UN environment programme | Mediterranean Action Plan Barcelona Convention | SPA/RAC

#MedSymposia

symposia.spa-rac.org

4th MEDITERRANEAN SYMPOSIUM ON THE CONSERVATION OF CORALLIGENOUS AND OTHER CALCAREOUS BIO-CONCRETIONS

20 | 21 September 2022
Genoa, Italy

Partners: ISPRA, Università di Genova, UISTAV, S.I.B.M.

Donors: MAVA, Co-funded by the European Union

The Mediterranean Symposia are an Ocean Decade Action endorsed by IOC-UNESCO

Disclaimer

Copyright

United Nations Environment Programme
Mediterranean Action Plan
Specially Protected Areas Regional Activity Centre
Boulevard du Leader Yasser Arafat
B.P.337 - 1080 Tunis Cedex - TUNISIA
car-asp@spa-rac.org

For bibliographic purposes, this document may be cited as:

UNEP/MAP – SPA/RAC, 2022. Proceedings of the 4th Mediterranean Symposium on the conservation of Coralligenous & other Calcareous Bio-Concretions (Genova, Italy, 20-21 September 2022). BOUAFIF C., OUERGHI A., edits, SPA/RAC publi., Tunis, 202 p.

Cover photo

This publication has been prepared with the financial support of the MAVA Foundation and the European Union.

For more information

www-spa-rac.org
symposia.spa-rac.org

Proceedings of the
4th Mediterranean Symposium
on the Conservation of the Coralligenous
and other calcareous bio-concretions

FORWARD

Dear Colleagues,

The United Nations Environmental Programme Mediterranean Action Plan – Specially Protected Areas Regional Activity Centre (UNEP/MAP – SPA/RAC) – Barcelona Convention has initiated since year 2000 a series of scientific symposia, dedicated to key habitats and NIS by organising the first Mediterranean Symposium on Marine vegetation. This initiative while aiming essentially to take stock of the recently available scientific data and to promote the cooperation between specialists and key actors working in the Mediterranean, has evolved since then to cover now Coralligenous, Dark Habibtats and Non-Indigenous species as well.

These symposia have been initiated as implementation of the UNEP/MAP regional action plans related to (i) **the Conservation of Marine Vegetation in the Mediterranean Sea** (adopted by the Contracting Parties to the Barcelona Convention in 1999 and updated in 2012), (ii) **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), (iii) **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 (iv) the **Action Plan concerning Species Introduction and Invasive Species** (Adopted by the Contracting Parties to the Barcelona Convention in 2003 and updated in 2016).

The "Mediterranean Symposia on Marine Key Habitats and NIS" are an important output, not only of the UNEP/MAP Mid-Term Strategy for the period 2016-2021 (Decision IG.22/1), but also for NTZ/MPA project "Empowering the legacy: scaling up co-managed and financially sustainable No-Take Zones / Marine Protected Areas", financed by MAVA foundation under its Mediterranean Strategy and by the IMAP-MPA project "Towards achieving the Good Environmental Status of the Mediterranean Sea and Coast through an Ecologically Representative and Efficiently Managed and Monitored Network of Marine Protected Areas" .

For more than two decades, the symposia have provided, within the framework of the Barcelona Convention, a platform for dialogue between the scientific community, managers, and decision makers.

This year, SPA/RAC in collaboration with the Italian Institute for Environmental Protection and Research (ISPRA), the university of Genoa and its Department of Earth, the Environment and Life Sciences of the University of Genoa (DISTAV) and the association "Società Italiana di Biologia Marina" (SIBM), organized a new edition of the Mediterranean Symposia in Genoa, from 19 to 23 September 2022, as follows:

- 7th Mediterranean Symposium on Marine Vegetation (19-20 September 2022)
- 4th Mediterranean Symposium on the conservation of coralligenous and other calcareous bio-concretions (20-21 September 2022)
- 3rd Mediterranean Symposium on the conservation of dark habitats (21-22 September 2022)
- 2nd Mediterranean Symposium on the non-indigenous Species (22-23 September 2022)

This edition was also a good opportunity to discuss new topics such as monitoring and definition of Good Environmental Status (GES), monitoring and assessment scale in the Mediterranean and, in this way, contribute to enhancing Science-Policy interface and to strengthening links ang cooperation between SPA/RAC and Barcelona Convention system and scientists and scientific institutions in the Mediterranean.

Khalil ATTIA
SPA/RAC Director

Tatjana Hema
UNEP/MAP Coordinator

CONTENTS

CONTENTS

PROGRAMME

Tuesday 20 September 2022

10:30-11:00 **Opening of the 4th Mediterranean Symposium on the Conservation of Coralligenous and other Calcareous Bio-concretions**

Session 1: **Mapping and characterization of coralligenous habitats**
Chair: **Leonardo TUNESI**, Rapporteur: **Asma YAHYAOUI**

11:00-11:15 "**CorMedNet: building a database on the distribution, demography and conservation status of sessile species for Mediterranean coralligenous assemblages**" by **Cristina LINARES,** FIGUEROLA-FERRANDO L., GÓMEZ-GRAS D., PAGÉS-ESCOLÀ M., OLVERA A., AUBACH A., AMATE R., FIGUEROLA B., KERSTING D.K., LEDOUX J.B., LÓPEZ-SANZ A., LÓPEZ-SENDINO P., MEDRANO A., ZENTNER Y., GARRABOU J.

11:15-11:30 **"Bridging together research and technological innovation: first results and expected bearings of the project CRESCIBLUREEF on Mediterranean Coralligenous**" by **Antonietta ROSSO,** ALTIERI C., BAZZICALUPO P., BERTOLINO M., BRACCHI V.A., BRUNO F., CIPRIANI M., COSTA G., D'ALPA F., DONATO G., FALLATI L., GALLO A., GUIDO A., LEONARDI R., MUZZUPAPPA M., NEGRI M.P., SANFILIPPO R., SAVINI A., SCIUTO F., SERIO D., TADDEI RUGGIERO E., VARZI A.G., VIOLA A., BASSO D.

11:30-11:45 "**State of knowledge on the deep coralligenous rings of Cape Corsica following the scientific expedition Gombessa 6 (2021)**" by **Julie DETER**, BALLESTA L., MASSEY J.-L., GUILBERT A., HOLON F., DELARUELLE G., BLANDIN A., MARRE G., RAUBY T., MOUILLOT D., VELEZ L., DEJEAN T., DI IORIO L., HOCDE R., FURFARO G., JORRY S., BOUCHETTE F., FERRIER-PAGES C., CHARRIERE A., IZART A., FERRANDINI M., PLUQUET F., PERGENT G., PERGENT-MARTINI C., LUONGO G., DANOVARO G., BOISSERY P., CANCEMI M.

11:45-12:00 "**Evaluation the ecological status of the vermetid reefs along the Lebanese coats, eastern Mediterranean Sea**" by **Ali BADREDDINE**

12:00-14:00 ***Lunch break***

14:00-14:15 "**Review of the geographic and bathymetric distribution of Maërl beds in Tunisian waters**" by **Raouia GHANEM**, BEN SOUISSI J., GARRABOU J.

14:15-14:30 "**Insights on the biodiversity of coralligenous and dark habitats from northern Tunisia, with focus on bryozoans**" by **Rakia AYARI-KLITI**, TAYLOR P.D., ROSSO A.

14:30-14:45 Discussion

Session 2: **Assessing conservation status and processes in the coralligenous**
Chair : **Hocein BAZAIRI**, Rapporteur : **Yassine Ramzi SGHAIER**

14:45-15:00 "**Coralligenous and other calcareous bio-concretions within the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast**" by **Silvija KIPSON,** YAHYAOUI A., AISSI M., OUERGHI A., ROBERT A., TUNESI L., RENDE F., AGNESI S., ANNUNZIATELLIS A., ANGIOLILLO M., GIUSTI M., BADDREDINE A., MAVRIČ B., BERNARDEAU ESTELLER J.A., DÍAZ D., MASSUTÍ E., TAŞKIN E., ÇINAR M.E., GARRABOU J.

15:00-15:15 "**Can emblematic species become a pest? The case of Astrospartus mediterraneus (Risso, 1826) (Echinodermata: Ophiuroidea) in the artisanal fishing grounds of the Cap de Creus area (NW Mediterranean Sea)**" by **Marina BIEL-CABANELAS,** MONASTRELL M., SANTÍN A., SALAZAR J., BAENA P., VILADRICH N., GORI A., MONTSENY M., CORBERA G., AMBROSO S., GRINYÓ, J.

15:15-15:30 "**Monitoring coralligenous reefs in Italian coastal waters within the Marine Strategy Framework Directive**" by **Martina RADICIOLI,** ANGIOLILLO M., GIUSTI M., PROIETTI R., FORTIBUONI T., SILVESTRI C., TUNESI L.

15:30-15:45 "**Ecological status of the Ligurian coralligenous habitats assessed by the MedSens index"** by **Massimo PONTI,** CERRANO C., GHETTA M., ABBIATI M., TURICCHIA E.

15:45 – 16:00 Discussion

16:00 – 16:15 ***Coffee break***

Session 2: (continued) **Assessing conservation status and processes in the coralligenous**
Chair: **Carlo Nike BIANCHI**, Rapporteur: **Mehdi AISSI**

16:15-16:30 "**CIGESMED for divers: A successful approach combining science and citizen involvement for the monitoring of NW Mediterranean coralligenous reefs**" by **Giulia GATTI,** BARTH L., GRANCHER T., BASTHARD-BOGAIN S., BLONDEAUX V., BIANCHIMANI O., ESTAQUE T., MONFORT T., RICHAUME J., CHEMINÉE A.

16:30-16:45 "**A rapid assessment method for citizen-scientists to monitor the conservation status of Mediterranean coralligenous assemblages**" by **Laura FIGUEROLA-FERRANDO,** LINARES C., ZENTNER Y., LÓPEZ-SENDINO P., GARRABOU, J.

16:45-17:00 "**Temporal variability in the response to thermal stress in the red gorgonian, *Paramuricea clavata*: insights from common garden experiments**" by **Sandra RAMIREZ-CALERO,** BENSOUSSAN N, LÓPEZ-SENDINO P, GÓMEZ-GRAS D, MONTERO-SERRA I, PAGÈS-ESCOLÀ M, MEDRANO A, LÓPEZ-SANZ A, FIGUEROLA, L, LINARES C, LEDOUX JB, GARRABOU J.

17:00-17:15 "**New insights on bioerosion processes in the northern Adriatic coralligenous reefs**" by **Eva TURICCHIA,** ABBIATI M., BETTUZZI M., CALCINAI B., MORIGI M.P., SUMMERS A.P., PONTI M.

17:15-17:30 "**Variability between observers in rapid visual assessment of coralligenous assemblages in the Marine Protected Area of Portofino (Ligurian Sea)"** by **Annalisa AZZOLA,** BIANCHI C.N., MORRI C., OPRANDI A., MONTEFALCONE M.

17:30-17:45 Discussion

20:00-23:00 ***Gala Dinner***

Wednesday 21 September 2022

Session 3: **Impacts and disturbances threatening key Mediterranean formations (including global change)**
Chair : **Vesna MACIC**, Rapporteur : **Asma YAHYAOUI**

8:30-8:45 "**T-MEDNet climate change coastal observation network: tracking and assessing effects on thermal regimes and their effects in Mediterranean coastal ecosystems**" by **Joaquim GARRABOU**, BENSOUSSAN N., AZZURRO E. & the T-MEDNet network

8:45-9:00 "**Climate adaptative management in Marine Protected Areas: the case of marine heatwaves and diving frequentation on the conservation of coralligenous habitat forming species**" by **Yanis ZENTNER,** ROVIRA G., ORTEGA J., MARGARIT N., CASALS D., MEDRANO A., PAGÈS-ESCOLÀ M., MONTERO-SERRA I., ASPILLAGA E., CAPDEVILA P., FIGUEROLA-FERRANDO L., HEREU B., GARRABOU J., LINARES C.

9:00-9:15 "**The need for change in a changing world: fishing impact within the Tavolara-Punta Coda Cavallo Marine Protected Area**" by **Ilaria AMEDEO**, CANESSA M., PANZALIS P., TRAINITO E.

9:15-9:30 "**Impact, remediation, and recovery of coralligenous reefs after the Concordia ship wreckage**" by **Edoardo CASOLI**, VENTURA D., MANCINI G., MAZZA M., BELLUSCIO A., ARDIZZONE G.

9:30-9:45 "**Soft coral and gorgonian assemblages exempted of thermal stress but threatened by high anthropogenic pressures in the Sea of Marmara**" by **Nur Eda TOPÇU**, GÜRESEN S. O., YILMAZ I.N., STEINUM T., TURGAY E., YARDIMCI E., KARATAŞ S., DOĞAN O., BARRAUD T., SARACOGLU C., AURELLE D.

9:45-10:00 "**No one is safe: destruction of coralligenous concretions and other benthic sciaphilic communities in the MPA Cape Greco (Cyprus)**" by Carlos JIMENEZ, PETROU A., **Magdalene PAPATHEODOULOU**., RESAIKOS V.

10:00-10:15 Discussion

10:15 – 10:30 ***Coffee break***

10:30-11:45 **Poster Session**

11:45-12:00 **Awards for best oral communication and poster**

12:00-12:15 **Closure of the Symposium**

12:15-14:00 ***Lunch Break***

****

ORAL COMMUNICATIONS

****

Ilaria AMEDEO, CANESSA M., PANZALIS P., TRAINITO E.
Via Santa Chiara 11, 07026 Olbia
E-mail: ilaria.amedeo1@gmail.com

THE NEED FOR CHANGE IN A CHANGING WORLD: FISHING IMPACT WITHIN THE TAVOLARA-PUNTA CODA CAVALLO MPA

Abstract
Professional and recreational fishing has an important impact on seabed habitats and related fishery resources. Between 2016-2020, this study was conducted on the benthic community, on the impacts associated with artisanal and sport fishing and on the settlement of alien species within the Marine Protected Area of Tavolara - Punta Coda Cavallo (NE Sardinia, Mediterranean Sea). In the channel between the islands of Tavolara and Molara, the study area (~300 ha, 2% of the MPA area) is included in the zone C (with lower protection) and is the more affected by fishing. It is characterized by granite outcrops, emerging from a detrital plain. Rocks host a peculiar benthic community of great ecological importance, dominated by large erect sponges (mainly protected under Barcelona Convention), where coralligenous concretions (sensu stricto) are residual. Gorgonians are widespread, and other particularly protected species under Barcelona Convention are diffusely distributed. The surveys on 82 sites showed that fishing gears were found in 81% of the investigated sites, proving a significant impact on the area. In 37% of the sites, eradicated or dead erect species were found. In 61% of the sites, gorgonians were observed with conspicuous signs of mechanical damage (necrosis and growth of epibionts). Moreover, while the presence of plastic debris affects 17% of the sites, the propagation of Caulerpa cylindracea was found on 49% of the sites. Overall, the habitat of high naturalistic value demonstrates an extensive state of suffering. The recorded data support the need to review the previous estimates of vulnerability and usability of the area, in order to develop management activities aiming at the protection and conservation of this unique habitat.

Key-words: fishing impact, gorgonians, lower protection level, conservation, Mediterranean Sea

Introduction
The mass mortality episodes involving coral forests and other marine benthic species have progressively increased due to accelerated global warming phenomena (Cerrano *et al.*, 2000; Coma *et al*., 2009; Huete-Stauffer *et al*., 2011; Ventura *et al*., 2019). Moreover, due to their morphology, erected species such as gorgonians and massive sponges are highly susceptible to a wide variety of anthropogenic impacts (Harmelin & Marinopoulos, 1994; Bavestrello *et al.,* 1997; Bo *et al*., 2014, Angiolillo *et al*., 2015; Betti *et al*., 2020), and, in particular, to recreational and professional demersal fishing activities, that, through gear physical contact, cause severe abrasion, branch breaks or total organisms extirpation (Bavestrello *et al*., 1997; Otero *et al*., 2016), also favoring the development of epibionts, which, in turn, lead to greater mechanical stress. Moreover, the stress due to positive thermal anomalies or NIS species (Cebrian *et al*., 2018) adds to the mechanical impacts, reducing not only the fishery resources but also the ecosystem integrity and compromising the whole functionality.
Although most of the studies regard sporadic sites within Marine Protected Areas (Cupido et al., 2009**;** Coma *et al*., 2009; Gambi et al., 2010; Crisci *et al.*, 2011) the lack of detailed information about the location of vulnerable habitats reduces the efficacy management measures by Bodies.
The Tavolara – Punta Coda Cavallo Marine Protected Area (NE Sardinia) hosts a

remarkable natural heritage (Trainito & Navone, 2008). In particular, recent studies have shown the presence of a peculiar benthic community developed on granite outcrops, characterized by a limited growth of crustose corallines, the dominance of erect sponges and irregular distribution of gorgonians; in addition to these peculiarities, the presence of protected species contributes to making this habitat a distinctive facies with a high conservation value (Canessa *et al*., 2021). It should be emphasized that the survey area considered here is located in zone C (with a lower level of protection) and that its relevance for conservation purposes was assessed by Rovere *et al*. (2012) on the basis af data available at that time. The need for strict protection was assessed only on a small portion of the area (target specie *A. poypoides* and *S. savaglia*), which anyway was classified as medium-low level of environmental quality, medium-low level of vulnerability, and high or maximum level of susceptibility to use.
The aim of this study was to investigate the real threat on benthic assemblages due to artisanal and sport fishing pressure, evaluate the health status of erected species, the presence of alien species, and the distribution of species living in areas of particular interest in the Mediterranean Sea (ASPIM species) in the channel between the island of Tavolara and Molara and contribute to the reevaluation of the area for conservation purposes.

Material and methods

Data from professional and artisanal fishing sites were collected between 2018-2020, as part of different activities and monitoring campaigns. The GPS coordinates of signal buoys were collected for fishing gears, classified in gillnets (trammel and monofilament gillnets), pots and bonitos and used to reconstruct their track on QGIS platform.
During 2016-2020, scuba diving photo surveys and video ROV transects in 82 sites from 35 to 70 m depth allowed to obtain evidence that also sport fishing gears contribute to mechanical damage and to collect data for the construction of three synthetic indexes: **(V) Vulnerability -** combines the presence and abundance (absent, rare, diffuse, widespread) of the sensitivity of species to mechanical damages (absence of erected species, erected species not *P. clavata*, erected specie + *P. clavata*, erected species + *P. clavata* + *S. savaglia*). **(I) Impacts** - results from the sum of six types of damages: i) extirpation; ii) partial mechanical breaking of branches and/or the more or less extensive removal of the tissue; iii) abandoned lines/fishing gears; iv) anthropogenic debris; v) occurrence of *Caulerpa cylindracea*; vi) presence of the *Filograna/Salmacina* complex, as an indicator of thermal stress. **(A) BC species -** indicates the occurrence of species protected under Barcelona Convention.

Results

In total, 86 cove fishing sites were detected: 83 gillnets (trammel and monofilament gill), 2 pots and one bonito. The entity of fishing pressure within Tavolara MPA resulted mainly located in the middle of the Tavolara Channel (Fig. 1).
The rocky outcrops here present were characterized by the peculiar benthic community described in Canessa *et al*. (2021). It is shaped by erect species, mainly gorgonians (*Eunicella cavolini*, *E. singularis*, *E. verrucosa*, *Paramuricea clavata*), erect sponges (*Axinella polyploides*, *Spongia officinalis* (Fig. 3G), *Sarcotragus foetidus*) and branched bryozoans. In some sites, protected species under the Barcelona Convention (*Savalia savaglia* (6 sites), *Aplysina cavernicola* (32 sites), *Cystoseira zosteroides* (29 sites)) were recorded; only 17 (21%) hosted coralligenous *sensu stricto* bioconstructions of very limited extension.
In correspondence to this area, the assessment of the impacts and stress on benthic

communities was evaluated (Fig. 2-3).

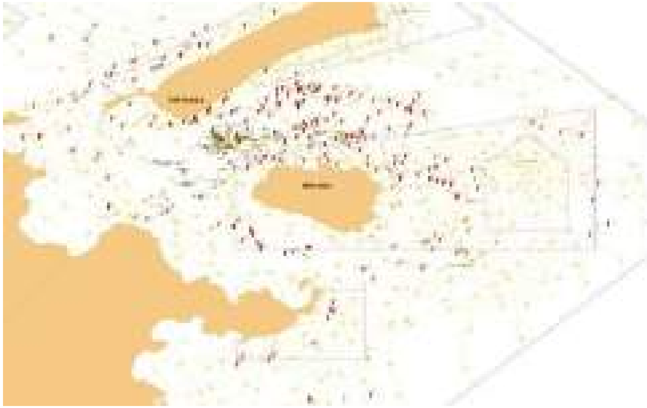


Fig. 1: Geolocalization of the 86 cove sites collected in 2018-2020, within the Tavolara – Punta

Coda Cavallo Marine Protected Area. The red arrows indicate the signals buoys of professional gears. There is evidence that the main fishing pressure is in the central part of the area.

