al*., 2018). This is the first study about benthic communities in a marine cave in the Aegean coasts of Turkey. More detailed and long-term studies are necessary to understand the biota and species composition of underwater caves in this area.

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POSTERS

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CHARACTERIZATION OF BENTHIC COMMUNITIES IN MARINE CAVES OF THE ISLAND-DOMINATED AEGEAN SEA (EASTERN MEDITERRANEAN)

Abstract
The Aegean Sea hosts a considerable number of marine caves, the great majority of which are located in the island-dominated South Aegean region. Herein, nine marine caves from different Aegean islands were investigated for the first time by means of SCUBA diving and non-destructive sampling (photoquadrats). A total of 70 taxa belonging to 8 taxonomic groups were identified. Multivariate analysis revealed three main clusters of caves, reflecting primarily their geomorphologic character: a) deep (>10 m) submerged and semi-submerged caves, b) shallow semi-submerged caves (<6 m depth), and c) a semi-submerged cave with internal freshwater springs that was largely differentiated from all others. However, PERMANOVA results indicated significant differences between all caves suggesting a high level of individuality.

Key-words: Sessile benthos, hard substrate, heterogeneity, community structure

Introduction

Marine caves are characterized by unique topographical and ecological features which are reflected on the structure of sessile benthos (Gerovasileiou *et al*., 2017). In the eastern Mediterranean, the Aegean Sea hosts more than 600 marine caves, the great majority of which are located in the island-dominated South Aegean (Sini *et al*., 2017). Nevertheless, only a small number of marine caves has been quantitatively investigated to assess the structure of sessile benthic communities.

Materials and methods

Nine newly explored marine caves from different Aegean islands, extending from Evia Island to the Cyclades Archipelago and the coasts of Crete, were investigated by means of SCUBA diving and non-destructive sampling. In every cave, 16 photoquadrats (25 x 25 cm) were randomly obtained from vertical walls. Spatial coverage of sessile taxa was estimated using photoQuad (Trygonis & Sini, 2012). Multivariate resemblance of the nine caves was assessed with cluster analysis, based on the Bray-Curtis similarity index (square root-transformed coverage data) and the SIMPROF test. PERMANOVA (one-way) was used to investigate the effect of geographic position (fixed, 9 levels) to the observed patterns. Statistical analyses were performed using PRIMER-E v6.

Results

A total of 70 taxa belonging to 8 groups were identified (5 Macroalgae, 1 Foraminifera, 41 Porifera, 6 Anthozoa, 4 Polychaeta, 2 Mollusca, 8 Bryozoa, and 3 Ascidiacea). The number of taxa observed in each cave varied from 19 to 40. Sponges were the dominant taxon in terms of species number in all caves whereas coverage per taxon varied among the caves. Multivariate resemblance analysis revealed three main clusters of caves (Fig.

1), reflecting their geomorphologic traits: A) deep submerged and semi-submerged caves (>10 m), B) shallow semi-submerged caves (<6 m), and C) a semi-submerged cave with internal freshwater springs that was different from all others. PERMANOVA results revealed significant differences between all pairs of caves ($p<0.01$ in all cases).

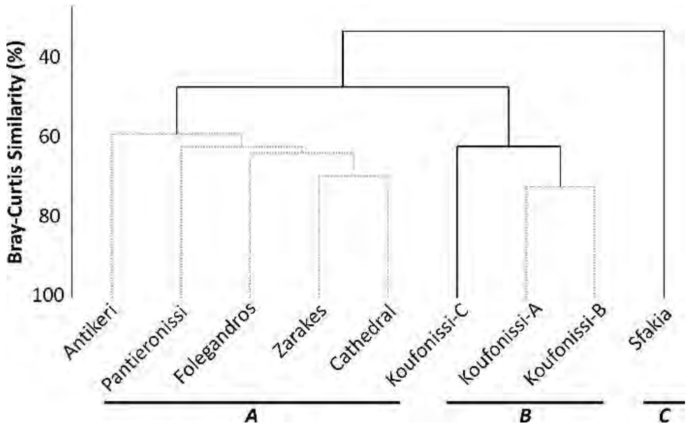

Fig. 1: Multivariate resemblance of marine cave benthos. Black lines indicate significantly different groups of caves at 5% level according to the SIMPROF test.