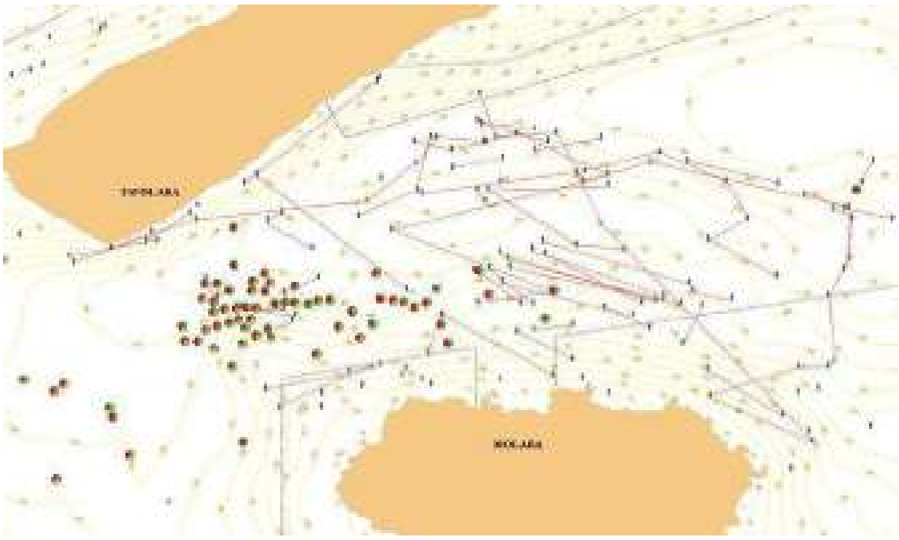


Fig. 2: Map of the study area: the 82 diving sites investigated are highlighted in blue, all located within Zone C. The red arrows indicate the signal buoys; the tracks of gears were estimated and are represented by the red dashed line.

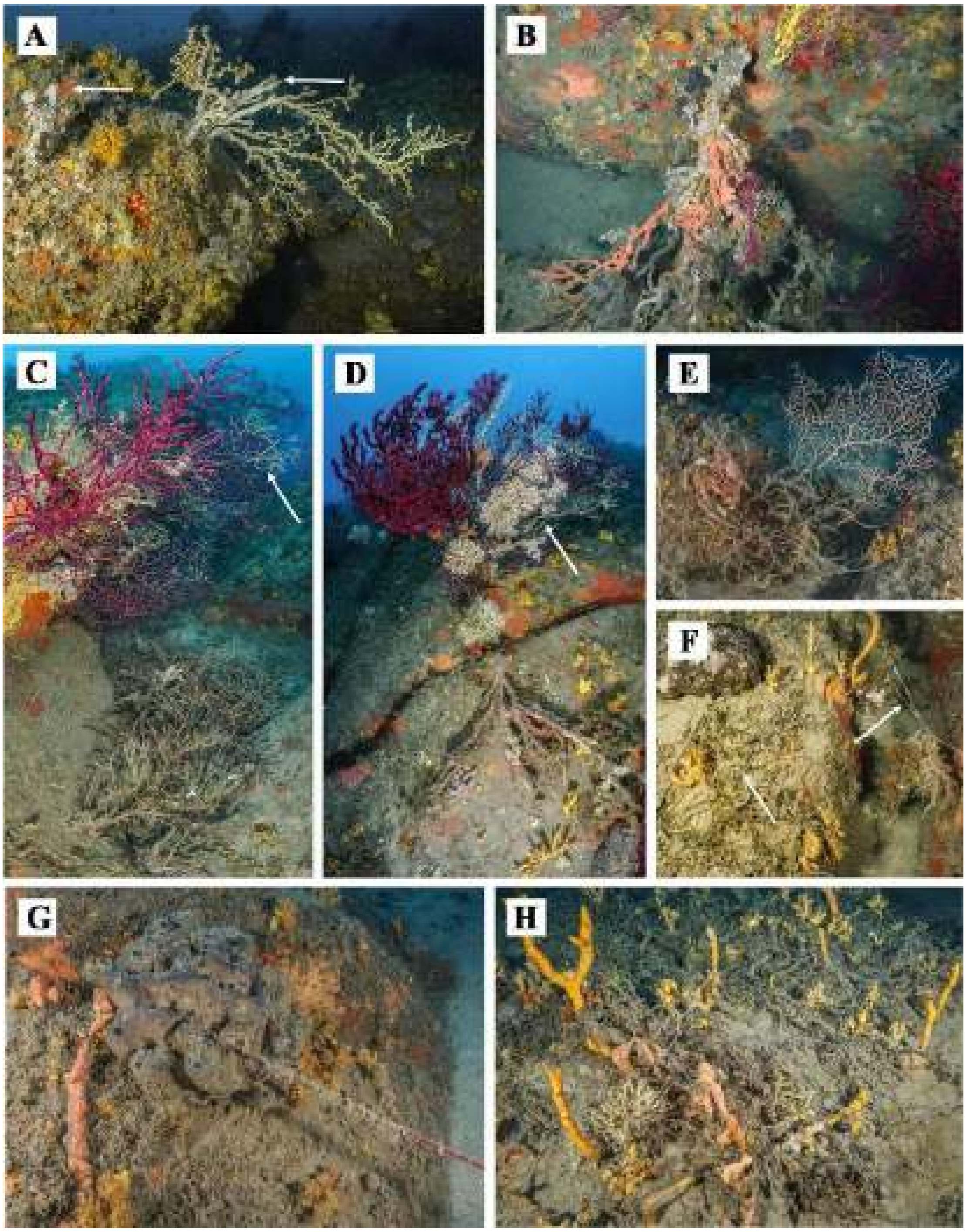


Fig. 3: A. Two colonies of *S. savaglia* broken by mechanical impacts (white arrows); B. A large colony of *S.savaglia* extirpated and covered by epibionts; C. Colonies of *P. clavata* affected by warming in the distal parts, on the bottom a pile of dead and extirpated skeletons; D. Colonies of *P. clavata* affected by warming in the distal parts, colonized by *Salmacina/Filograna*, on the bottom a dead extirpated skeleton; E. A colony of *E. verrucosa* damaged at the base by a lost sporting line; F. Silty bottom covered by *C. cylindracea* and bryozoans extirpated by a line. G. A fishing line damaging *S. officinalis*; H. A lost line damaging an *A. polypoides* facies.

Impacts were recorded in all the investigated sites except one (81 of 82), in particular, made by lost fishing gears, both professional and sports (Fig. 3E), and mechanical abrasion, recorded in 61% of the sites; damages were more evident and recurrent in sites were *P. clavata* was particularly abundant, while other erected species resulted less affected. On many colonies, the injured part was colonized by a wide variety of epibionts, such as bryozoans, hydrozoa, sponges and algae. Among the 19 recorded BC protected species, occurring in 81 out of 82 sites, also colonies of *S. savaglia* were found with broken branches or completely extirpated and covered with epibionts (Fig 4 A-B). The most diffused erect sponge, *Axinella polypoides* was also found extirpated or damaged in many sites (Fig. 3 H). *Caulerpa cylindracea* (Fig. 3H) was found in 40 sites (49%), while the *Filograna/Salmacina* complex (Fig. 3D) was observed in 29 sites (35%), as gorgonian's epibiont.

Discussion and conclusions

The study of the impacts of artisanal and sport fishing on benthic communities within the Tavolara - Punta Coda Cavallo MPA highlighted a strong pressure in correspondence of a very small area (actually included in zone C, where both the activities are allowed), where sensitive habitat occurrence has recently been assessed. The state of health was assessed to understand the conservation value of the study area and the risks to which they are subjected. In general, the significant presence of erect organisms, especially gorgonaceous and erect sponges, in an evident state of suffering, has been widely documented in these sites. Beyond the widespread presence of extirpated colonies (Fig. 3C-D), the other specimens reported naked skeleton portions at the basal implant of the colonies, as obvious signs of mechanical damage, clearly different from the heating effect, which, on the contrary, mostly affect the apical part of the organism (Cerrano *et al*., 2000) (Fig. 3C). The concurrence of both the types of stress (fishing mechanical impacts and global warming) magnifies the risk for the gorgonians and other erected species and favours the diffusion of epibionts and alien invasive species, like *Caulerpa cylindracea*.

In conclusion, fishing activities act a significant impact on the communities living in the investigated areas, currently included in a low protection zone. The need for a more accurate assessment of the threats and of the real location of sensitive habitats and species appears a good opportunity to improve the sustainable management of these resources of high ecological value. Quick response in terms of regulations and of zoning delimitations is increasingly urgent, opposite to the sudden change in habitats under the pressure of global warming.

Acknowledgements

The authors thank the "Slow dive" team for its support during the diving activities.

Bibliography

ANGIOLILLO M., DI LORENZO B., FARCOMENI A., BO M., BAVESTRELLO G., SANTANGELO G., CAU A., MASTACUSA V., CAU AL., SACCO F., CANESE S. (2015) - Distribution and assessment of marine debris in the deep Tyrrhenian Sea (NW Mediterranean Sea, Italy). *Marine Pollution Bulletin*, 92(1-2): 149-159.

BAVESTRELLO G., CERRANO C., ZANZI D., CATTANEO-VIETTI R. (1997) - Damage by fishing activities to the Gorgonian coral *Paramuricea clavata* in the Ligurian Sea. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 7(3): 253-262.

BETTI F., BAVESTERLLO G., BO M., RAVANETTI G., ENRICHETTI F., COPPARI M., CAPPANERA V, VENTURINI S., CATTANEO-VIETTI R. (2020) - Evidences of fishing impact on the coastal gorgonian forests inside the Portofino MPA (NW Mediterranean Sea).

Ocean & Coastal Management, 187: 105105.

BO M., BAVA S., CANESE S., ANGIOLILLO M., CATTANEO-VIETTI R., BAVESTRELLO G. (2014) - Fishing impact on deep Mediterranean rocky habitats as revealed by ROV investigation. *Biological Conservation*, 171: 167-176.

CANESSA M., BAVESTRELLO G., TRAINITO E., BIANCHI C.N., MORRI C., NAVONE A., CATTANEO-VIETTI R. (2021) - A large and erected sponge assemblage on granite outcrops in a Mediterranean Marine Protected Area (NE Sardinia). *Regional Studies in Marine Science*, 44: 101734.

CEBRIAN, E., TOMAS, F., LÓPEZ-SENDINO, P., VILÀ M., BALLESTEROS E. (2018) - Biodiversity influences invasion success of a facultative epiphytic seaweed in a marine forest. *Biol Invasions* **20,** 2839–2848. https://doi.org/10.1007/s10530-018-1736-x

CERRANO C., BAVESTRELLO G., BIANCHI C.N., CATTANEO-VIETTI R., BAVA S., MORGANTI C., MORRI C., PICCO P. SARA G., SCHIAPARELLI S., SICCARDI A., SPONGA F. (2000) - A catastrophic mass-mortality episode of gorgonians and other organisms in the Ligurian Sea (North-western Mediterranean), summer 1999. *Ecology letters*, 3(4): 284-293.

COMA R., RIBES M., SERRANO E., JIMéNEZ E., SALAT J., PASCUAL J. (2009) - *Global warming-enhanced stratification and mass mortality events in the Mediterranean*. Proceedings of the National Academy of Sciences, 106(15): 6176-6181.

CRISCI C., BENSOUSSAN N., ROMANO J.C., GARRABOU J. (2011) - Temperature anomalies and mortality events in marine communities: insights on factors behind differential mortality impacts in the NW Mediterranean. *PLoS One*, 6(9): e23814.

CUPIDO R., COCITO S., BARSANTI M., SGORBINI S., PERIANO A., SANTANGELO G. (2009)- Unexpected long-term population dynamics in a canopy-forming gorgonian coral following mass mortality. Mar Ecol Prog Ser 394: 195−200

GAMBI M.C., BARBIERI F., SIGNORELL, S., SAGGIOMO, V. (2010) - Mortality events along the Campania coast (Tyrrhenian Sea) in summers 2008 and 2009 and relation to thermal conditions. *Biol. Mar. Mediterr.* **17**, 126–127 (2010).

HARMELIN J.G., MARIANOPOULOS J. (1994) - Population structure and partial mortality of the gorgonian *Paramuricea clavata* (Risso) in the north-western Mediterranean (France, Port-Cros Island). *Marine life*, 4(1): 5-13.

HUETE-STAUFFER C., VIELMINI I., PALMA M., NAVONE A., PANZALIS P., VEZZULLI L., MISIC C., CERRANO C. (2011) - *Paramuricea clavata* (Anthozoa, Octocorallia) loss in the Marine Protected Area of Tavolara (Sardinia, Italy) due to a mass mortality event. *Marine Ecology*, 32: 107-116.

OTERO M.D.M., NUMA C., BO M., OREJAS C., GARRABOU J., CERRANO C., KRUŽIC´ P., ANTONIADOU C., AGUILAR R., KIPSON S., LINARES C., TERRÓN-SIGLER A., BROSSARD J., KERSTING D., CASADO-AMEZÚA P., GARCÍA S., GOFFREDO S., OCAÑA O., CAROSELLI E., MALDONADO M., BAVESTRELLO G., CATTANEO-VIETTI R.¸ ÖZALP B. (2017) - Overview of the conservation status of Mediterranean Anthozoa.

ROVERE A., FERRARIS F., PARRAVICINI V., NAVONE A., MORRI C., BIANCHI C.N. (2013) - Characterization and evaluation of a marine protected area:‘Tavolara–Punta Coda Cavallo’(Sardinia, NW Mediterranean). *Journal of Maps*, 9(2): 279-288.

TRAINITO E., NAVONE A. (ed.) (2008) – Tavolara. Nature at work...working in nature. 286 pp. Carlo Delfino editore. Sassari.

VENTURA J., LINARES C., BALLESTEROS E., COMA R., URIZ M.J., BENSOUSSAN N., CEBRIAN E. (2019) - Biodiversity loss in a Mediterranean ecosystem due to an extreme warming event unveils the role of an engineering gorgonian species. *Scientific reports*, 9(1): 1-11.

Rakia AYARI-KLITI, TAYLOR P.D., ROSSO A.
Université de Carthage, Institut National des Sciences et Technologies de la Mer, Laboratoire de Biodiversité Marine, 29 Rue Général Khereddine, 2015 Kram, Tunis
Email: rakia.ayariepkliti@instm.rnrt.tn

INSIGHTS ON THE BIODIVERSITY OF CORALLIGENOUS AND DARK HABITATS FROM NORTHERN TUNISIA, WITH FOCUS ON BRYOZOANS

Abstract

Sciaphilous communities from an overhang located at 78 m depth at Cap Negro (northern Tunisia) were collected by diving in 2014. Bryozoans are the most diverse group of epibionts on benthic organisms acting as substrata, i.e., the red coral Corallium rubrum and other skeletonised species such as the solitary scleractinian Caryophyllia calveri and the brachiopods Lacazella mediterranea and Joania cordata, these two latter so far unreported from Tunisia. In addition, some bryozoans sorted from a dredged coralligenous sample from the Cap Bon Peninsula at 38 m depth and conserved since 2006 were also studied.

The preliminary inventory allowed the identification of 27 species. Most of these are rare; four species from Cap Negro (Microporella appendiculata, Prenantia cf. inerma, Plagioecia sarniensis, and Crassimarginatella mathildae) are new records for Tunisian waters. Savignyella lafonti and Schizomavella halimedae are newly reported from the Cap Bon Peninsula. The discovery of colonies belonging to Carbasea cf. carbasea from the same locality could bear on its long-time questioned occurrence in the Mediterranean. Further species are not yet included in the inventory because the material needs a deeper taxonomic study pending their recovery and examination from further samples collected in similar deep and/or dark habitats. Some new records are illustrated with scanning electron micrographs and discussed briefly when necessary.

Although preliminary, the present results are significant additions to the bryozoans and brachiopods diversity of Tunisian remarkable habitats and point to the need for a greater focus on these still understudied ecosystems and their underestimated biodiversity.

Key-words: benthos, epibiosis, diversity, new records, overhang.

Introduction

Bryozoan diversity from Tunisian waters, especially in sciaphilous habitats is inadequately studied. Only five bryozoan species were identified from six Tunisian marine caves (Dridi *et al*., 2019). d'Hondt & Mascarell (2004) listed 201 species using data from a limited number of old scattered studies and by identifying others in the collections of the Muséum national d'Histoire naturelle, Paris. Other new occurrences from Tunisian waters have been published by Ayari *et al*. (2008; 2012a-b); Ayari & Taylor (2014) and Ben Ismail *et al*. (2009; 2012). The total number of 223 bryozoan species known from Tunisia (Ayari & Taylor, 2014) represents nearly 40% of the total number of Mediterranean bryozoans listed by Rosso & Di Martino (2016). Ayari & Taylor (2014) pointed out that the bryozoans have been neglected in Tunisian ecological studies due to taxonomic difficulties, and that estimating their true diversity will require sampling different regions and habitats,

coupled with the use of scanning electron microscopy. Aiming to enhance our current knowledge about Tunisian bryozoans, coralligenous localities from Cap Bon Peninsula and the fauna associated with the red coral *Corallium rubrum* within Cap Negro overhang are studied focusing on bryozoans.
This preliminary work represents an overview of sciaphilous calcareous organisms and a first assessment of bryodiversity from some remarkable Tunisian habitats (overhangs and coralligenous bottoms) which possibly host specific bryozoan assemblages.

Materials and Methods

Samples (20 x 20 cm scraped quadrats) were collected using SCUBA diving from Cap Negro (north-west Tunisia) (Fig. 1) at 78 m in 2014. They were obtained in cooperation with coral divers within red coral habitats. Other samples from the dredging of coralligenous bottoms from Cap Bon Peninsula (Fig. 1) had been dried and conserved since 2006. The studied one was taken in front of El Haouria at 38 m depth.
Detached and cemented bryozoans were sorted and examined under a stereomicroscope at the Biodiversity Laboratory of the National Institute of Marine Science and Technology (INSTM). To obtain information on small-scale features and to differentiate between some congeneric species, some specimens were scanned uncoated using a JEOL IT500 microscope operating at low-vacuum and back-scattered electron mode at the Natural History Museum, London.
Only new records from this preliminary inventory are presented below; most of these are figured and discussed when necessary.

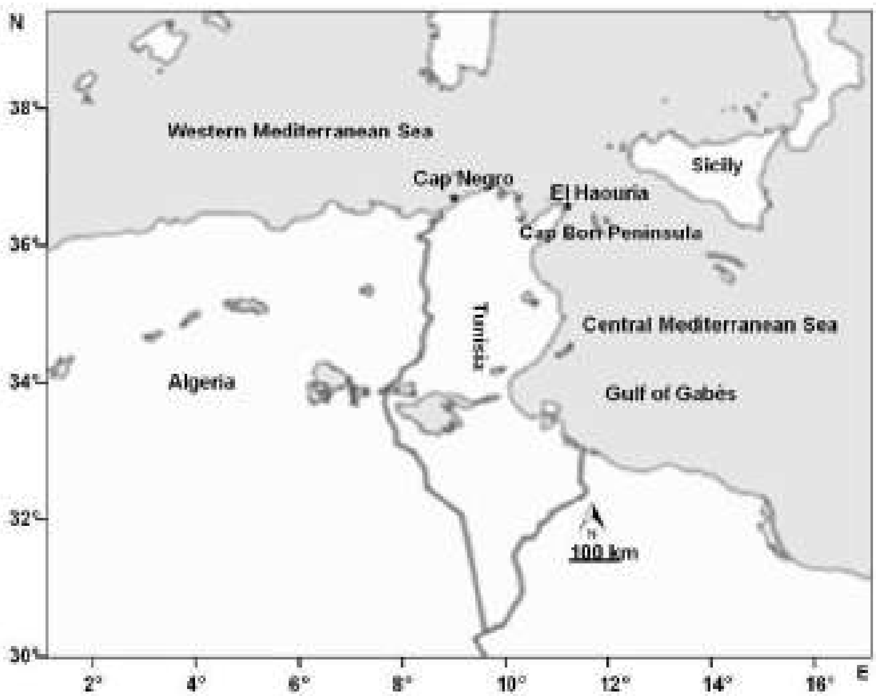


Fig. 1: Location of the sampling stations of Cap Negro and Cap Bon Peninsula in northern Tunisia.

Results

A total of twenty bryozoan species were found in the Cap Negro overhang. Most of them occurred cemented to scleractinians, *Coralium rubrum*, serpulid tubes and brachiopods. This last taxonomic group is represented by *Joania cordata* (Risso, 1826) (Fig. 2A–B) and *Lacazella mediterranea* (Risso, 1826) (Fig. 2C–D) which are reported here and figured for the first time from Tunisia. Sponges also were represented by the calcarean *Leucandra* sp. Haeckel, 1872 (Fig. 4A–C).

New bryozoan records from the overhang at Cap Negro

Crassimarginatella mathildae Pica & Berning, 2022 (Fig. 3A–B), *Plagioecia sarniensis* (Norman, 1864) (Fig. 3 C–D) and *Microporella appendiculata* (Heller, 1867) (Fig. 5D) are newly reported from Tunisian waters. The third of these, previously known from dark habitats (Di Martino & Rosso, 2021), is here shown to have a geographical distribution extended to the southern coasts of the Mediterranean basin. *Prenantia* cf. *inerma* (Calvet, 1906) (Fig. 3E– F), newly recorded in Tunisian waters, was recently added to the Mediterranean bryozoan fauna by Rosso & Di Martino (2016) following Pizzaferri (2010). *Prenantia* cf. *inerma* encountered in the Cap Negro overhang has a suboral imperforate area coarsely granular and very large lateral areolar and frontal pores, features not previously seen in the genus *Prenantia*.

On the same scleractinian skeleton spatial competition was observed resulting in the overgrown of *Cribrilaria radiata* by *Crassimarginatella mathildae* (Fig. 3A–B) and mostly by the dominant sponge competitor *Leucandra* sp. (Fig. 4C).

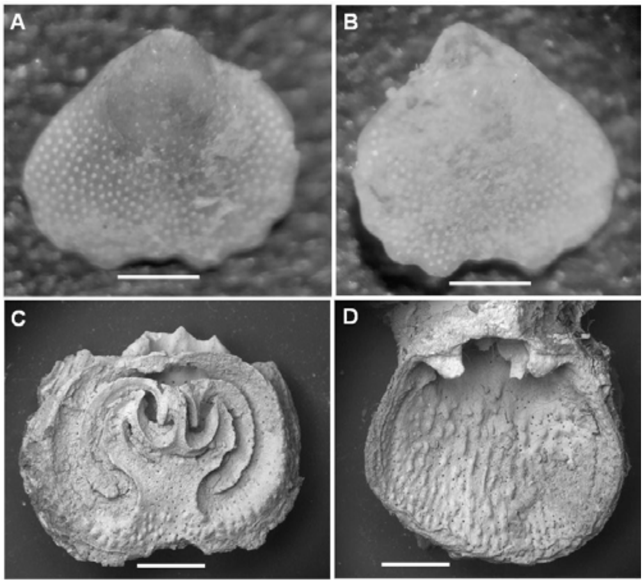


Fig. 2: (A–B) *Joania cordata* (Risso, 1826) complete specimen (stereomicrograph): (A) ventral view; (B) dorsal view; (C–D) *Lacazella mediterranea* (Risso, 1826), scanning electron micrographs: (C) inner view of dorsal valve; D, inner view of ventral valve. Scale bars: A, B, C, D =1 mm.

New bryozoan records from the coralligenous bottom of the Cap Bon Peninsula

Colonies of *Savignyella lafontii* (Audouin, 1826) and *Schizomavella halimedae* Gautier, 1955, newly reported from Tunisian waters, respectively encrust an ascidian of the family Didemnidae and the green alga *Flabellia petiolata* (Turra) Nizamuddin, 1987. Among other species encountered, *Carbasea* cf. *carbasea* (Ellis

& Solander, 1786) was reported detached from its substrate (Fig. 5A–C). However, some authors (e.g. Zabala & Maluquer, 1988; Hayward & Ryland, 1998) have questioned its presence in the Mediterranean where *Chartella papyrea* (Pallas, 1766) has been reported, a similar species with which *C. carbasea* could be confused. The main morphological features mentioned by Prenant & Bobin (1966) for distinguishing *C. carbasea* from *C. papyrea*, are the absence of ovicells (embryos brooded in internal ovisacs) and the presence of narrow lateral kenozooids bordering fronds in the former species. These characters, including the presence of kenozooids twice the length of the autozooids, occurred in colonies figured by Ayari & Taylor (2014) and are present in the presently examined new specimen. Comparison of our specimen with type material is, however, needed to ascertain the conspecificity.

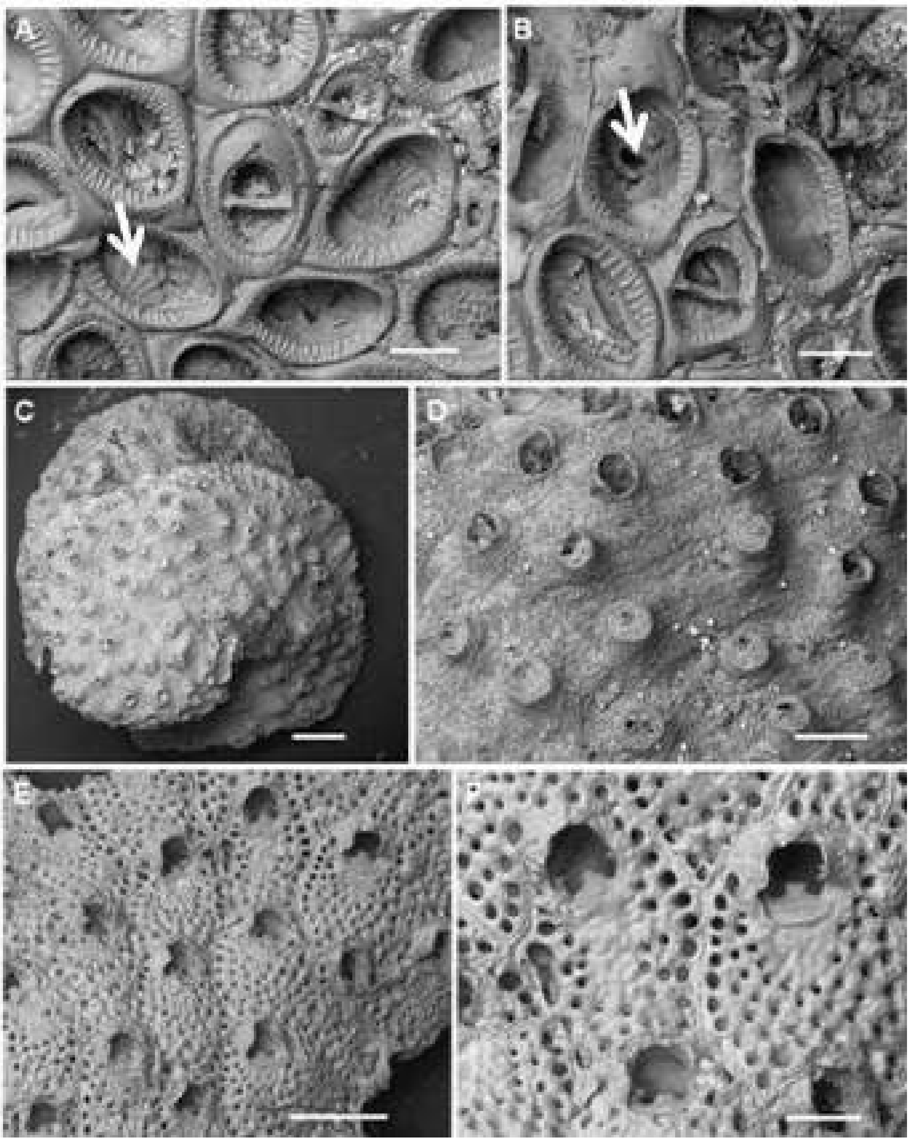


Fig. 3: (A–B) A *Crassimarginatella mathildae* Pica & Berning, 2022 colony overgrowing *Cribrilaria radiata* (arrowed): (A) Two types of vicarious avicularia with narrow downcurved mucro; (B) Ovicellate zooids and avicularia, a primary orifice of *Cribrilaria radiata* (arrowed); (C–D) *Plagioecia sarniensis* (Norman, 1864): (C) Colony; (D) secondary nanozooids developed on closing plates; (E-F) *Prenantia* cf. *inerma* (Calvet, 1906): (E) group of autozooids; (F) Details of autozooids. Scales bars: A, B, D, F = 200 µm ; C,E = 500 µm.

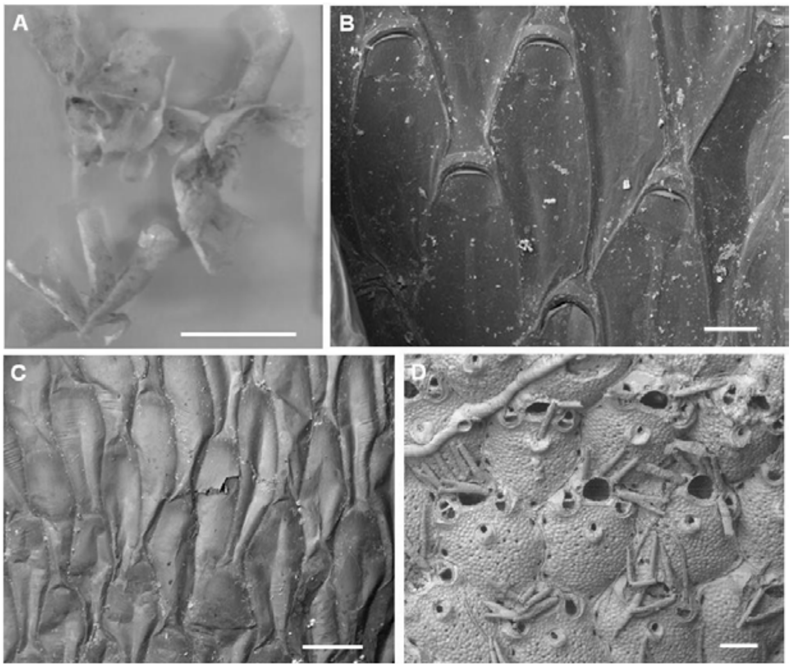


Fig. 4: (A–C) *Leucandra* sp. Haeckel, 1872: (A) Dried specimen encrusting a scleractinian (stereomicrograph); (B) details of giant and small choanosomal triactines; (C) the same specimen overlapping *Cribrilaria radiata*. Scales bars: A = 300 µm; B, C = 500 µm.

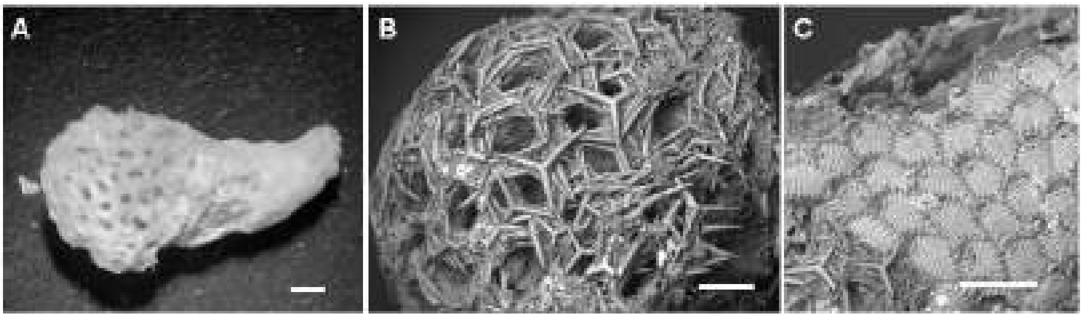


Fig. 5: (A–C) Carbasea cf. carbasea (Ellis & Solander, 1786): (A) Colony morphology: (B) Frontal side with some autozooids; (C) Reverse side; (D) *Microporella appendiculata* (Heller 1867): some autozoecia. Scale bars: A= 2 cm; B, D = 200 µm; C = 500 µm.

Discussion and conclusions

The skeletonised organisms identified here have not been previously recorded from Tunisia and/or from the southern coasts of the Mediterranean basin. This overview provides new information about the presence and the distribution of deep water scleractinian epibionts from Tunisian coralligenous and dark habitats. These preliminary results produce significant additions to brachiopod (two species) and bryozoan (seven species) diversity of the Tunisian waters. In total, six species from the overhang of Cap Negro, and three bryozoans from the coralligenous bottom of the Cap Bon Peninsula are newly reported, pointing to the need of focusing on these still understudied ecosystems and their underestimated biodiversity. Such records are required for biodiversity monitoring and conservation planning.

Acknowledgements

The authors would like to thank Mr. Oussama Saoudi, diver at the National Institute of Marine Sciences and Technologies (INSTM), who planned the sampling operations with his professional diving colleagues. Samples from the Cap Bon Peninsula were collected in 2006 in the framework of a thesis on Tunisian polychaetes of Zaabi Sana as part of the EBHAR research project (Etat du Benthos et des Habitats Remarquables). This study is part of taxonomic inventories of the benthic fauna at the Biodiversity laboratory of the INSTM. AR received funds by the University of Catania through "PiaCeRi-Piano Incentivi per la Ricerca di Ateneo 2020/22 linea di intervento 2".

Bibliography

AYARI KLITI R., AFLI A., AISSA P. (2012a) - Diversité taxonomique des Bryozoaires ctenostomes et cyclostomes au large du golfe de Tunis. *Bull. Inst. Nat. Scient. Tech.* Salammbô, 39: 55–71.

AYARI KLITI R., AFLI A., AISSA P. (2012b) - Diversite taxonomique des Bryozoaires cheilostomes au large du golfe de Tunis. *Bull. Inst. Nat. Scient. Tech. Salammbô,* 39: 73– 116.

AYARI R., TAYLOR P.D. (2014) - Some Bryozoa from Tunisia, Western Mediterranean Sea. In: *Bryozoan Studies* 2013, Rosso A., Wyse Jackson A.N., Porter J. (Eds). Proceedings of the 16th IBA Conference, 2013 Catania, Italy. *Studi Trentini Sci. Nat.*, 94: 11-20.

AYARI R., TAYLOR P.D., AFLI A., AISSA P. (2008) - A new species of the cheilostome bryozoan *Trematooecia* Osburn, 1940 from the Mediterranean Sea. *Cah. Biol. Mar.*, 49: 261–267.

BEN ISMAIL D., BEN HASSINE O.K., MASCARELL G., D'HONDT J.-L. (2009) - Description d'un nouveau bryozoaire (Cheilostomes) de Méditerranée occidentale (Tunisie): *Parellisina curvirostris raibauti*, subsp. nov. *Bul. Soc. Zool. France,* 134 (3–4): 313–319.

BEN ISMAIL D., RABAOUI L., DIAWARA M. BEN HASSINE O.K. (2012) – The Bryozoan assemblages and their relationship with certain environmental factors along the shallow and subtidal Tunisian coasts. *Cah. Biol. Mar.*, 53: 231–242.

DI MARTINO E., ROSSO A. (2021) - Seek and ye shall find: new species and new records of *Microporella* (Bryozoa, Cheilostomatida) in the Mediterranean. *ZooKeys* 1053: 1–42.

DRIDI A., ZRIBI I., MNASRI I., ACHOURI M.S., ZAKHAMA-SRAIEB R. (2019) - Preliminary data on the distribution of marine caves along the Tunisian coast. *In*: BOUAFIF C., LANGAR H., OUERGHI A. (Eds.), *Proceedings of 2nd Mediterranean symposium on the conservation of coralligenous and other calcareous bio-concretions (Portorož, Slovenia, 29-30 October 2014)*, RAC/SPA publ., Tunis: 41–46.

HAYWARD P.J., RYLAND J.S. (1998) - Cheilostomatous Bryozoa: part 1. Aeteoidea - Cribrilinoidea: notes for the identification of British species. 2nd ed. Synopses of the British fauna (New series), 10: 1–366.

D'HONDT, J.-L., MASCARELL, G. (2004) - Les bryozoaires marins et d'eau douce de Tunisie. *Bulletin de la Société Zoologique de France*, 129 (4), 437–457.

PIZZAFERRI, C. (2010) - New specimens of *Prenantia cheilostoma* (Manzoni) from the Pliocene of Castell'Arquato area (Western Emilia Region, N Italy). *Quaderno di Studi e Notizie di Storia Naturale della Romagna*, 31, 89–-117.

PRENANT M., BOBIN G. (1966) - Bryozoaires. Deuxième partie: chilostomes Anasca. *Faune de France*, 68: 1–647.

ROSSO A., DI MARTINO E. (2016) - Bryozoan diversity in the Mediterranean Sea: an update. *Medit. Mar. Sci.,* 17/2, 2016, 567–607

ZABALA M., MALUQUER P. (1988) - Illustrated keys for the classificationof Mediterranean Bryozoa. *Treb. Mus Zool*. Barcelona, 4: 1–294.

Annalisa AZZOLA, BIANCHI C.N., MORRI C., OPRANDI A., MONTEFALCONE M.
Seascape Ecology Laboratory, DiSTAV (Department of Earth, Environment and Life Sciences), University of Genoa, Genoa, Italy
E-mail: annalisa.azzola@edu.unige.it

VARIABILITY BETWEEN OBSERVERS IN RAPID VISUAL ASSESSMENT OF CORALLIGENOUS ASSEMBLAGES IN THE MARINE PROTECTED AREA OF PORTOFINO (LIGURIAN SEA)

Abstract
Coralligenous reefs are a habitat of high conservation value, which needs continuous monitoring for its management. Among the vast array of existing methods, visual criteria are to be preferred as they are not destructive and make immediately available the data collected. However, a problem often neglected is the variability between observers, which might blur the efficiency of habitat characterization and evaluation. Observers might differ for both their expertise (e.g., specialization) and experience (e.g., number of scuba surveys done or length of the scientific career). In this paper, we compare the output of vertical transects carried out by an expert diving scientist and a trainee on five coralligenous reefs in the Marine Protected Area of Portofino (Ligurian Sea). Both observers recorded on a diving slate the occurrence and semi-quantitative abundance of conspicuous epibenthic sessile species every 5 m of depth between 25 m and 50 m. Three main assemblages were recognized, discriminated mainly by depth: i) Association with algae such as Zanardinia typus, Dictyota dichotoma and Dictyopteris polypodioides at around 25-30 m depth; ii) Association with Cystoseira zosteroides at around 30 m depth; and iii) Facies with Paramuricea clavata at around 40 m depth. Differences between observers were always significantly lower than environmental variability, the latter being essentially due to species patchiness.

Key-words: scuba surveys; temperate rocky reefs; depth; slope; NW Mediterranean Sea

Introduction
Coralligenous reefs represent, in terms of extent, biodiversity and production, one of the most important coastal marine habitats in the Mediterranean Sea, capable of creating an extremely complex and diverse seascape (Ballesteros, 2006; Montefalcone et al., 2017), whose value is comparable to that of tropical coral reefs (Bianchi, 2001). Coralligenous reefs are a vulnerable ecosystem, due to its susceptibility to mechanical damage (caused for example by fishing gear) and to the slow growth rates of its component species (Ferrigno et al., 2017).
Despite its vulnerability and high conservation value, coralligenous reefs are not formally protected, being not included in the list of Sites of Community Importance (SCI) defined by the Habitats Directive (92/43/EEC). Only recently, in the framework of the Marine Strategy Framework Directive, they have been defined as a "special habitat": the assessment of its health status is considered a valuable contribution in defining the Environmental Status of Mediterranean marine regions or sub-regions (E.C., 2008). Coralligenous reefs have also been included in the European Red List of marine habitats, where they are classified as "data deficient", highlighting the need of surveys and accurate monitoring plans.

As for the type of surveying method to be adopted, the use of non-destructive techniques, which do not require the collection and sacrifice of specimens, are to be preferred and highly recommended for the study and the monitoring of valuable habitats such as coralligenous reefs (Bianchi et al., 2022). Rapid Visual Assessment (RVA) responds to this need, based on observations and measurements made directly underwater. This method allows for adequate taxonomic detail and for a comprehensive data collection, as it integrates topographical and ecological information (Gatti et al., 2015).
Although visual surveys are the most appropriate techniques in the study of coralligenous, they undoubtedly may have an inherent limit in the "observer effect": information collected by different diving scientists may be biased by their dissimilar expertise (e.g., specialization) and experience (e.g., number of scuba surveys done or length of the scientific career) possibly influencing sampling quality and data analysis (Azzola et al., 2022 and reference therein).
The aim of the present work is to evaluate observer effect in the characterization and evaluation of the coralligenous assemblages of Portofino Marine Protected Area (MPA).

Materials and methods

Portofino (MPA) covers 345 ha of sea in the Ligurian Sea (NW Mediterranean). The sea bottoms of Portofino MPA are mainly characterized by vertical and sub-vertical rocky cliffs that, below 20-25 m depth, host extensive coralligenous formations (Bavestrello et al., 2022).
Underwater surveys were carried out in five sites by two diving scientists, with different expertise and level of experience (one expert and one trainee). In each site, they carried out vertical transects of 4 m total width, every 5 m depth from 50 m to 25 m, also recording substratum slope. Along the vertical transects, the percentage cover of conspicuous species (i.e., species of a size that would allow their recognition and identification underwater) was visually estimated (Gatti et al., 2015, 2017) and directly recorded on a diving slate. The percentage cover of all the conspicuous species was organized in a data matrix (depth × slope × observer) × species to perform statistical analyses.
Different assemblages of the Portofino MPA coralligenous were recognised through Cluster Analysis and then assimilated and named according to the SPA/RAC habitat classification (SPA/RAC–UNEP/MAP, 2019; Montefalcone et al., 2021).
To highlight observer effect in the characterization of each assemblage, variability between observers was compared with environmental variability. The percent dissimilarity between the two diving scientists was measured by the following formula:

$$\text{Dissimilarity } \% = (1 - BC) \times 100,$$

where BC is the Bray Curtis Index; environmental variability was estimated by subtracting the variability between observers from the overall variability within the assemblage. Differences between observer variability and environmental variability were evaluated by Student's t-test.
All the statistical analyses were performed by the free software PaSt (Hammer et al., 2001).

Results

Three assemblages were identified (Fig. 1): i) one dominated by the brown algae *Zanardinia typus*, *Dictyota dichotoma*; and *Dictyopteris polypodioides*; ii) one dominated by the brown alga *Cystoseira zosteroides*; and iii) one dominated by the sea fan

Paramuricea clavata. They closely match the SPA/RAC habitats MC1.513a (Association with algae, except Fucales, Laminariales, Corallinales and Caulerpales), MC1.512a (Association with Fucales or Laminariales), MC1.514b (Facies with Alcyonacea). All the habitats identified showed some typical coralligenous traits: MC1.513a, despite being dominated by algae, is also characterized by the presence of the sea fans *Paramuricea clavata* and *Eunicella cavolini*; while MC1.512a and MC1.514b, despite being dominated by two different species, are both characterized by a considerable abundance of encrusting corallinales (*Lithophyllum/Mesophyllum* complex).

The distribution of the three assemblages recognised in the coralligenous of Portofino MPA was mainly discriminated by depth, and secondarily by substratum slope: MC1.513a was distributed between 25 m and 40 m depth, and especially at around 30 m; MC1.512a occurred between 30 m and 40 m depth; and MC1.514b was widely distributed between 25 m (on sub-vertical substrates) and 50 m (on gently sloping substrates) peaking at 40 m depth. MC1.513a was located in the depth zone most prone to the colonization by the invasive alga *Caulerpa cylindracea* and the development of mucilaginous aggregates (*Acinetospora crinita*) (Fig. 1).