Discussion and conclusions

The observed resemblance patterns confirm the hypothesis that different geomorphological types of caves harbor distinct benthic communities, whilst presenting a high level of individuality. Overall, this assessment contributes to the limited knowledge on marine cave biodiversity in the understudied Eastern Mediterranean and provides a baseline for future monitoring activities and conservation initiatives.

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MICROFACIES OF THE BIOTIC CRUSTS FROM TWO AEGEAN SUBMARINE CAVES (EASTERN MEDITERRANEAN)

Abstract
This work extends the knowledge on bioconstructions growing in cryptic marine environments with the characterization of the biotic crusts found in the Eastern Mediterranean Sea. The walls and vaults of Fara and Agios Vasilios Caves (Lesvos Island, Greece) are covered with bryozoans, serpulids, coralline algae, scleractinian corals and sponges. Skeletons of these organisms are often cemented together to form small bioconstructions. Serpulids, bryozoans and sponges dominate the innermost dark cave sectors. Fine sediments (microcrystalline calcite) deposited via *microbial metabolic processes, are a minor component, but testify the presence of bacteria in the crusts. The correlation between microbial activity and abundance of sponges could explain the development of the studied bioconstructions that have smaller sizes (few centimeters) in comparison to larger biostalactites common in other Mediterranean caves.*

Key-words: Submarine caves, Aegean Sea, bioconstructions, micrite, biomineralization

Introduction

Submarine caves are cryptic habitats of the littoral zone characterized by reduction or absence of light, marked oligotrophy and low water circulation. In these environments, nutrient input through freshwater seeps or current storms favor the growth of dense serpulid aggregates and associated suspension feeding organisms (bryozoans, corals, sponges and ascidians). These organisms and associated microbial communities form large aggregates and contribute to bioconstructions projecting from the walls and vaults of caves (Guido *et al*., 2013). Here we extend the knowledge on bioconstructions growing in cryptic marine environments with the characterization of the biotic crusts found in Fara (F) and Agios Vasilios (AV) Caves (Lesvos Island, Greece).

Materials and Methods

The AV and F caves are located on the Lesvos Island, E Aegean Sea, NE Mediterranean (Fig. 1). Caves' morphology and biotic associations have been discussed in Gerovasileiou and Voultsiadou (2016), Sanfilippo *et al*. (2017) and Rosso *et al*. (2018). Here selected biotic crusts were processed for microfacies characterization with a stereomicroscope (Zeiss Axioplan Imaging II). Incident light emitted by Hg high-pressure vapor bulb was used to excite epifluorescence in carbonate samples to reveal the distribution of organic matter remains.

Results

Walls and vaults of AV and F caves are mainly covered with bryozoans and serpulids and, subordinately, coralline algae, corals and sponges. These organisms form carbonate concretions attributable to boundstone facies with two main carbonate components:

skeletons and micrite (microcrystalline calcite). Autochthonous micrite, with calcite crystals ≤4 μm in size, shows peloidal and aphanitic textures and emits bright fluorescence due to the presence of organic matter relics closely related to the bioinduced crystals. Crusts are characterized by the presence of microcavities filled by autochthonous micrite with spicules and organic matter remains.