Within each assemblage, dissimilarity between the two observers was always significantly lower than environmental variability (Fig. 2). This may be due to species patchiness: for MC1.513a none of the species was present in all the observations made in that assemblage in different sites; for MC1.512a and MC1.514b only the dominant species (i.e., *C. zosteroides* and *P. clavata*, respectively) was recorded in all the relevant observations.

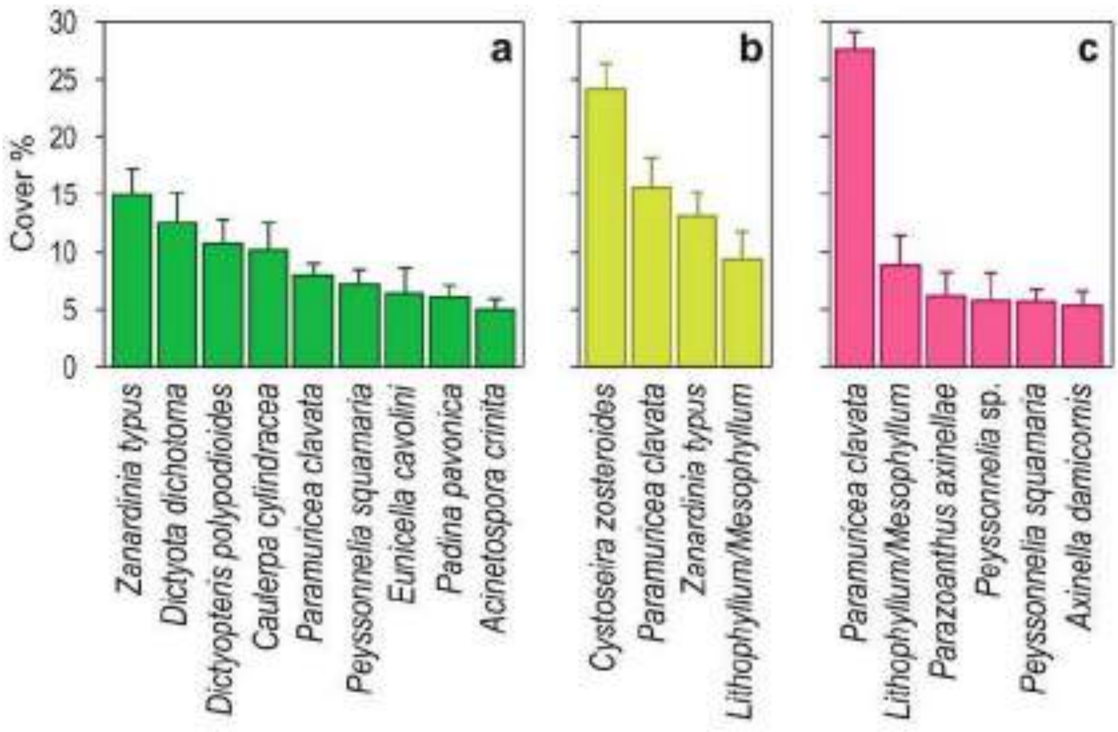


Fig. 1: Cover (%) of the most important species (i.e., species with a mean cover > 5%) of the three coralligenous assemblages identified with Cluster Analysis: a) MC1.513a Association with algae, except Fucales, Laminariales, Corallinales and Caulerpales; b) MC1.512a Association with Fucales or Laminariales; c) MC1.514b Facies with Alcyonacea.

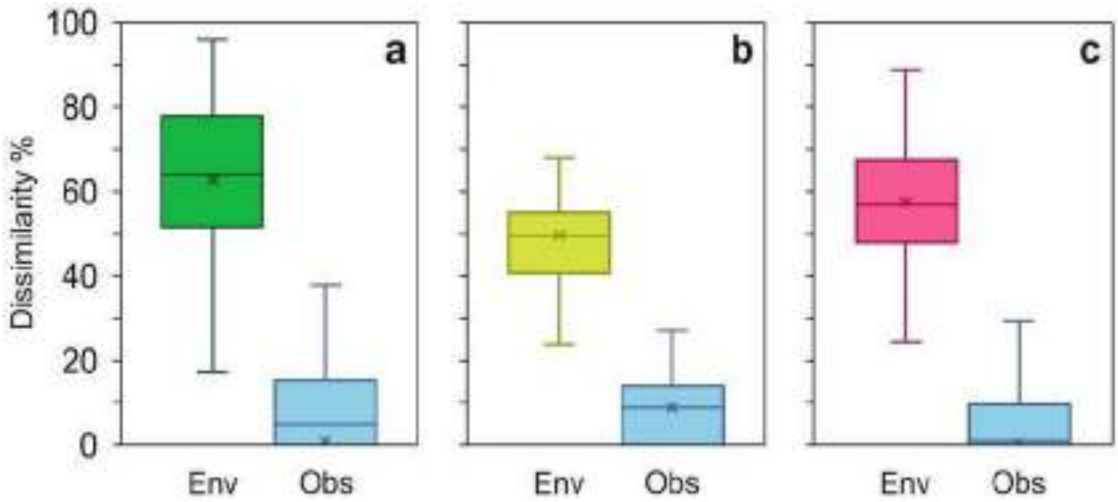


Fig. 2: Dissimilarity (%) due to the environmental variability (Env) was always significantly higher compared to the differences between observers (Obs): a) MC1.513a (p = 5E-24); b) MC1.512a (p = 7E-17); c) MC1.514b (p = 3E-88).

Discussion and conclusions

The rocky reefs of Portofino MPA have been the stage of one of the first experiences of study based on visual observations by diving (Tortonese, 1958, 1961; Bianchi and Morri, 2000), thanks to the unprecedented collaboration between the sport diver Duilio Marcante (1914-1985) and the natural scientist Enrico Tortonese (1911-1987). Nearly 70 years after, our study - however preliminary and partial - indirectly corroborates the results of that pioneer investigation. Gatti et al. (2017) were indeed capable of comparing the data of Marcante and Tortonese with later visual data collected in the 1980s through the 2000s to detect change over time and estimate the magnitude of such change, mostly linked to the climate shift of the 1980s-90s (Bianchi et al., 2019).

Although the present work involved surveys at only five sites by only two observers, the significance of the results suggested that the difference between observers may be negligible in the characterization and evaluation of coralligenous assemblages. Gatti et al. (2015) showed that the assessment of coralligenous state of health was not affected by the experience of different diving scientists who collected visual data. Field observations resulted objective and reliable, with the advantage of obtaining data immediately, without further time-consuming analyses of photos or videos in the laboratory (Bianchi et al., 2004). Similarly, in a study on the rocky reefs of Capo Carbonara MPA, conducted at two different times by four observers through visual surveys, it was shown that the observer effect did not hamper detecting change over time in the benthic communities under the effect of global and local pressures (Azzola et al., 2022).

Our result confirm that visual methods may be considered robust to observer bias, and should become part of the fundamental training of diving scientists. On the other hand, visual surveys protocols should always take into account the assessment of observer variability in the characterization and evaluation of coralligenous assemblages.

Acknowledgments

Authors are grateful to Stefano Zachopoulos, Eleonora Zanon, Elena Castelli and Stefano Aicardi (Subtribe, Genoa) for the logistic support. Giorgio Barsotti, Claudio De Angelis and Giuseppe Galletta (GDA, Genoa) helped during field activities.

Bibliography

AZZOLA A., ATZORI F., BIANCHI C.N., CADONI N., FRAU F., MORA F., MORRI C., OPRANDI A., ORRÙ P.E., MONTEFALCONE M. (2022) - Variability between observers does not hamper detecting change over time in a temperate reef. *Mar. Environ. Res.*, 177: 105617.

BALLESTEROS E. (2006) - Mediterranean coralligenous assemblages: a synthesis of present knowledge. *Oceanogr. Mar. Biol. Annu. Rev.*, 44: 123-195.

BAVESTRELLO G., BETTI F., BIANCHI C.N., BO M., CAPPANERA V., CORRADI N., MONTEFALCONE M., MORRI C., RELINI G. (2022) - Il promontorio di Portofino: 150 anni di storia di biologia marina. *Notiz. Soc. It. Biol. Mar.*, 81: 53-114.

BIANCHI C.N. (2001) - La biocostruzione negli ecosistemi marini e la biologia marina italiana. *Biol. Mar. Medit.*, 8: 112-130.

BIANCHI C.N., AZZOLA A., BERTOLINO M., BETTI F., BO M., CATTANEO-VIETTI R., COCITO S., MONTEFALCONE M., MORRI C., OPRANDI A., PEIRANO A., BAVESTRELLO G. (2019) - Consequences of the marine climate and ecosystem shift of the 1980-90s on the Ligurian Sea biodiversity (NW Mediterranean). *Eur. Zool. J.*, 86(1): 458-487.

BIANCHI C.N., AZZOLA A., COCITO S., MORRI C., OPRANDI A., PEIRANO A., SGORBINI S., MONTEFALCONE M. (2022) - Biodiversity monitoring in Mediterranean marine protected areas: Scientific and methodological challenges. *Diversity*, 14(1): 43.

BIANCHI C.N., MORRI C. (2000) - Training scientific divers - Italian style. *Ocean Challenge*, 10(1): 25-29.

BIANCHI C.N., PRONZATO R., CATTANEO-VIETTI R., BENEDETTI-CECCHI L., MORRI C., PANSINI M., CHEMELLO R., MILAZZO M., FRASCHETTI S., TERLIZZI A., PEIRANO A., SALVATI E., BENZONI F., CALCINAI B., CERRANO C., BAVESTRELLO G. (2004) - Hard bottoms. *Biol. Mar. Medit.*, 11(1): 185-215.

E.C. (2008) - DIRECTIVE 2008/56/EC of the European Parliament and of the Council, of 17 June 2008, establishing a framework for Community action in the field of marine environmental policy (Marine Strategy Framework Directive). *Official Journal of the European Union*, G.U.C.E. 25/6/2008, L 164/19.

FERRIGNO F., RUSSO G.F., SANDULLI R. (2017) - Coralligenous Bioconstructions Quality Index (CBQI): a synthetic indicator to assess the status of different types of coralligenous habitats. *Ecol. Indic.*, 82: 271-279.

GATTI G., BIANCHI C.N., MONTEFALCONE M., VENTURINI S., DIVIACCO G., MORRI C. (2017) - Observational information on a temperate reef community helps understanding the marine climate and ecosystem shift of the 1980-90s. *Mar. Pollut. Bull.*, 114: 528-538.

GATTI G., BIANCHI C.N., MORRI C., MONTEFALCONE M., SARTORETTO S. (2015) - Coralligenous reefs state along anthropized coasts: application and validation of the COARSE index, based on a rapid visual assessment (RVA) approach. *Ecol. Indicat.*, 52: 567-576.

HAMMER Ø., HARPER D.A.T., RYAN P.D. (2001) - PaSt: paleontological statistics software package for education and data analysis. *Palaeontol. Electron.*, 4: 4.

MONTEFALCONE M., MORRI C., BIANCHI C.N., BAVESTRELLO G., PIAZZI L. (2017) - The two facets of species sensitivity: stress and disturbance on coralligenous assemblages in space and time. *Mar. Pollut. Bull.*, 117: 229-238.

MONTEFALCONE M., TUNESI L., OUERGHI A. (2021) - A review of the classification systems for marine benthic habitats and the new updated Barcelona Convention classification for the Mediterranean. *Mar. Environ. Res.*, 169: 105387.

SPA/RAC–UNEP/MAP (2019) - Updated classification of benthic marine habitat types for the Mediterranean region. Tunis: United Nations Environment Programme, Mediterranean Action Plan, Specially Protected Areas, Regional Activity Centre.

TORTONESE E. (1958) - Bionomia marina della regione costiera fra Punta della Chiappa e Portofino (Riviera ligure di levante). *Arch. Oceanogr. Limnol.*, 11(2): 167-210.

TORTONESE E. (1961) - Nuovo contributo alla conoscenza del bentos della scogliera ligure. *Arch. Oceanogr. Limnol.*, 12(2): 163-183.

Ali BADREDDINE
Tyre Coast Nature Reserve-Tyre-south Lebanon
E-mail: ali.badreddine@hotmail.com

EVALUATION OF THE ECOLOGICAL STATUS OF VERMETID REEFS ALONG THE LEBANESE COAST, EASTERN MEDITERRANEAN SEA

Abstract
Vermetid reefs are key habitats that provide crucial ecosystem services. Unfortunately, they are under siege due to local anthropogenic pressure and global climate change, with documented decline in the Eastern Mediterranean. This study evaluates the ecological status of vermetid reefs along the Lebanese coast (Eastern Mediterranean), where seawater warming, habitat degradation, non-indigenous species, fishing activities, and coastal urbanization threaten the two main reef-builder species: Dendropoma anguliferum *and* Vermetus triquetrus*. Ten sites were randomly selected among those belonging to three impact classes: i) not impacted (i.e., protected), ii) moderately impacted (i.e., low anthropogenic pressure), and iii) impacted (i.e., high anthropogenic pressure). Two non-destructive methods (photo-quadrats and point intercept transects) were applied to assess the presence of living/dead vermetids. Living individuals of the endemic reef-builder D. anguliferum and of V. triquetrus were found mainly at the not impacted site. Regular monitoring of the vermetid reefs along the Lebanese coast is highly recommended for their conservation.*

Key-words: Vermetid reefs, *Dendropoma anguliferum*, *Vermetus triquetrus*, Eastern Mediterranean, Lebanese coast.

Introduction
Vermetid reefs are widespread along the warmer sectors of the Mediterranean Sea, including the Lebanese coast (Badreddine *et al.*, 2019; Terradas-Fernandez *et al.*, 2019; Gordó-Vilaseca *et al.*, 2021). Nevertheless, these unique biogenic reefs are poorly studied, and rarely the object of appropriate management activities (Milazzo *et al.*, 2017; Badreddine *et al.*, 2019). In the Eastern Mediterranean they are collapsing due to multiple global (e.g. acidification, sea level rise, ocean warming, Rilov, 2016) and local impacts (e.g. coastal urbanization, Di Franco *et al.*, 2011, and pollution, Rilov, 2016) whose occurrence has been growing in the last few decades (Rilov *et al.*, 2019, 2020a, 2020b; Albano *et al.*, 2021). Vermetid reefs have been listed in the Mediterranean Red Data Book of threatened seascapes (Boudouresque *et al.*, 1990) and in the IUCN Red List of vulnerable habitats (Gubbay *et al.*, 2016). The reef-building vermetids belonging to the "*Dendropoma petraeum* complex" are included in the Annex II of the Protocol for Specially Protected Areas and Biodiversity in the Mediterranean Sea (Barcelona Convention), and *Dendropoma* spp. and *Vermetus triquetrus* are considered as species deserving protection (Milazzo *et al.*, 2017; Badreddine *et al.*, 2019; Gordó-Vilaseca *et al.*, 2021).
Vermetid reefs along the Lebanese coastline are suffering from marine sand and gravel extraction, sewage and oil dumping, unsustainable and illegal fisheries, habitat degradation, recreational uses, coastal urbanization, and non-indigenous species, along with large-scale impacts such as the effects of climate change (Badreddine, 2018 and

references therein). This study aims to assess the current conservation status of the vermetid reefs along the Lebanese coastline.

Materials and Methods

Ten sites from the south to the north of Lebanon were randomly selected in areas with different levels of human pressures (Tab. 1). Human pressures were assessed based on LUSI (Land Use Simplified Index, Flo *et al.*, 2011), as reported in Badreddine *et al.* (2018). Surveys were conducted at low tide and under calm water conditions. The numbers of living and dead vermetids belonging to the species *Dendropoma anguliferum* (Monterosato, 1878) and *Vermetus triquetrus* Bivona-Bernardi, 1832 were assessed by photo-quadrats and point intercept transects.

Photo-quadrats consisted of ten 10×10 cm plots randomly placed both in the inner (5 photo-replicates) and the outer edges (5 photo-replicates) of the reefs, and photographed with a digital camera (Sony, DSC-W550). Living individuals were distinguished from empty shells by the presence of the shell operculum, which goes lost in dead individuals. Counts were performed using the open access ImageJ software and reported as number of individuals/100 cm^2.

Point Intercept Transects consisted of 10 random 5 m long transects, laid parallel to the coastline along both the inner edge (5 transects) and the outer edge (5 transects) of the reefs. The presence of living vermetids was assessed every 20 cm for each transect (25 points/transect), and values were expressed as percent frequency.

Tab.1 Sites considered for the assessment of vermetid reefs along Lebanese coast, their coordinates, the corresponding LUSI index and conditions (see Flo *et al.*, 2011 for further details)

Sites	Latitude, Longitude	LUSI	Conditions
Nakoura	33°8′25.15″N, 35° 9′14.82″E	0	Not-Impacted
Tyre	33°16′33.58″N, 35°11′34.64″E	3	Moderately-Impacted
Saksakiyeh	33°26'22.99"N, 35°16'27.34"E	3	Moderately-Impacted
Beirut	33°54′ 9.15″ N, 35°29′ 2.02″ E	28	Impacted
Jbeil	34°7'19.04"N, 35°38'31.34"E	7	Moderately-Impacted
Batroun	34°15′ 1.26″ N, 35°39′ 23.97″ E	5	Moderately-Impacted
Hannoush	34°18'20.04"N, 35°40'29.32"E	5	Moderately-Impacted
Enfeh	34°21'13.48"N, 35°43'49.69"E	4	Moderately-Impacted
Tripoli	34°26′ 15.77″ N, 35°48′ 40.03″ E	31	Impacted
Palm Island Nature Reserve	34°29'45.20"N, 35°46'26.24"E	1	Not-Impacted

Results

Based on photo-quadrats (Fig. 1), the maximum living vermetid density was recorded along the reef of Nakoura (protected site) with a maximum of 25 individuals ± 0.1/100 cm^2 (Mean ± S.E.) of *Dendropoma anguliferum* in the outer edge, and 35 individuals ± 3.2/100 cm^2 (Mean ± S.E.) of *Vermetus triquetrus* in the inner edge. *D. anguliferum* was also recorded in the outer edge of the protected site of Palm Island Nature Reserve (2 individuals ± 0.1/100 cm^2), and in the moderately impacted sites of Tyre (2 individuals ± 0.1/100 cm^2) and Enfeh (1 individual ± 0.1/100 cm^2). *V. triquetrus* was also recorded in the protected site of Palm Island Nature Reserve (15 individuals ± 3.0/100 cm^2), and the moderately impacted reefs of Tyre (15 individuals ± 1.0/100 cm^2), Saksakiyeh (13 individuals ± 2.1/100 cm^2), Jbeil (8 individuals± 2.1/100 cm^2), Batroun (10 individuals ± 1.3/100 cm^2), Enfeh (10 individuals ± 3.3/100 cm^2), and Hannoush (6 individuals ± 2.5/100 cm^2).

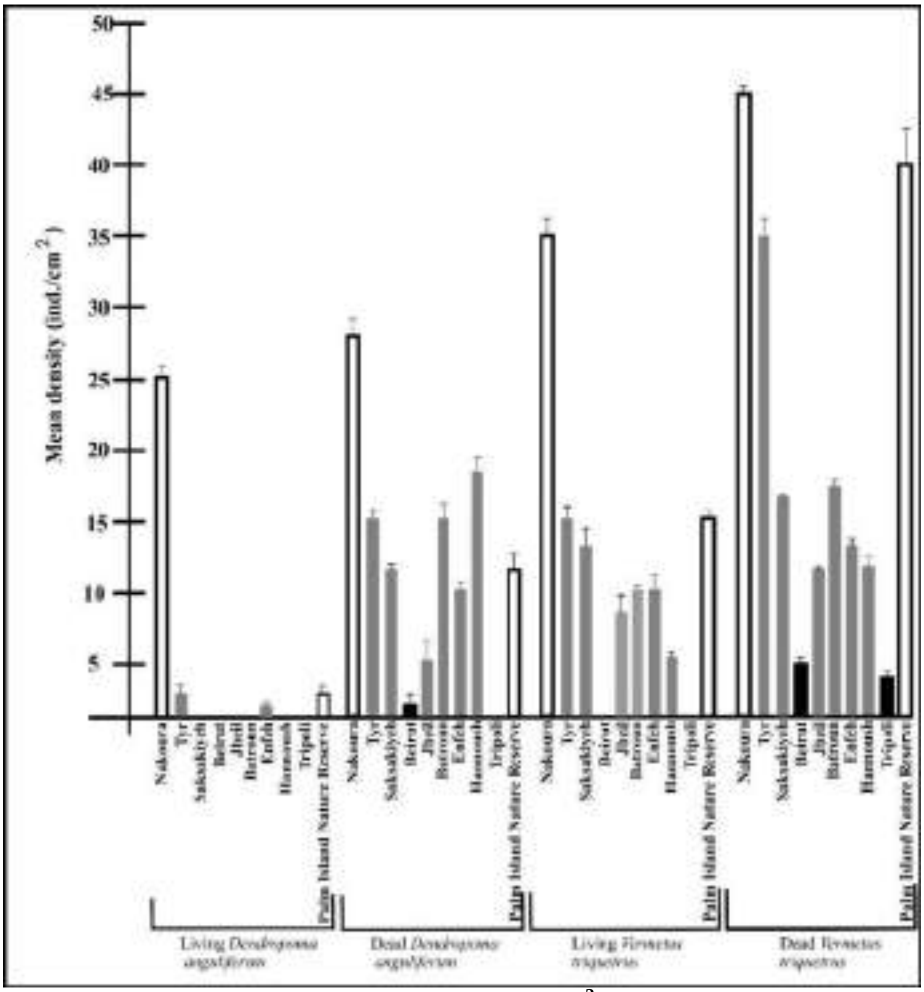


Fig. 1: Mean density (± standard error)/100 cm^2 of living and dead vermetids (*Dendropoma anguliferum* and *Vermetus triquetrus*) at the ten sites monitored. White: not impacted; grey: moderately impacted; black: impacted.

According to the transect method (Fig. 2), *D. anguliferum* occurred on the outer reef edges of Nakoura (with a mean frequency of 38.6%), Palm Island Nature Reserve (6.7%), Tyre (17.5%), and Enfeh (4.1%). *V. triquetrus* was recorded in patches in the inner edge of Nakoura, Tyre, Saksakiyeh, Jbeil, Batroun, Enfeh, and Hannoush (with average frequency ranging from 27% to 60%). Both vermetid species were absent in the impacted sites of Beirut and Tripoli.

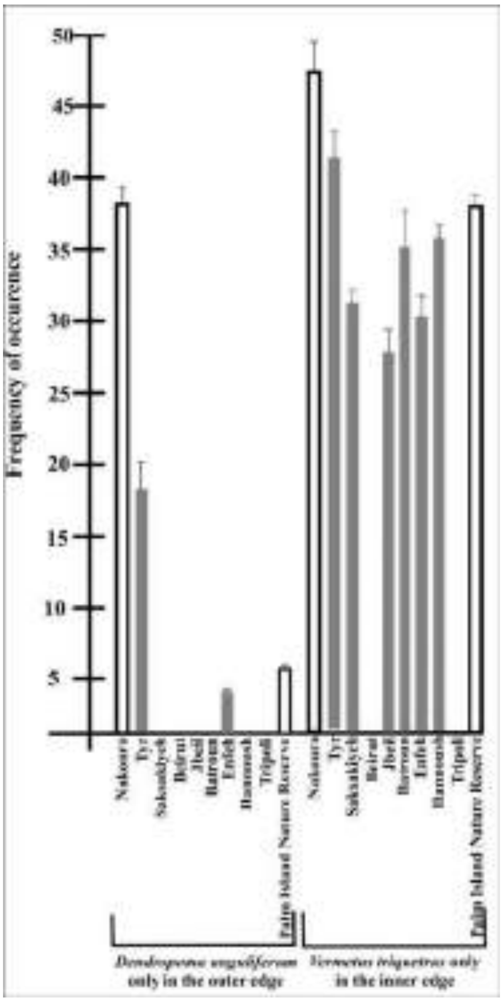


Fig. 2: Mean percent frequency of occurrence, ± standard error (S.E.), of *Dendropoma anguliferum* and *Vermetus triquetrus* in the ten reefs studied. White: not impacted; grey: moderately impacted; black: impacted.

Discussions and conclusions

This study confirmed that living individuals of the main reef builder species *Dendropoma anguliferum* and *Vermetus triquetrus* are still present along the Lebanese coast. This finding is important considering that *D. anguliferum* is an endemic species of the Levantine Sea, whose local extinction seems to be presently underway (Badreddine *et al.*, 2019 and references therein). Living individuals of *D. anguliferum* were observed mainly in the non-impacted sites (Nakoura and Palm Island Nature Reserve), and with low densities in some moderately impacted sites (Tyre and Enfeh). *V. triquetrus* has been recorded in both non impacted and moderately impacted reefs. *V. triquetrus* has specific resistance to human pressures, and its dispersal potential is high (Badreddine *et al.*, 2019 and references therein). No living individuals of *D. anguliferum* have been recorded in the last years along the Levantine coast, except on the Lebanese coast where a low density of living *D. anguliferum* was recorded in 2002 and 2017 (Badreddine *et al.*, 2019 and references therein). However, the high densities of dead shells of *D. anguliferum* in the non-impacted and moderately impacted sites confirm that its population along the Lebanese coast confronts a regional loss. The low abundance of dead shells in the high impacted site of Beirut and Tripoli could be the sign of an older loss of *D. anguliferum* followed by the erosion of the shells.

Vermetid reefs along the Lebanese coast are subjected to many pressures. Artificialization concerns more than 32% of the Lebanese coastline (Badreddine *et al.*, 2018). Trampling by the public, especially fishers, and especially in summer, may affect settlement and survival of vermetid recruits. Pollution from the asbestos mines or factories producing phosphate fertilizers, and illegal sewage (urban, industrial and agricultural) discharges affect the whole biota of the vermetid reefs. Fishers who collect worms, crabs, shrimps, mollusks, and even some macroalgae associated with the vermetid reefs, and use them as bait for fishing. Marine litter and accidental oil spills affect the longevity of some species associated with the vermetid reefs. Other major pressures include the seawater warming, the continuous income of invasive species (especially the mussel *Brachidontes pharaonis*) from the Suez Canal, the proliferation of some toxic algae, and acidification, which may cause the dissolution of vermetid shell (Milazzo *et al.,* 2017 and references therein).

The implementation of restoration actions of *D. anguliferum* is complex because of the characteristics of the species. The living individuals of *D. anguliferum* observed in Nakoura and Palm Island Nature Reserve, and the low density in Tyre and Enfeh, should be regularly monitored (using non-destructive methods). From a regional point of view, it is highly recommended to update the information on the *D. anguliferum* population along the Levantine coast, to investigate their ecology and to guarantee their protection and conservation.

Acknowledgements

This study has been performed with the help, support, and fund of the Special Protected Areas Regional Activity Centre (SPA/RAC) under the framework of the IMAP/MPA project financed by the European Union.

Bibliography

ALBANO P.G., STEGER J., BOŠNJAK M., DUNNE B., GUIFARRO Z., TURAPOVA E., HUA Q., K. DARRELL S., R. GIL, ZUSCHIN M. (2021) - Native biodiversity collapse in the Eastern Mediterranean. *Proceedings of the Royal Society B*, 288 (1942): 20202469.

BADREDDINE A. (2018) - Les écosystèmes côtiers du littoral libanais: état écologique, évolution, conservation. Doctoral thesis, Univ. Nice Sophia Antipolis: 218 p.

BADREDDINE A., ABBOUD-ABI SAAB A., GIANNI F., BALLESTEROS E. (2018) - First assessment of the Ecological Status in the Levant Basin: application of the CARLIT index along the Lebanese coastline. *Ecological Indicators,* 85 (2018): 37-47.

BADREDDINE A., MILAZZO M., ABBOUD-ABI SAAB M., BITAR G., MANGIALAJO L. (2019) - Threatened biogenic formations of the Mediterranean: Current status and assessment of the vermetid reefs along the Lebanese coastline (Levant basin). *Ocean Coastal Management,* 169: 137-146.

BOUDOURESQUE, C.F., MEINESZ, A., BALLESTEROS, E., BEN MAIZ, N., BOISSET, F., CINELLI, F., CIRIK, S., CORMACI, M., JEUDY DE GRISSAC, A., LABOREL, J., LANFRANCO, E., LUNDBERG, B., MAYHOUB, H., PANAYOTIDIS, P., SEMROUD, R., SINNASAMY, J.M., SPAN, A. (1990) - Livre Rouge ‘‘Gérard Vuignier’’ des végétaux, peuplements et paysages marins menacés de Méditerranée. MAP Technical Report Series 43. UNEP/IUCN/GIS Posidonie, Athens, 245 pp. *in* UNEP/IUCN/GIS Posidonie. 1990. Livre rouge „Gérard Vuignier‟ des végétaux, peuplements et paysages marins menacés de Méditerranée. *MAP Techn. Rep. Ser.,*No. 43. UNEP, Athens, 250pp

DI FRANCO A., GRAZIANO M., FRANZITTA G., FELLINE S., CHEMELLO R., MILAZZO M. (2011) - Do small marinas drive habitat specific impacts? A case study from Mediterranean Sea. *Marine Pollution Bulletin*, 62: 926–933.

GORDÓ-VILASECA C., TEMPLADO J., COLL M. (2021) - The need for protection of Mediterranean vermetid reefs. The Encyclopedia of Conservation, 1-7. https://doi.org/10.1016/B978-0-12-821139-7.00102-1

GUBBAY S., SANDERS N., HAYNES T., JANSSEN J.A.M., RODWELL J.R., NIETO A., GARCÍA CRIADO M., BEAL S., BORG J., KENNEDY M., MICU D., OTERO M., SAUNDERS G., CALIX M. (2016) - European red list of habitats. Part 1: Marine habitats. European Union.

MILAZZO M., RODOLFO-METALPA R., SAN CHAN V.B., FINE M., ALESSI C., THIYAGARAJAN V., HALL-SPENCER J.M., CHEMELLO R. (2014) - Ocean acidification impairs vermetid reef recruitment. *Scientific Reports*, 4 (1): 1-7.

MILAZZO M., FINE M., LA MARCA E.C., ALESSI C., CHEMELLO R. (2017) - Drawing the line at neglected marine ecosystems: ecology of vermetid reefs in a changing ocean. In: Marine animal forests: the ecology of benthic biodiversity hotspots (Rossi S., Bramanti L., Gori A., Orejas C., Eds.). Springer International Publishing, Cham, Switzerland: 345-367.

RILOV G. (2016). Multi-species collapses at the warm edge of a warming sea. *Scientific Reports*, 6: 36897 | DOI: 10.1038/srep36897.

RILOV G., MAZARIS A.D., STELZENMÜLLER V., HELMUTH B., WAHL M., GUY-HAIM T., MIESZKOWSKA N., LEDOUX J.-B., KATSANEVAKIS S. (2019). Adaptive marine conservation planning in the face of climate change: what can we learn from physiological, ecological and genetic studies? *Global Ecology and Conservation*, 17: e00566.

RILOV G., FRASCHETTI S., GISSI E., PIPITONE C., BADALAMENTI F., TAMBURELLO L., MENINI E., GORIUP P., MAZARIS A.D., GARRABOU J. (2020a) - A fast-moving target: achieving marine conservation goals under shifting climate and policies. *Ecological Applications*, 30: e02009.

RILOV G., PELEG O., GUY-HAIM T., YERUHAM E. (2020b) - Community dynamics and ecological shifts on Mediterranean vermetid reefs. *Marine Environmental Research*, 105045.

TERRADAS-FERNANDEZ M., ZUBCOFF J., RAMOS-ESPLA A.A. (2019). Early succession patterns in a Mediterranean vermetid reef. *Journal of Sea Research*, 152: 101-768.

Marina BIEL-CABANELAS, MONASTRELL M., SANTÍN A., SALAZAR J., BAENA P., VILADRICH N., GORI A., MONTSENY M., CORBERA G., AMBROSO S., GRINYÓ, J.
Institut de Ciències Del Mar (ICM-CSIC), Barcelona, Spain
E-mail: marinabiel@icm.csic.es

CAN AN EMBLEMATIC SPECIES BECOME A PEST? THE CASE OF *ASTROSPARTUS MEDITERRANEUS* (RISSO, 1826) (ECHINODERMATA: OPHIUROIDEA) IN THE ARTISANAL FISHING GROUNDS OF THE CAP DE CREUS AREA (NW MEDITERRANEAN SEA)

Abstract
Astrospartus mediterraneus (Risso, 1826) (Echinodermata: Ophiuroidea) is an emblematic Mediterranean species yet, it has few reports and hasn't received much attention from the marine scientific community to date. In the framework of a project to assess how to mitigate the impact of artisanal fishing on benthic communities at the Site of Community Importance (SCI) of Cap de Creus (NW Mediterranean) (MITICAP Project), an unusually high abundance of the basket star (A. mediterraneus) was observed in 2018 as part of the by-catch of the local artisanal fishers. Indeed, the fishers involved in the project reported that this species had increased in abundance and expanded its distribution over the past years, ultimately interfering with their fishing activity. This work benefits from the Local Ecological Knowledge of the fishers, analyses field surveys and aims to elucidate the abundance, distribution, size, and structure of A. mediterraneus populations; as well as to examine the possible impact this species has on the artisanal fisheries performance. Data collection was performed through by-catch photo analysis of regular fishing events from May to August, analysis of video-transects recorded by means of Remote Operated Vehicles and conducting interviews with fishers to identify the impact. Basket stars were associated with rocky substrates with presence of gorgonians located between 50 to 80 m depth, preferentially occurring on sloping areas. Despite their high abundances (0.45±0.71 ind/m^2), the aggregations witnessed in the Cap de Creus area could not be determined as an outbreak due to the lack of longtime monitoring data thus, yet it seems apparent based on the LEK of the fishers that the species has been on the rise for the past years and they unanimously consider that its proliferation causes them a handicap in terms of monetary and time losses.

Key-words: Ophiuroid blooms, artisanal fishing, Local Ecological Knowledge, ROV, Mediterranean Sea

Introduction
The basket star *Astrospartus mediterraneus* (Risso, 1826) is the sole representative of the Gorgonocephalidae family in the Mediterranean Sea (Ocaña & Pérez-Ruzafa, 2004), where it is considered as a rare and emblematic species (Fitori *et al.*, 2022; Mallol, 2010; Zibrowius, 1978) in need of conservation and protection (Cocito *et al.*, 2015; Fitori *et al.*, 2022). Yet with almost no information regarding its biology or ecology (Zibrowius, 1978). In 2018, within the frame of the MITICAP Project which aimed to reduce the impacts derived from artisanal fishing in the Cap de Creus Natural Park and SCI, fishers from the guilds of Port de la Selva and Cadaqués (Alt Empordà, Catalonia)

stated that over the past 5 years they noticed a substantial increase in *A. mediterraneus* abundances. Indeed, after assessing the fishing by-catch generated by different gears it was evident that *A. mediterraneus* represented a large proportion of captured organisms (Santin *et al.*, 2022). This situation started to be perceived by fishers from both guilds as a problem. In this context, this research aims to gain insight on these topics and determine their relation and affectation to artisanal fisher's performance.

Materials and methods

This study was conducted on the fishing grounds shared by both collaborating guilds which are mostly located in the north side of the Cap de Creus (CdC) area (42º19'12" N, 03º19'34" E) located in the north-western region of the Mediterranean Sea (Fig 1.).

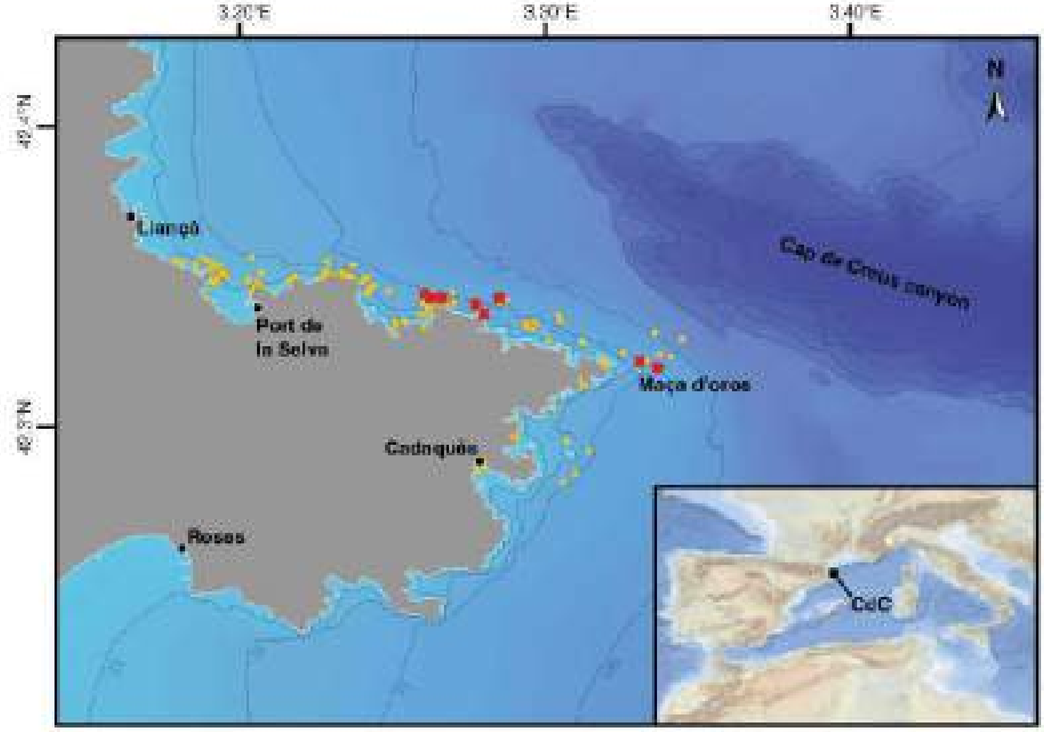


Fig. 1 : Cap de Creus marine area. The yellow circles indicate the survey stations with presence of *A. mediterraneus.* Red squares Indicates where videotransects took place

Members of the research team joined the artisanal fishers' fleet from Port de la Selva and Cadaqués guilds (Alt Empordà, Catalonia, Spain) during regular fishing journeys. The fishing events took place coinciding with the spiny lobster (*Palinurus elephas* J. C. Fabricius, 1787*)* and scorpion fish (*Scorpaena scrofa* (Linnaeus, 1758)) fishing season. For each fishing event data about sea conditions, type of gear used, setting and collection time of fishing gear data, gear depth, and coordinates were gathered (Montseny *et al.*, 2019). *Astrospartus mediterraneus* caught in trammel nets were untangled and photographed with a graduated grid in centimetric units for scale. To characterize the artisanal fishing grounds in the Cap de Creus area, a total of 19 video transects were recorded onboard the vessel 'Atlantic Explorer' using a Perseo ROV. For every individual of *A. mediterraneus* observed during the transect, the following information was compiled: elapsed time since the beginning of the video, universal time coordinates, depth, associated substrate type (including epiphyted organisms, if any), and the geographical coordinates. Moreover, each sampling unit’s substrate type and slope were also registered, following the categories in Santín *et al.* (2018). To accurately estimate the impact of the basket star' possible outbreak, fishers completed a survey about this issue. In order to be eligible to take the survey, the selection criteria were: (i) being an active artisanal fisher and (ii) working on the Catalan coast.

Results

The average disc diameter size was 2.67 ± 0.97 cm, ranging between 0.19 – 6.67 cm. Most aggregations from cluster analyses showed 60% of individuals with a size-frequency between 2 and 3 cm, followed by classes of 1 to 2 cm (20–30%) and 3 to 4 cm (10%). Statistical analysis showed populations with a dominance of small to medium size classes (1 to 5 cm) and a prevalence of 2–3 cm individuals. Results show a species’ prevalence in the northern and eastern parts of the Cap de Creus area. However, largest densities are found at the northwest flank of the study area where the species showed its densest aggregations (Fig.2b). Even so, the greatest abundances (over 150 individuals) occurred in just a few points, spread along the entire sampled area (Fig.2a).

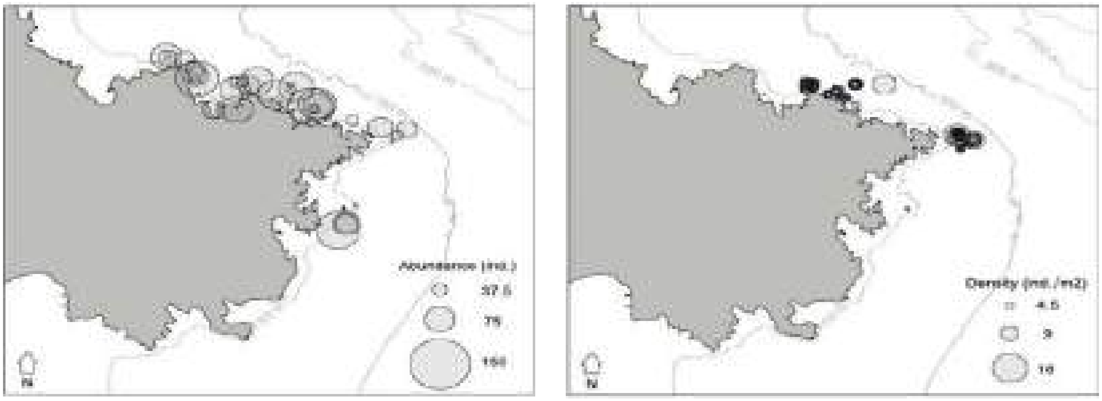


Fig. 2: Geographic distribution of A. mediterraneus in the study area, based on by-catch (abundance (a) and videotransect (density) (b) data.

Both data from video analyses and fishing events showed a similar bathymetrical distribution for the species, with an overall distribution between 35 — 85 m, but with a high incidence of *A. mediterraneus* restricted between 50 and 80 m depth. In this regard, there is a clear density increase for *A. mediterraneus* in the continental shelf below 50 m depth. Regarding the relationship between species' density and the presence of ecosystem engineers, there was an evident preference of the basket star for gorgonian forests. *A. mediterraneus* was also associated with sloping areas, showing a prevalence for this type of habitat.

Regarding the survey’s analysis, 26 fishers answered the questionnaire, from 9 different fishers’ guilds located on the Catalan coast. The answers were stated as follows: 69.2% of surveyed fishers believe that there is an abundance increase of basket star individuals on the Catalan coast. Among them, 42.1% answered that between 40 and over 50 baskets stars get entangled daily in their fishing gear and 47.6% devoted 1-3 hours to clean the fishing gear from the species. Yet all of them agreed that it constitutes an obstacle to their job performance. About the economic cost of this bycatch on their fishing gear, they estimate a monetary loss of 30-100€ per week in bycatch cleaning and fixing damaged gears provoked by this species, but all of them coincide in the difficultness to assess a specific quantity.