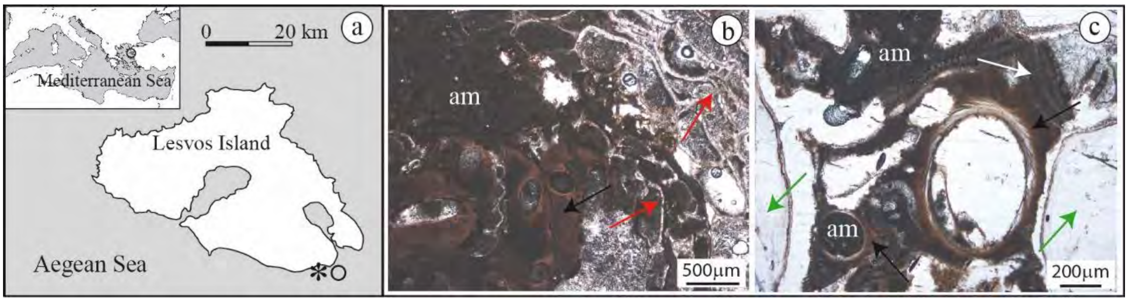

Fig. 1: a) Lesvos Island (circle) in the Mediterranean Sea and location of Fara (asterisk) and Agios Vasilios (circle) caves. b-c) Boundstone facies of crusts from Fara (b) and Agios Vasilios (c) caves. Black arrow: serpulids; red arrow: bryozoans; white arrow: red algae; green arrow: microcavity with sponge spicules; am: autochthonous micrite.

Discussion and conclusions

This is the first attempt to characterize carbonate crusts of submarine caves of the Aegean Sea. Like other Mediterranean examples, the studied AV and F caves host cryptic communities typical of restricted conditions and whose skeletons form biotic crusts on cave' surfaces. Unlike other Mediterranean caves, however, only thin crusts develop. Demosponges are recognizable for the diffuse presence of spicules inside the crusts, mainly concentrated in microcavities interpreted as voids left by the decay of sponge soft tissues. The autochthonous micrite engulfing siliceous spicules represents bioinduced calcite and suggests the first presence of microbial communities. Differences in size between the biotic crusts of Lesvos caves and those of other Mediterranean areas (Sicily, Apulia and Cyprus) needs to be further investigated, but the abundance of sponges in these caves presumably played a limiting role in the development of large bioconstructions.

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RECOMMENDATIONS OF THE 2ND MEDITERRANEAN SYMPOSIUM ON THE CONSERVATION OF DARK HABITATS

1. Scientific knowledge on dark habitats has increased but not as rapid as for other habitat types. So far, most studies focus on the habitat identification and mapping of the occurrence of selected large-sized species and there is a lack of quantitative data on populations and trends. There is an urgent need to speed up the increase of knowledge by investing in research and conservation activities, especially in the understudied eastern and southern Mediterranean basins.
2. Although dark habitats cover >90% of the Mediterranean Sea, they are underrepresented in networks of marine protected areas.
3. Dark habitats are extremely vulnerable. Despite the limited information about temporal trends there is clear evidence of their decline and deterioration (e.g. due to temperature rise, destructive fishing practices such as bottom trawling, offshore oil and gas exploration and drilling). In order to achieve conservation targets it is important to assess vulnerability and prioritize protection of the most fragile ones.
4. Since restoration of dark habitats is extremely difficult and expensive and, in many cases, requires methods that still need to be defined, special emphasis should be paid to the application of the precautionary approach for the management of human activities, making sure to reduce as much as possible threats and impacts. For instance, this could be envisaged by prohibiting trawling activities from the most sensitive sites.
5. It is crucial to promote tools and protocols for the identification, monitoring and management of human activities and pressures which affect dark habitats (e.g. non-destructive visual census techniques, new technologies), as well as taxonomic studies, since these habitats host rich and still unknown biodiversity.
6. Local ecological knowledge and citizen science approaches should be integrated in the process of identifying dark habitats, species distribution and their threats.
7. The establishment of a dedicated network focusing in dark habitats is highly recommended, promoting capacity building initiatives (e.g. workshops and training), in order to facilitate the exchange of experience and data sharing on dark habitats across the Mediterranean Sea.

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