Discussion

According to the data obtained, *Astrospartus mediterraneus* abundance and density higher values do occur in the studied area and present a high relation with deep rocky substrates with presence of gorgonian assemblages, preferentially occurring on slopping areas. Results show, as the fishers had suspected, the presence of unusual *A. mediterraneus'* aggregations in the area appears to be proven, with up to 150 individuals caught in a single fishing event, and density values far above those of other Mediterranean areas (Terribile *et al.*, 2016). Nevertheless, although the mean number of individuals in the video transects was 0.45±0.71 ind/m^2, basket stars' density values were not homogeneous with the Cap de Creus area, with dense aggregations (1.07 ± 2.51 ind/m^2) occurring within a well-defined bathymetric range, between 55 to 80 m depth. The highest densities mainly occurred on sloping rocky outcrops, where they frequently occurred atop gorgonians. The average disc diameter (2.67 ± 0.34 cm) might suggest that present-day aggregations in the study area have appeared quite recently, pointing towards a recent outburst mainly formed by relatively young individuals. A plausible cause for the spectacular population outbreaks registered for these species could be linked to an increment both in quantity and quality of their food source due to water eutrophication (Duineveld *et al.*, 1987; Josefson *et al.*, 1993), increased water temperatures derived from climate change (Billett *et al.*, 2001; Wigham *et al.*, 2003), or lack of predators in the area (Cheser, 1969; Duineveld *et al.*, 1987). Nevertheless, while several factors or combination of factors could explain the recorded outburst of *A. mediterraneus* in the studied area, the lack of long-term data and the scarcity of information regarding the ecology of the studied species only allow for speculative hypothesis on the matter, with the exact causes that have triggered the population outburst remaining unknown. As a result of the surveys conducted, it is clear that basket stars are perceived negatively by the fisher's communities as their increase in abundance is associated with an economic loss for artisanal fishers and constitutes an obstacle to their job performance. A possible solution for the fishers affected by this problem in the area would be to modify their fishing habits in order to avoid, or at least reduce, the basket star bycatch incidence on their fishing gear. Nevertheless, this might not be a solution for artisanal fishers in the area, as their main targeted species (spiny lobster and scorpion fish) are strongly associated with mid-deep rocky outcrops (Díaz *et al.*, 2001), as it is the case of *A. mediterraneus*, which points towards a problem without a near solution.

Conclusions

The ecological traits and habitat preference for the Cap de Creus *Astrospartus mediterraneus* aggregations have been stipulated. Basket stars have a habitat preference for sloping rocky substrates with the presence of gorgonians in a depth range between 50 to 80 m depth, preferentially occurring on slopping areas. Cap de Creus' aggregations could not be determined as an outbreak because of the lack of long time-sensitive data. Nevertheless, comparing the central disc size among other Mediterranean regions, they are considered aggregations of young individuals. On the socio-economic impact and concerning fishers' perception on this topic, there is unanimity about the existence of a problem on this issue. They consider that the basket star's increase causes them a handicap in terms of monetary and time losses. Despite the new ecological insights provided by this study, there is still a massive gap in knowledge regarding the biology of *A. mediterraneus*. To properly assess this issue, additional biological studies are further needed as they will be of paramount importance to improve our knowledge and better understand the outbreak origin of *A. mediterraneus* in the Cap de Creus marine area.

Acknowledgments

The authors would like to thank the crew of the R/V “Atlantic Explorer”, the artisanal fishermen from Port de la Selva and Cadaqués and the Cap de Creus Natural Park for their aid. Their work was performed under the MitiCap and ResCap projects, which are founded by the Fundación Biodiversidad from the Ministerio para la Transición Ecológica, through the Pleamar Program, co-funded by the European Maritime and Fisheries Fund.

Bibliography

BILLETT D. S. M., BETT B. J., RICE A. L., THURSTON M. H., GALÉRON J., SIBUET M., WOLFF G. A. (2001) - Long-term change in the megabenthos of the Porcupine Abyssal Plain (NE Atlantic). In *Progress in Oceanography (50)* 324-348.

CHESER R. H. (1969) - Destruction of pacific corals by the sea star *Acanthaster planci*. *Science*, *165*: 280–283.

COCITO S., DELBONO I., BARSANTI M., DI NALLO G., LOMBARDI C., PEIRANO A. (2015) - Underwater itineraries at Egadi Islands: Marine biodiversity protection through actions for sustainable tourism. *Energia, Ambiente e Innovazione*, 69–75.

DÍAZ D., MARÍ M., ABELLÓ P., DEMESTRE M. (2001) - Settlement and juvenile habitat of the European spiny lobster Palinurus elephas (Crustacea: Decapoda: Palinuridae) in the western Mediterranean Sea. *Scientia Marina*, *65*(4): 347–356.

DUINEVELD G. C. A., KONITZER A., HEYMAN R. P. (1987) - *Amphiura filiformis* (Ophiuroidea: Echinodermata) in the North Sea. Distribution, present and former abundance and size composition. *Netherlands Journal of Sea Research*, *21*(4): 317–329.

FITORI A., FITURI A. EL BADREDDINE A., AGUILAR R. (2022) - First Record of the Basket Star Astrospartus Mediterraneus (Risso, 1826) (Echinodermata: Ophiuroidea) in the Libyan Waters. *International Journal of Agriculture & Environmental Science*, *9*(1): 49–50.

JOSEFSON A. B., JENSEN J. N., ERTEBJERG G. (1993) - The benthos community structure anomaly in the late 1970s and early 1980s-a result of a major food pulse? In *Mar. Biol. EC&* (Vol. 172).

MALLOL S. (2010) - La col·lecció zoològica Joan Ortensi de Roses: procés de revisió i recuperació. *Annals de l’Institut d’Estudis Empordanesos*, *41*: 183–212.

MONTSENY M., LINARES C., VILADRICH N., OLARIAGA A., CARRERAS M., PALOMERAS N., GRACIAS N., ISTENIČ K., GARCIA R., AMBROSO S., SANTÍN A., GRINYÓ J., GILI J. M., GORI A. (2019) - First attempts towards the restoration of gorgonian populations on the Mediterranean continental shelf. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *29*(8): 1278–1284.

OCAÑA A., PÉREZ-RUZAFA A. (2004) - Andalusian coast echinoderms. *Acta Granatense*, *3*: 83–136.

SANTIN A., GRINYÓ J., AMBROSO S., BAENA P., BIEL-CABANELAS M., CORBERA G., SALAZAR J., MONTSENY M., GILI J.-M. (2022) - Fishermen and scientists: synergies for the exploration, conservation and sustainability of the marine environment. In M. V. Martínez de Albéniz (Ed.), *The ocean we want: inclusive and transformative ocean science* (pp. 77–79). Institut de Ciències del Mar, CSIC.

SANTÍN A., GRINYÓ J., AMBROSO S., URIZ M. J., GORI A., DOMINGUEZ-CARRIÓ C., GILI J. M. (2018) - Sponge assemblages on the deep Mediterranean continental shelf and slope (Menorca Channel, Western Mediterranean Sea). *Deep Sea Research Part I: Oceanographic Research Papers*, 131: 75–86.

TERRIBILE K., EVANS J., KNITTWEIS L., SCHEMBRI P. J. (2016) - Maximizing MEDITS: Using data collected from trawl surveys to characterize the benthic and demersal assemblages of the circalittoral and deeper waters around the Maltese Islands (Central Mediterranean). *Regional Studies in Marine Science*, 3: 163–175.

WIGHAM B. D., TYLER P. A., BILLETT D. S. M. (2003) - Reproductive biology of the abyssal holothurian *Amperima rosea*: An opportunistic response to variable flux of surface derived organic matter? *Journal of the Marine Biological Association of the United Kingdom*, *83*(1): 175–188.

ZIBROWIUS H. (1978) - Nouvelles observations de l'ophiure gorgonocéphale *Astrospartus mediterraneus* sur la cote méditerraneéenne de France. Bibliographie annotée et répartition. *Station Marine D'Endourne*, Marseille (4) 157 -169.

Edoardo CASOLI, VENTURA D., MANCINI G., MAZZA M., BELLUSCIO A., ARDIZZONE G.
Department of Environmental Biology, Sapienza University of Rome, 00185 Rome, Italy.
E-mail: edoardo.casoli@uniroma1.it

IMPACT, REMEDIATION, AND DYNAMICS OF CORALLIGENOUS REEFS AFTER CONCORDIA SHIP WRECKAGE

Abstract:
We present results from the 10-years monitoring (from 2012 to 2021) of the structure of coralligenous assemblages assessed through FULL-HD recorded videos from 45 up to 70 m depth, following the Concordia shipwreck. After the baseline surveys aimed at defining the natural assemblages (2012), coralligenous reefs were heavily impacted during the shipwreck removal activities (2013-2014). From 2015 to 2018, the seabed was cleaned from fine sediment and heavy debris that represented the major pressures affecting the reefs, and the re-colonization of bare surfaces started. Currently , the reefs' recovery is still far from being achieved; several opportunistic taxa dominate the initial stages of assemblages' development that differ from those of 2012. The application of the COARSE index reveals a slight increase in the reefs' ecological quality compared to the assessment carried out in 2014.

Key-words: recovery, resilience, impact assessment, ecological quality, opportunistic taxa

Introduction

The synergic pressure of Global Change and human activities is rapidly undermining the structure and functioning of rocky reef communities in the Mediterranean Sea, leading to fast and unpredictable degradation trends. The multitude of human activities taking place all over the Mediterranean basin produce impacts on almost all of its surface (Gerovasileiou *et al*., 2019). The increasing concern for coralligenous reefs is due to the loss of long-living ecosystem engineers (e.g., encrusting red algae and erect invertebrates). Such process leads to community oversimplification, promotes non-indigenous species spread, and drastically alters the functioning of the bioconstruction (Bevilacqua et al., 2021). In the past twenty years, the effects of anthropogenic disturbances on coralligenous reefs have been extensively investigated through field surveys and experiments, especially in the Tyrrhenian Sea, allowing the development of several ecological indices (Deter et al., 2012; Gatti et al., 2015; Piazzi et al., 2021). If this significantly increased the identification of sensitive taxa and impacted assemblages, only a few studies have investigated the dynamics of impacted reefs so far. Understanding the mechanisms capable of driving the re-colonization dynamics of impacted coralligenous reefs is pivotal in defining regime shifts and quantifying recovery potential.
The Concordia cruise ship sank a few hundred meters northern from Giglio Porto on the 13th of January 2012. The wreck removal operation started a few months after the disaster and ended in July 2014, when the wreck was refloated and then towed to Genoa harbour. Fine sediment dispersion, debris release, and installation of man-made structures affected the integrity and the ecological status of the coralligenous reefs within the wreckage area (Casoli *et al*., 2017). After the wreck removal, the seafloor was accurately cleaned (2015 – 2018) from all the abovementioned disturbances: as a consequence, dead portions of

coralligenous reefs were revealed, representing unique substrates to study the natural re-colonization processes on impacted bioconstruction. The present study aimed to *i*) describe the 10-year dynamics of coralligenous reefs impacted by Concordia wreck, *ii*) identify the taxa leading the re-colonization process, and *iii*) quantify the ecological status and the recovery of the bioconstructions.

Materials and methods

Field activities were carried out along the east coast of Giglio Island (central Tyrrhenian Sea, Italy), in the area interested by the Concordia ship wreckage and its subsequent removal activities. The seafloor at this location is characterized by two monzogranite rocky ridges (identified as the S and N ridges), where the shipwreck laid, developing from a few meters up to 80 m depth, separated from each other and surrounded by sandy sediments. Closed Circuit Breathing Apparatus (CCUBA) divers carried out HD video acquisition in the summer of 2012, 2013, 2014, 2018, 2019, 2020, and 2021, covering the same route every year (Fig. 1), swimming and filming at a distance of 1 m above the substratum. We identified four stations (between 45 and 70 m depth) per rocky ridge and in the proximity of each station we extracted 12 HD pictures from videos for qualitative and quantitative analyses of the coralligenous assemblages.

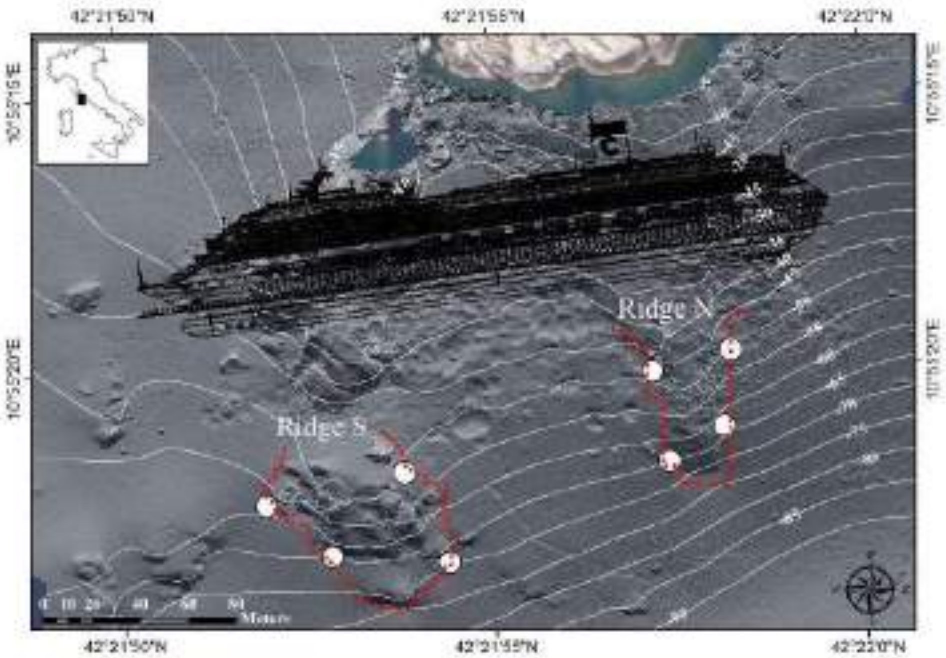


Fig. 1: Map of the study area showing seafloor topography (MBES acquired in 2015), the position of the wreck, routes where videos were acquired (red dotted lines), and location of the sampling stations (white dots).

The presence/absence of taxa, identified at the lowest possible taxonomic level, was recorded in each picture; the presence of debris, sediments, and bare surfaces affecting the coralligenous reefs was also registered. The structure of benthic assemblages at the different stations was assessed by measuring the frequency of occurrence of each taxon. The differences in the structure of coralligenous assemblages according to years were visualized through a Principal Component Analysis (PCA). For a visual representation, we aggregated the information at the taxonomical group level. An Analysis of Similarities (ANOSIM) was carried out on a Bray-Curtis similarity matrix calculated on the frequency of occurrence data to test differences in assemblages' structure according to years. Then, we calculated the mean number of species (α diversity) and the mean distance of all stations from centroids calculated in the PERMDISP analysis (β diversity), and the value of the COARSE index, according to the modification proposed by Casoli *et al*. (2017). The variation of the three descriptors according to time was tested using Multivariate permutational analyses of variance (PERMANOVA).

Results

A total of 69 taxa (14 algae, 55 invertebrates) were recognized through image analysis. The differences in the structure of coralligenous assemblages were evident on the factorial plane of the PCA (32.80% of the total variance explained), where four groups were evident, constituted respectively by 2012 samples, 2013-2014 samples, 2018 samples, and 2019-2020-2021 samples (Fig. 2). The ANOSIM revealed significant differences in the composition of the coralligenous assemblages among years (R = 0.400; $p < 0.01$).

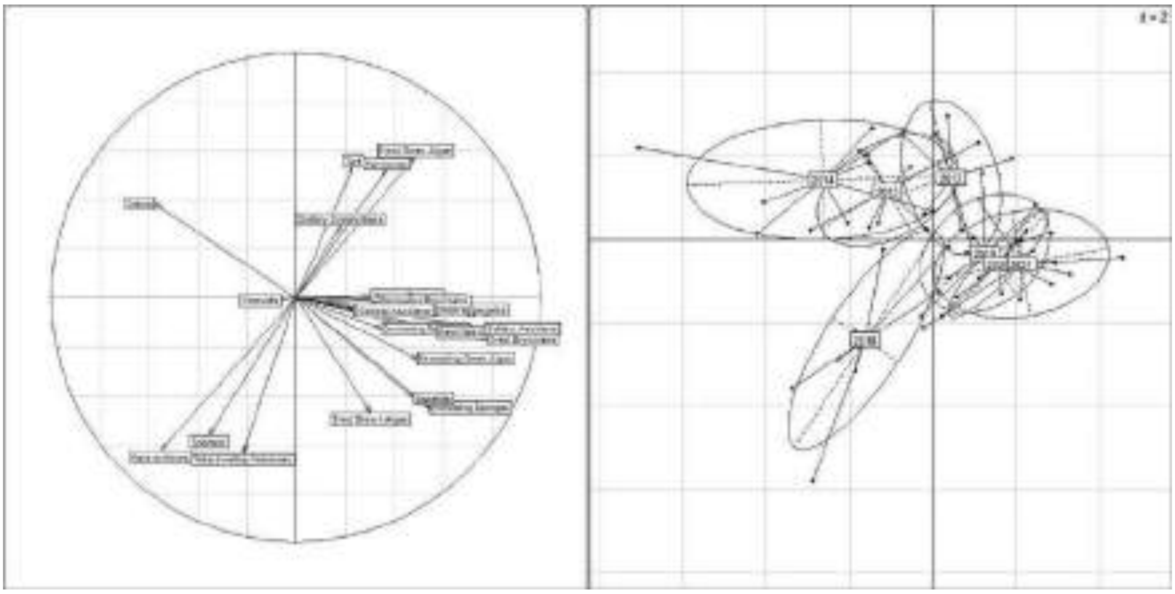


Fig. 2: Results of the PCA performed on the structure of coralligenous assemblages. The left panel shows the taxonomical groups defining the multifactorial plane; in the right panel, the sample distribution grouped according to the explanatory variable "year" with 95% confidence ellipses on the group means.

We observed a shift from assemblages dominated by encrusting red algae, fan corals, and erect green algae in 2012, to impacted reefs with sediment, debris, and bare surfaces in 2013, 2014, until the end of seafloor cleaning in 2018. The succession on impacted reefs was led by the spread of species that rapidly re-colonized the bare surface: *Reteporella grimaldii* (Jullien, 1903), *Carpomitra costata* (Stackhouse) Batters, 1902, *Arthrocladia villosa* (Hudson) Duby, 1830, *Antho (Antho) inconstans* (Topsent, 1925), and *Halocynthia papillosa* (Linnaeus, 1767).

The α diversity and COARSE index showed a similar pattern with significant differences among years (Fig. 3; $p < 0.05$): the two descriptors decreased during the wreck removal, if compared to the baseline survey (2012), and increased since 2018, after the seafloor cleaning operations. In the last three sampling events, the mean number of species was higher than the pre-disturbance condition in 2012. The β diversity showed an inverse trend, with higher values measured in 2014. However, differences among years were not significant.

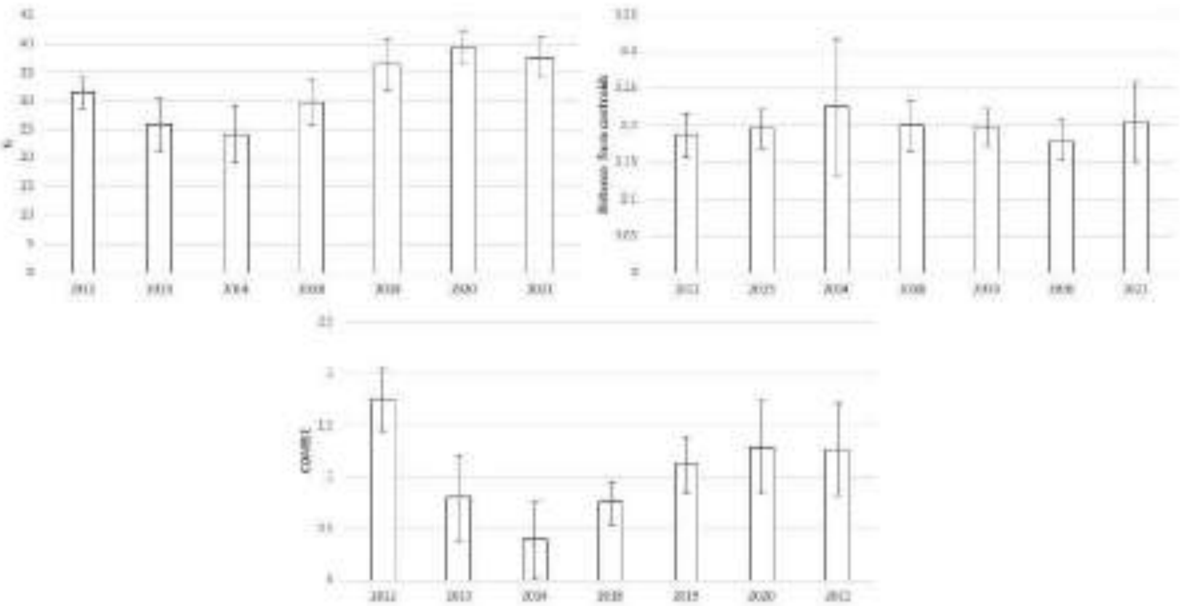


Fig. 3: Trends of the three descriptors used to assess the ecological status of the coralligenous reefs: Number of species (α diversity), distance from centroids (β diversity), and COARSE index.

Discussion and conclusions

The results of the present study highlight a significant shift in the structure of coralligenous assemblages toward a different stable state dominated by opportunistic taxa. This pattern reflects the conceptual framework proposed for the Mediterranean rocky reefs by Bevilacqua *et al*. (2021). Even if all the disturbances have been removed through the active remediation interventions, the recovery of the assemblages is far from being achieved, and returning to the original state will likely require a long time. This is particularly evident for habitat-forming organisms, such as fan corals, which show low recovery potential that could need more than a decade in the current scenario of Climate Change (Gómez-Gras *et al.*, 2021).

The re-colonization process was rapid but not complete because bare surfaces still characterize some of the investigated reefs; the increase of α diversity and COARSE index in the last four years was mostly due to the colonization of opportunistic taxa. The larval dispersion, substrate selection, ability to colonize bare bottoms, absence of competition, fast dynamics and growth rate might play a pivotal role in favoring the spread of these taxa (Casoli *et al.*, 2020; 2021). The identification of taxa driving the re-colonization process is of special interest to assessing the loss of ecological functions and understanding future trajectories of change of coralligenous reefs. Furthermore, the provided results confirm the low recovery potential of one of the most valuable

Mediterranean coastal ecosystems, highlighting the urgent need to reduce human pressures and increase restoration efforts.

Bibliography

BEVILACQUA S., AIROLDI L., BALLESTEROS E., BENEDETTI-CECCHI L., BOERO F., BULLERI F., CEBRIAN E., CERRANO C., CLAUDET J., COLLOCA F., COPPARI M., DI FRANCO A., FRASCHETTI S., GARRABOU J., GUARNIERI G., GUERRANTI C., GUIDETTI P., HALPERN B.S., KATSANEVAKIS S., MANGANO M.C., MICHELI F., MILAZZO M., PUSCEDDU A., RENZI M., RILOV G., SARÀ G., TERLIZZI A. (2021) - Mediterranean rocky reefs in the Anthropocene: Present status and future concerns. *Advances in Marine Biology*, 89: 1-51.

CASOLI E., VENTURA D., CUTRONEO L., CAPELLO M., JONA-LASINIO G., RINALDI R., CRISCOLI A., BELLUSCIO A., ARDIZZONE G.D. (2017) - Assessment of the impact of salvaging the Costa Concordia wreck on the deep coralligenous habitats. *Ecological Indicators*, 80: 124-134.

CASOLI E., MANCINI G., VENTURA D., PACE D.S., BELLUSCIO A., ARDIZZONE G.D. (2020) - *Reteporella* spp. success in the re-colonization of bare coralligenous reefs impacted by Costa Concordia shipwreck: The pioneer species you did not expect. *Marine Pollution Bulletin*, 161: 111808.

CASOLI E., VENTURA D., MANCINI G., PACE D.S., BELLUSCIO A., ARDIZZONE G.D. (2021) - High spatial resolution photo mosaicking for the monitoring of coralligenous reefs. *Coral Reefs*, 40(4): 1267-1280.

DETER J., DESCAMP P., BALLESTA L., BOISSERY P., HOLON F. (2012) - A preliminary study toward an index based on coralligenous assemblages for the ecological status assessment of Mediterranean French coastal waters. *Ecological indicators*, 20: 345-352.

GATTI G., BIANCHI C.N., MORRI C., MONTEFALCONE M., SARTORETTO S. (2015) - Coralligenous reefs state along anthropized coasts: Application and validation of the COARSE index, based on a rapid visual assessment (RVA) approach. *Ecological Indicators*, 52: 567-576.

GEROVASILEIOU V., SMITH C.J., SEVASTOU K., PAPADOPOULOU N., DAILIANIS T., BEKKBY T., FIORENTINO D., MCOWEN C.J., AMARO T., TUNKA BENGIL E.G., BILAN M., BOSTRÖM C., CARREIRO-SILVA M., CEBRIAN E., CERRANO C., DANOVARO R., FRASCHETTI S., GAGNON K., GAMBI G., GREHAN A., HEREU B., KIPSON S., KOTTA J., LINARES C., MORATO T., OJAVEER H., ORAV-KOTTA H., SARA A., SCRIMGEOUR R. (2019) - Habitat mapping in the European Seas-is it fit for purpose in the marine restoration agenda?. *Marine Policy*, 106: 103521.

GÓMEZ-GRAS D., LINARES C., LÓPEZ-SANZ A., AMATE R., LEDOUX J.B., BENSOUSSAN N., DRAP P.,. BIANCHIMANI O., MARSCHAL C., TORRENTS O., ZUBERER F., CEBRIAN E., TEIXIDÓ N., ZABALA M., KIPSON S., KERSTING D.K., MONTERO-SERRA I., PAGÈS-ESCOLÀ M., MEDRANO A., FRLETA-VALIĆ M., DIMARCHOPOULOU D., LÓPEZ-SENDINO P., GARRABOU J. (2021)- Population collapse of habitat-forming species in the Mediterranean: a long-term study of gorgonian populations affected by recurrent marine heatwaves. *Proceedings of the Royal Society B*, 288(1965): 20212384.

PIAZZI L., GENNARO P., CECCHI E., BIANCHI C.N., CINTI M.F., GATTI G., GUALA I., MORRI C., SARTORETTO F., SERENA F., MONTEFALCONE M. (2021) - Ecological status of coralligenous assemblages: Ten years of application of the ESCA index from local to wide scale validation. *Ecological Indicators*, 121: 107077.

Julie DETER, BALLESTA L., MASSEY J.-L., GUILBERT A., HOLON F., DELARUELLE G., BLANDIN A., MARRE G., RAUBY T., MOUILLOT D., VELEZ L., DEJEAN T., DI IORIO L., HOCDE R., FURFARO G., JORRY S., BOUCHETTE F., FERRIER-PAGES C., CHARRIERE A., IZART A., FERRANDINI M., PLUQUET F., PERGENT G., PERGENT-MARTINI C., LUONGO G., DANOVARO G., BOISSERY P., CANCEMI M.
Andromède océanologie, 34130 Mauguio (France)/ Université de Montpellier-UMR MARBEC
E-mail: julie.deter@andromede-ocean.com

STATE OF KNOWLEDGE ON THE DEEP CORALLIGENOUS RINGS OF CAPE CORSICA FOLLOWING THE SCIENTIFIC EXPEDITION GOMBESSA 6 (2021)

Abstract
Described in 2012, «coralligenous atolls» are rings (diameter = 25 m) composed of a coralligenous central core and a crown made of rhodoliths. Thousands exist in a unique place: a 4-km² area at 115 m depth in the Natural Marine Park of Cape Corse and Agriate (French Mediterranean) and outside the French exclusive economic zone. In summer 2021, the Gombessa 6 expedition used oceanographic tools and then an innovative diving technique (autonomous saturation diving with electronic rebreathers) in order to implement the protocols of 41 researchers. The aim was to discover the mysterious origin of the rings, evaluate their age and dynamics of change, and study their associated flora and fauna. Two central cores were cored by divers; results are expected for the autumn. The central cores seem to gradually disappear under sedimentation and crevices according to 3D models compared between 2014 and 2021. Fifty species of fish were detected using environmental DNA metabarcoding. Sediment samples analyses are still in progress in order to study the diversity and functions of micro-organisms and to study the trophic conditions (carbohydrates, proteins, lipids) in relation to the presence (if any) of particular substances (gas, fresh water). Measures of current velocity did not show any gas or water vertical effusion. Fine bathymetry was surveyed over 6,815 ha in order to complete the existing maps of 2011 and 2014. The analysis of these maps, coupled with images from divers and ROV and geologic maps showed that the rings are located between faults and next to a fossil coastline presenting an alignment of large underwater caves over 5 km. The knowledge about this unique ecosystem is well advanced and the enigma of the origin of the rings is perhaps being solved. A sequel to the expedition is being planned for summers 2022 and 2023.

Key-words: eDNA, caves, coralligenous atolls, mapping, rhodoliths

Introduction

Discovered in 2006 (Pluquet, 2006) and described in 2012 as «coralligenous atolls» (Bonacorsi et al., 2012), this new coralligenous morphotype is composed of a «central massive coralligenous core, a halo of detritic bottom (ten meters wide) and a peripheral crown (one to three meters wide) consisting of a coralligenous structure, combined with free rhodoliths (pralines) and many invertebrates (including sponges, bryozoans and echinoderms)». For the moment, this morphotype is known in a unique site located 25 km off northern Cap Corse (Bonacorsi et al., 2012) within the Parc Naturel marin du Cap Corse et de l'Agriate (PNMCCA, French Mediterranean) and outside the French

exclusive economic zone. Since then, two oceanographic campaigns (using side scan sonar, multibeam echosounder, sparker, ROV and submarine with 3D photogrammetry) attempted to inventory and characterize theses structures (Pergent-Martini et al., 2014). Different typologies understood as atolls at different stages of evolution in relation to phenomena of bioerosion or bioconstruction were observed and led to the hypothesis of a biological origin, with the original formation occurring during a period when the sea level was lower, several thousand years ago (Pergent-Martini et al., 2014).
The oceanographic campaign Gombessa 6 «Cap Corse» was carried out in summer 2021 with the aim of validating the origin of these structures, evaluate their age and their dynamics of change, to know the associated fauna and flora and to evaluate the threats to these unique ecosystems renamed coralligenous rings to avoid confusion with coral atolls.

Materials and methods

The Gombessa 6 oceanographic campaign consisted of four work packages.

i) Complete the existing mapping using multibeam echosounder (Sonic 2022), a ROV (ULISSE) and divers in May and June 2021
ii) Better characterize the coralligenous rings and their dynamics by implementing a core sample within two central cores, measuring environmental parameters (temperature sensors and autonomous SeaBird SBE 19 plus V2 SeaCAT Profiler CTD) and hydrodynamics (acoustic doppler velocimetry), building 3D models (photogrammetry)
iii) Make an inventory of the associated fauna and flora (species, sediment, acoustic, water sampling and pictures/videos)
iv) Quantify the threats to these ecosystems (acoustics and marine traffic)

Work packages ii and iii were led using an innovative diving techniques invented and tested in 2019 during the campaign Gombessa 5 «Planète Méditerranée»: the autonomous saturation diving with electronic rebreathers.

Results and discussion

The bathymetric campaign involved a total acquisition area of 6850 ha, of which 5165 ha were within the perimeter of the PNMCCA and 1650 ha outside the Park in the northern part of the Cape. A total of 1417 rings was counted (271 with a central core, 386 without any core, 760 with an unknown status), 508 were within the PNMCCA. These rings were detected between 90 and 135 m depth but the majority were situated between 110 and 120 m depth. The analysis of this data, coupled with images from divers and ROV and geologic maps showed that the rings are located between faults and next to a fossil coastline presenting an alignment of large underwater caves (at 94 m depth) over 5 km.
Between 1st and 12th July 2021, nine dives were made between 94 and 120 m depth for a total exploration time of 128 h (32 h × 4 divers, the longest dive took 4h30, Fig. 1). This particularly long dive time allowed the implementation of all the planned protocols. Two cores (40 and 90 cm long) were sampled; the analyses are still in progress in order to know the heterogeneous composition, age and growth rate.

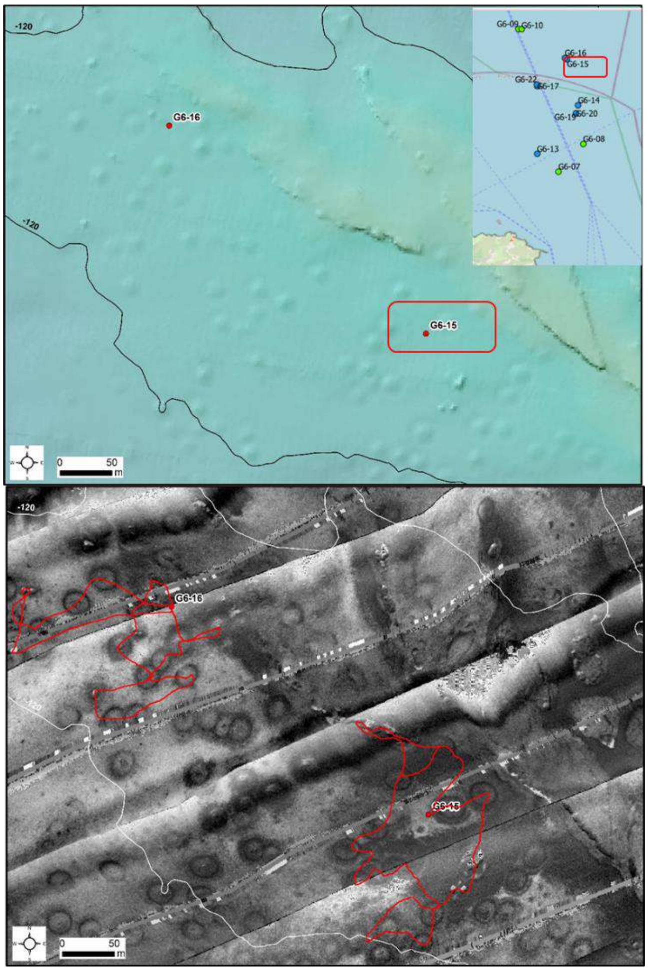


Fig.1: Example showing the location of site G6-15 on [1] the Digital Terrain Model made in June 2021 and [2] existing sonar mosaic (CAPCORAL). The divers' exploration route is in red.

Two temperature sensors were installed for one year. Environmental data (depth, salinity, temperature, pH, conductivity, density, oxygen, % oxygen saturation, turbidity, fluorescence, and light) is being published and made available on Seanoe. ADV measured a current speed between 20 and 30 $m \cdot sec^{-1}$ and did not detect any evidence of significant vertical effusion during its measurement (13 days). The visual comparison of two pictures of the same core taken in 2014 and 2021 showed an increase in crevices and sedimentation but no changes concerning the cover of conspicuous species. Three other rings were rendered in 3D by photogrammetry (Marre et al., 2019) for archiving and precise measurement of dimensions showing that rings are finally domes (0.36±0.09 m high) overhung by a core (0.67±0.37 m high).
Benthic biodiversity sampled on the core, within the halo, crown and outside the ring area were studied using environmental DNA metabarcoding. The great amount of sequences is still being analyzed. eDNA metabarcoding (water samples: Boulanger et al., 2021) was also used for a fish inventory: 50 species were detected (Table 1).

Tab. 1: List of fish detected by eDNA metabarcoding (N= 6 water samples)

class	order	family	scientific name
Actinopteri	Anguilliformes	Congridae	*Conger conger*
Actinopteri	Anguilliformes	Muraenidae	*Muraena helena*
Actinopteri	Aulopiformes	Chlorophthalmidae	*Chlorophthalmus*
Actinopteri	Blenniiformes	Blenniidae	*Blennius ocellaris*
Actinopteri	Blenniiformes	Blenniidae	*Parablennius rouxi*
Actinopteri	Caproiformes	Caproidae	*Capros aper*
Actinopteri	Carangiformes	Carangidae	*Seriola dumerili*
Actinopteri	Carangiformes	Carangidae	*Trachurus* sp.
Actinopteri	Gadiformes	Gadidae	*Merlangius merlangus*
Actinopteri	Gadiformes	Macrouridae	*Coelorinchus*
Actinopteri	Gobiiformes	Gobiidae	*Crystallogobius linearis*
Actinopteri	Gobiiformes	Gobiidae	*Lebetus guilleti*
Actinopteri	Gobiiformes	Gobiidae	*Lesueurigobius suerii*
Actinopteri	Istiophoriformes	Istiophoridae	*Istiophorus albicans*
Actinopteri	Istiophoriformes	Xiphiidae	*Xiphias gladius*
Actinopteri	Labriformes	Labridae	*Coris julis*
Actinopteri	Labriformes	Labridae	*Labrus mixtus*
Actinopteri	Lophiiformes	Lophiidae	*Lophius piscatorius*
Actinopteri	Myctophiformes	Myctophidae	*Ceratoscopelus*
Actinopteri	Myctophiformes	Myctophidae	*Lampanyctus* sp.
Actinopteri	Myctophiformes	Myctophidae	*Myctophum punctatum*
Actinopteri	Myctophiformes	Myctophidae	*Notoscopelus elongatus*
Actinopteri	Perciformes	Scorpaenidae	*Scorpaena scrofa*
Actinopteri	Perciformes	Sebastidae	*Helicolenus*
Actinopteri	Perciformes	Serranidae	*Anthias anthias*
Actinopteri	Perciformes	Serranidae	*Serranus cabrilla*
Actinopteri	Perciformes	Triglidae	*Chelidonichthys cuculus*
Actinopteri	Perciformes	Triglidae	*Chelidonichthys lucernus*
Actinopteri	Perciformes	Triglidae	*Chelidonichthys* sp.
Actinopteri	Perciformes	Triglidae	Triglidae
Actinopteri	Pleuronectiformes	Scophthalmidae	*Lepidorhombus boscii*
Actinopteri	Priacanthiformes	Cepolidae	*Cepola macrophthalma*
Actinopteri	Scombriformes	Scombridae	*Auxis* sp.
Actinopteri	Scombriformes	Scombridae	*Euthynnus alletteratus*
Actinopteri	Scombriformes	Scombridae	*Scomber colias*
Actinopteri	Scombriformes	Scombridae	*Thunnus thynnus*

Tab. 1 (continue): List of fish detected by eDNA metabarcoding (N= 6 water samples)

class	order	family	scientific name
Actinopteri	Spariformes	Sparidae	*Boops boops*
Actinopteri	Spariformes	Sparidae	*Pagellus acarne*
Actinopteri	Spariformes	Sparidae	*Pagellus bogaraveo*
Actinopteri	Spariformes	Sparidae	*Pagellus erythrinus*
Actinopteri	Spariformes	Sparidae	Sparidae
Actinopteri	Spariformes	Sparidae	*Spondyliosoma*
Actinopteri	Syngnathiformes	Callionymidae	*Callionymus maculatus*
Actinopteri	Syngnathiformes	Centriscidae	*Macroramphosus*
Actinopteri	Syngnathiformes	Mullidae	*Mullus surmuletus*
Actinopteri	Tetraodontiformes	Molidae	*Mola mola*
Actinopteri	Uranoscopiformes	Uranoscopidae	*Uranoscopus scaber*
Actinopteri	Zeiformes	Zeidae	*Zeus faber*
Chondrichthyes	Myliobatiformes	Dasyatidae	*Pteroplatytrygon*
Chondrichthyes	Rajiformes	Rajidae	*Raja* sp.

Octocorals were sampled for population genetics (waiting for funds) and phylosymbiosis study between bacterial microbiota and octocorals. *Callogorgia verticillata* colonies (suborder Calcaxonia) sampled on three cores presented a distinct microbiome in comparison to the members of the Haloxonia (*Eunicella* spp. and *Paramuricea clavata*) that cluster separately and follows the phylogeny along the lines of host species (Prioux et al., 2022). *Tritonia callogorgiae*, the large nudibranch inhabiting *Callogorgia verticillata* forests recently described (Chimienti et al., 2020), was frequently observed. Other species identifications/validations are in progress.
The two hydro phones installed for 13 days on two different rings 1 km apart showed high noise pollution (maritime traffic), numerous active cetaceans and a low diversity of biological sounds; however rare and unknown sounds were detected and are still being analyzed. The acoustic biodiversity of these ecosystems was totally different from what we know from coastal coralligenous reefs (Di Iorio et al., 2021). High maritime traffic was confirmed using AIS (Automated Identification System) data and numerous fishing ghost nets were observed by the divers.

Conclusions

The results of the Gombessa 6 "Cap Corse" expedition complete the previous descriptions of the coralligenous rings. The innovative diving technique used (autonomous saturation diving) allowed the implementation and success of all the planned protocols. Many analyses are still in progress. An ancient biological origin linked to a particular local geological history is currently favored to explain the unique presence of these rings in the Cape Corsica area. New data acquisition is planned for summer 2022 and 2023 in order to validate the hypothesis and complete our understanding and the biodiversity inventory: seismic reflection, hydrophones, ADV on another site, cave exploration. Our observations suggest that an erosion process is underway and that the distance to the coast does not protect the rings from threats that are similar (fishing) or higher (maritime traffic) to what is known for coastal coralligenous habitats. This knowledge will help the marine park in its action plan.

Acknowledgments

We thank Carla Fournier for her help with the mapping and Camille Prioux and Jeroen van de Water for their help concerning the phylosymbiosis. The GOMBESSA CAP CORSE cruise was led by Andromède Océanologie and supported by Manufacture de Haute Horlogerie Suisse Blancpain and Blancpain Ocean Commitment, the Prince Albert II de Monaco Foundation, the Société des explorations de Monaco, Office Francais de la Biodiversité, and Agence de l'eau Rhône-Méditerranée-Corse (French Water Agency). The mission was also supported by La Marine Nationale (France Navy) and Préfecture Maritime de la Méditerranée. The authors also want to thank ARTE, INPP (Institut National de Plongée Professionnelle), Les Gens Bien Production, CNC, Parc Naturel Marin du Cap Corse et de l'Agriate (France Relance program), Ushuaïa TV, AP diving, Aqualung, Nikon, Molecular, Seacam, Yamaha, Paralenz, Bigblue, Neotek, Seaowl, Marlink, Subspace pictures, Suex and Francqueville without whom this expedition would not have been possible.
GOMBESSA CAP CORSE is an action recognized by the United Nations Decade of Ocean Sciences for Sustainable Development.

Bibliography

BONACORSI, M., PERGENT-MARTINI, C., CLABAUT, P., PERGENT, G. (2012) - Coralligenous "atolls": Discovery of a new morphotype in the Western Mediterranean Sea. *Comptes Rendus Biologies* 335, 668–672. https://doi.org/10.1016/j.crvi.2012.10.005

BOULANGER E., LOISEAU N., VALENTINI A., ARNAL V., BOISSERY P., DEJEAN T., DETER J., GUELLATI N., HOLON F., JUHEL J.-B., LENFANT P., MANEL S., MOUILLOT D. (2021) - Environmental DNA metabarcoding reveals and unpacks a biodiversity conservation paradox in Mediterranean marine reserves. *Proceedings of the Royal Society Biological Sciences* 288, rspb.2021.0112, 20210112. https://doi.org/10.1098/rspb.2021.0112

CHIMIENTI G., ANGELETTI L., FURFARO G., CANESE S., TAVIAN, M. (2020) - Habitat, morphology and trophism of *Tritonia callogorgiae* sp. nov., a large nudibranch inhabiting *Callogorgia verticillata* forests in the Mediterranean Sea. *Deep Sea Research Part I: Oceanographic Research Papers* 165, 103364. https://doi.org/10.1016/j.dsr.2020.103364

DI IORIO L., AUDAX M., DETER J., HOLON F., LOSSENT J., GERVAIS, C., BOISSERY P. (2021) - Biogeography of acoustic biodiversity of NW Mediterranean coralligenous reefs. *Scientific Reports* 11, 16991. https://doi.org/1038/s41598-021-96378-5

MARRE G., HOLON F., LUQUE S., BOISSERY P., DETER J. (2019) - Monitoring marine habitats with photogrammetry: A cost-effective, accurate, precise and high-resolution reconstruction method. *Frontiers in Marine Sciences* 6, 276. https://doi.org/10.3389/fmars.2019.00276

PERGENT-MARTINI C., ALAMI S., BONACORSI M., DANIEL B., RUITTON S., CLABAUT P., SARTORETTO S., PERGENT G. (2014) - New data concerning the coralligenous atolls of Cap Corse: an attempt to shed light on their origin. *In*: BOUAFIF C., LANGAR H., OUERGHI A. (Eds.), *Proceedings of 2nd Mediterranean symposium on the conservation of coralligenous and other calcareous bio-concretions (Portorož, Slovenia, 29-30 October 2014)*, RAC/SPA publ., Tunis: 129–134.

PLUQUET F. (2006) - Évolution récente et sédimentation des plates-formes continentales de la Corse. *Thèse de doctorat de l'Université de Corse*, Corte.

PRIOUX C., RIGNAT-PERRIER R., FERRIER-PAGÈS C., GUILBERT A., DETER J., BALLESTA L., ALLEMAND D., VAN DE WATER J. (2022) - Is there phylosymbiosis between bacterial microbiota and octocorals in the mesophotic zone of the Mediterranean and Red Seas? *In*: *Proceedings of the international coral reef symposium*. Bremen (Germany).

Laura FIGUEROLA-FERRANDO, LINARES C., ZENTNER Y., LÓPEZ-SENDINO P., GARRABOU, J.
Departament de Biologia Evolutiva, Ecologia i Ciències Ambientals, Institut de Recerca de la Biodiversitat (IRBIO) Universitat de Barcelona, Avda, Barcelona, Spain.
E-mail: lfiguerola@ub.edu

A RAPID ASSESSMENT METHOD FOR CITIZEN-SCIENTISTS TO MONITOR THE CONSERVATION STATUS OF MEDITERRANEAN CORALLIGENOUS ASSEMBLAGES

Abstract
Coralligenous assemblages are one of the highly diverse habitats in the Mediterranean Sea. During the last decades, they have suffered severe mass mortality events driven by marine heatwaves. The large spatio-temporal scales of these events emphasize the urgency of establishing cost-effective methods to assess their impacts. In this sense, citizen-science has become a powerful tool to enlarge the spatio-temporal scales of observation. To date, researchers have used different measures to assess the impacts that determine the conservation status of gorgonian populations, such as the use of different demographic parameters. Despite their effectiveness, these methods are time-consuming and require expertise. Thus, our aim is to validate a rapid, easy, and large-scale assessment method for scientists and citizen-scientists to examine the conservation status of Mediterranean gorgonians populations, which can be transferred to other organisms (e.g. sponges, bryozoans). The proposed method is based on the quantification of the percentage of affected colonies. To validate it, we benefit from an extensive database including >47.500 observations on Paramuricea clavata *populations in 7 North-Western Mediterranean locations between 1999 and 2021. We first established the significant relationship between both methods (r^2=0.84; $p<0.001$). Then, the method was applied and validated through the citizen-science approach, by comparing the data obtained by volunteers and scientists. Data obtained from volunteers showed more variability - although it diminished after only one training - and were able to assess the same impact category as scientists. In conclusion, the rapid assessment method "Percentage of affected colonies" is a powerful tool to be applied by scientists and citizen-scientists to monitor the conservation status of coralligenous assemblages.*

Key-words: Mediterranean coralligenous assemblages, Gorgonians, Mortality assessment, Marine heatwaves, Citizen Science.

Introduction
Coralligenous assemblages are unique calcareous formations of biogenic origin in the Mediterranean Sea, produced by the accumulation of encrusting algae growing in dim light conditions, with high ecological importance and exceptional biodiversity, harbouring approximately 10 % of Mediterranean species (Ballesteros, 2006). Some key species, especially octocorals and sponges, are characterized by slow population dynamics and long lifespans, which is translated to a high vulnerability to natural and anthropogenic stressors (Garrabou & Harmelin, 2002). For instance, Mediterranean coralligenous assemblages are highly impacted by global warming, in particular by marine heatwaves (MHWs; Garrabou *et al.*, 2009). These extreme events, characterized by abrupt and prolonged periods of high sea surface temperature at a particular location

(Oliver *et al.,* 2018) drive Mass Mortality Events (MMEs) affecting several phyla, spatial scales and depths (Garrabou *et al.,* 2009).

To gain a more comprehensive understanding of the population conservation status, to date, researchers have used "The mean percentage of injured surface" as the main method to assess the impact of MHWs on coralligenous assemblages. This robust method has been broadly used for more than 2 decades and in different Mediterranean regions for gorgonians (e.g. Linares *et al.,* 2005; Sini *et al.,* 2015), but also bryozoans (e.g. Pagès-Escolà *et al.,* 2018) and sponges (Cebrian *et al.,* 2011). Despite its effectiveness, it is time-consuming and requires some level of expertise. Thus, this demands the exploration of new methods to rapidly assess the conservation status of the gorgonian population, not only for scientists but also for citizen-scientists.

Citizen science is a growing practice in ecology (Brown & Williams, 2019), in which scientists and citizens collaborate to produce new knowledge and enhance learning for science and society (Vohland *et al.,* 2021). Marine citizen science (MCS) is a field continuously growing although it is still underrepresented compared with its terrestrial counterparts (Sandahl & Tøttrup, 2020). MCS projects are mainly focused on species occurrences (Vohland *et al.,* 2021). However, the use of citizen-generated data can transcend the monitoring of species occurrences, contributing to marine conservation, and even being also integrated into the Sustainable Development Goals framework (Fritz *et al.,* 2019). Despite this, data quality, precision, and accuracy records generated by citizen-scientists remain a concern (Aceves-Bueno *et al.,* 2017), thus becoming one of the most investigated aspects in citizen science (Lukyanenko *et al.,* 2020). However, several works confirm that they can be improved over time (Pescott *et al.,* 2015), expert validation, and training (e.g. Kosmala *et al.,* 2016), techniques frequently used in biological surveys (Falk *et al.,* 2019) and included in robust data quality assurance methods (Wiggins *et al.,* 2011).

In this context, the aim of this work is to validate a rapid, easy, and large-scale assessment method for scientists and citizen-scientists to examine the conservation status of Mediterranean gorgonian populations that can be applied to other organisms (e.g. sponges, bryozoans). Thus, the main objectives of this study are twofold. First, we validate the proposed method based on quantifying the percentage of affected colonies, by providing a comparison with the mean percentage of injured surface, as a common metric used in scientific studies. Data were obtained from different North-Western Mediterranean gorgonian populations that have been studied by our research group. The second objective is to validate the rapid assessment method through the citizen science approach, by comparing data obtained by scientists and citizen-scientists volunteers in a specific location, depth, and day. This will enable us to test the sampling ability of the volunteers and if they improve by experience, in order to integrate a long-term perspective. Taken together, our result formally validates the rapid assessment method for scientists and citizen-scientists to monitor the conservation status of coralligenous assemblages at large spatio-temporal scales.

Material and methods

The rapid assessment method "percentage of affected colonies" is based on quantifying the percentage of the injured colonies in about 100 colonies for each species, locality, and depth range. Since the method is mainly focused on the impact of MHWs, the depth range of affected colonies provides a good indicator of the bathymetrical distribution of mortality. Based on previous studies, we considered a colony to be affected by mortality when it shows injuries or surface covered by epibionts ≥10% of its surface (Linares *et al.*, 2008). As the final aim, we determined the conservation status of the population by dividing the mortality impact into four severity classes: non-impacted populations (<10% of affected colonies), low impacted populations (≥10, <30% of affected colonies), moderately impacted populations (≥30, <60% of affected colonies), and severely impacted populations (≥60% of affected colonies). To compare between methods, a total of 47.523 gorgonian colonies were sampled from 7 North-Western Mediterranean locations between the years 1999 and 2021 using randomized biological visual sampling. Despite visual sampling is involved in both methods, a different approach was applied in this case; the mean percentage of the injured surface method was applied in situ, while the percentage of affected colonies method was calculated ex-situ based on the first method. The red gorgonian *Paramuricea clavata* was chosen as the target species for this study although other species were sampled. Both assessment methods were correlated using Pearson's correlation.

To validate the rapid assessment method through the citizen science approach, we conducted 5 different campaigns on the rocky coast of Costa Brava (Catalunya, Spain). In each campaign, a total of 7-8 volunteers and 2-3 scientists performed the sampling protocol individually. We evaluate the expertise improvement by repeating the sampling with the same volunteers a second time, thus they were assigned as beginner or trained volunteers. Each sampling campaign started with a theoretical approach, followed by the sampling protocol. To accurately validate it, two marks were introduced on the vertical wall of the coralligenous population to indicate the beginning of the sampling transect. Each observer implemented the rapid assessment method in the same site and depth, starting from the reference point and moving throughout the same direction without exceeding a depth of ±2 m. The impact category determined by the quantification of the percentage of affected colonies, and the total number of sampled colonies, were used as the two variables to validate the accuracy and precision of the citizen-scientists, by comparing their results with scientists and among them (beginners and trained). Consequently, we evaluate the ability of volunteers to assess the same impact category as scientists, and if they reach the reference minimum value of sampled colonies (100). Finally, the non-parametric Kruskal-Wallis test was used to assess the effect of the three expertise levels on the total number of sampled colonies.

Results

Both conservation assessment methods were highly positively correlated (Pearson's correlation, $r^2 = 0.84$; $p < 0.001$), indicating that the higher the percentage of injured surface the greater the number of affected colonies. To reinforce these results, the high adjustment of confidence intervals observed in our study (0.80–0.87) reveals few uncertainties in the correlation prediction; however, they slightly expand as the impact category increases, in relation to the low sample size.

The application of the rapid assessment method into the citizen science approach revealed contrasting patterns between beginner and trained volunteers in both variables, showing an improvement over time (Tab. 1). Data obtained from volunteers showed more variability than those obtained by scientists but were able to assess the same impact category in terms of mean values (Tab. 1). Specifically, the impact category was tighter in expert volunteers, with a 78.57% of success with respect to the category determined by scientists (Tab. 1), while beginner volunteers succeed was 68.18% (Tab. 1). Regarding the total number of sampled colonies, beginners did not broadly reach the minimum of 100 colonies (74.65 ± 26.88; Tab. 1), showing statistically fewer sampled colonies than trained volunteers (109.21 ± 18.07; Tab. 1) and scientists (112.5 ± 10.31; Kruskal-Wallis; $p = 0.0029$; $p < 0.001$, respectively). In contrast, a vast majority of trained volunteers exceed the minimum reference value of sampled colonies and showed no statistical differences with scientists (Kruskal-Wallis, $p = 0.18$)

Tab. 1: Percentage of affected colonies assessed by volunteers and scientists (mean and standard deviation, SD) by sampling campaign. The proportion of volunteers that assess the same impact category as scientists (black) or different (grey), and the total number of sampled colonies (mean and standard deviation, SD), by expertise group

Volunteer expertise	Percentage of affected colonies (mean ± SD)		Proportion of volunteers that assess the same impact category as scientists	Total number of sampled colonies by volunteers expertise (mean ± SD)
	Volunteers	Scientists		
Beginner	37.00 ± 14.87	43.32 ± 4.43		74.65 ± 26.88
	41.40 ± 10.21	43.66 ± 5.18		
	33.80 ± 13.34	45.16 ± 1.31		
Expert	50.19 ± 9.23	43.43 ± 2.84		109.21 ± 18.07
	68.31 ± 8.61	79.03 ± 7.26		

Discussion and conclusions

Our results confirm that the percentage of affected colonies method provides a reliable assessment of the gorgonian conservation status and can therefore infer their impact category. As important as unravelling the population health status, are the implications of this method for conservation and management planning at broad spatio-temporal scales. Given that some coralligenous species were more affected than others in different MMEs linked to warming, the rapid assessment method should have the potential to adapt to other species from Mediterranean coralligenous assemblages, as they can be dominated by different species. For instance, it has applied to other gorgonian species (*Eunicella cavolini, E. singularis,* and *Leptogorgia sarmentosa*), octocorals (*Corallium rubrum*), but also scleractinian hexacorals (*Balanophyllia europaea, Cladocora caespitosa, Leptopsammia pruvoti, Madracis pharencis, Oculina patagonica*), and sponges (*Sarcotragus fasciculatus*; Garrabou *et al.*, 2009; Sini *et al.*, 2015; Kružić *et al.*, 2016).

Our study strengthens the relevance of training and expert validation in citizen science projects and is in line with other empirical validations (e.g. Pescott *et al.*, 2015; Falk *et al.*, 2019). It is noteworthy that the volunteers variability already diminishes after only one training, confirming that data quality, precision, and accuracy are improved over time in citizen science (Kosmala *et al.*, 2016). Thus, results demonstrate that citizen-scientists are competent to implement the rapid assessment protocol and categorize the same impact category as scientists, although with higher variability between them. For this reason, we recommend that first-time volunteers perform the sampling protocol, then report the mean number of affected colonies among them to avoid precision and accuracy problems; while, after the training, volunteers are sufficiently qualified and skilled to report the results individually or with those of the diving colleague.

In conclusion, the rapid assessment method percentage of affected colonies is a cost-effective, and low time-consuming strategy that can be easily performed by non-experts such as citizen-scientist. This powerful tool provides robust information to monitor the conservation status of coralligenous assemblages, revealing its utility in covering large spatial, temporal, and taxonomic scales.

Acknowledgments

This research has been partially funded by the Spanish Ministry of Economy and Innovation through the Smart project (CGL2012-32194), the HEATMED project (RTI2018-095346-B-I00, MCIU/AEI/FEDER, UE). JG acknowledge the funding of the Spanish government through the 'Severo Ochoa Centre of Excellence' accreditation (CEX2019-000928-S). CL gratefully acknowledges the financial support by ICREA under the ICREA Academia program. YZ was supported by FPU grant from "Ministerio de Universidades, Gobierno de España". LF was supported by FI SDUR grant (2020 FISDU 00482) from the "Generalitat de Catalunya". All researchers are part of the Marine Conservation research group - MedRecover (2017 SGR 1297) from the "Generalitat de Catalunya".

Bibliography

ACEVES-BUENO E., ADELEYE A.S., FERAUD M., HUANG Y., TAO M., YANG Y., ANDERSON S.E. (2017) - The accuracy of citizen science data: A quantitative review. Bull. Ecol. Soc. Am. 98 (4), 278-290.

BALLESTEROS E. (2006) - Mediterranean coralligenous assemblages: A synthesis of present knowledge. Oceanogr. Mar. Biol. Ann. Rev. 44, 123-195.

BROWN E.D., WILLIAMS, B.K. (2019) - The potential for citizen science to produce reliable and useful information in ecology. Conserv. Biol. 33 (3), 561-569.

CEBRIAN E., URIZ M.J., GARRABOU J., BALLESTEROS E. (2011) - Sponge mass mortalities in a warming mediterranean sea: Are cyanobacteria-harboring species worse off? PLoS One 6 86), e20211.

FALK S., FOSTER G., COMONT R., CONROY J., BOSTOCK H., SALISBURY A., KILBEY D., BENNETT J., SMITH B. (2019) - Evaluating the ability of citizen scientists to identify bumblebee (Bombus) species. PLoS One 14 (6), e0218614.

FRITZ S., SEE L., CARLSON T., HAKLAY M. (MUKI), OLIVER J.L., FRAISL D., MONDARDINI R., BROCKLEHURST M., SHANLEY L. A., SCHADE S., WEHN U., ABRATE T., ANSTEE J., ARNOLD S., BILLOT M., CAMPBELL J., ESPEY J., GOLD M., HAGER G., HE S., HEPBURN L., HSU A., LONG D., MASÓ J., MCCALLUM I., MUNIAFU M., MOORTHY I., OBERSTEINER M., PARKER A.J., WEISSPFLUG M., WEST S. (2019) - Citizen science and the United Nations Sustainable Development Goals. Nat. Sustain. 2 (10), 922-930.

GARRABOU J., COMA R., BENSOUSSAN N., BALLY M., CHEVALDONNÉ P., CIGLIANO M., DIAZ D., HARMELIN J. G., GAMBI M. C., KERSTING D. K., J. B. LEDOUX, LEJEUSNE C., LINARES C., MARSCHAL C., PÉREZ T., RIBES M., ROMANO J. C., SERRANO E., TEIXIDO N., TORRENTS O., ZABALA M., ZUBERER F., CERRANO C. (2009) - Mass mortality in Northwestern Mediterranean rocky benthic communities: Effects of the 2003 heat wave. Glob. Chang. Biol. 15 (5), 1090–1103.

GARRABOU J., HARMELIN J.G. (2002) - A 20-year study on life-history traits of a harvested long-lived temperate coral in the NW Mediterranean: Insights into conservation and management needs. J. Anim. Ecol. 71 (6), 966–978.

KOSMALA M., WIGGINS A., SWANSON A., SIMMONS B. (2016) - Assessing data quality in citizen science. Front. Ecol. Environ. 14 (10), 551-560.

KRUŽIĆ P., RODIĆ P., POPIJAČ A. & SERTIĆ M. (2016) - Impacts of temperature anomalies on mortality of benthic organisms in the Adriatic Sea. Mar. Ecol. 37 (6), 1190–1209.

LINARES C., COMA R., DIAZ D., ZABALA M., HEREU B., DANTART L. (2005) - Immediate and delayed effects of a mass mortality event on gorgonian population dynamics and benthic community structure in the NW Mediterranean Sea. Mar. Ecol. Prog. Ser. 305, 127–137.

LINARES C., COMA R., GARRABOU J., DÍAZ D., ZABALA M. (2008) - Size distribution, density and disturbance in two Mediterranean gorgonians: Paramuricea clavata and Eunicella singularis. J. Appl. Ecol 45 (2), 688-699.

LUKYANENKO R., WIGGINS A., ROSSER H.K. (2020) - Citizen science: An information quality research frontier. Inf. Syst. Front. 22 (4), 961-983.

OLIVER E.C.J., DONAT M.G., BURROWS M.T., MOORE P.J., SMALE D.A., ALEXANDER L. V., BENTHUYSEN J. A., FENG M., SEN GUPTA A., HOBDAY A.J., HOLBROOK N.J., PERKINS-KIRKPATRICK S.E., SCANNELL H.A., STRAUB S.C., WERNBERG T. (2018) - Longer and more frequent marine heatwaves over the past century. Nat. Commun. 9 (1), 1–12.

PAGÈS-ESCOLÀ M., HEREU B., GARRABOU J., MONTERO-SERRA I., GORI A., GÓMEZ-GRAS D., FIGUEROLA B., LINARES C. (2018) - Divergent responses to warming of two common co-occurring Mediterranean bryozoans. *Sci. Rep*. 8 (1), 1–9.

PESCOTT O.L., WALKER K.J., POCOCK M.J.O., JITLAL M., OUTHWAITE C.L., CHEFFINGS C.M., HARRIS F., ROY D.B. (2015) - Ecological monitoring with citizen science: The design and implementation of schemes for recording plants in Britain and Ireland. *Biol. J. Linn. Soc*. 115 (3), 505-521.

SANDAHL A., TØTTRUP A.P. (2020) - Marine citizen science: Recent developments and future recommendations. Citiz. Sci. Theory Pract. 5 (1), 24.

SINI M., KIPSON S., LINARES C., KOUTSOUBAS D., GARRABOU J. (2015) - The yellow gorgonian Eunicella cavolini: Demography and disturbance levels across the Mediterranean Sea. PLoS One 10 (5), e0126253.

VOHLAND K., LAND-ZANDSTRA A., CECCARONI L., LEMMENS R., PERELLÓ J., PONTI M., SAMSON R., WAGENKNECHT K. (2021) - Editorial: The science of citizen science evolves. In: The Science of Citizen Science (Vohland K. et al., eds). Springer, pp. 1-12.

WIGGINS A., NEWMAN G., STEVENSON R.D. & CROWSTON K. (2011) - Mechanisms for data quality and validation in citizen science. In: Proceedings - 7th IEEE International Conference on e-Science Workshops. IEEE, pp. 14-19.

Joaquim GARRABOU, BENSOUSSAN N., AZZURRO E. & the T-MEDNet network
Institut de Ciències del Mar-CSIC, Passeig Marítim de la Barceloneta 37-49, 08003 Barcelona, Spain
E-mail: garrabou@icm.csic.es

T-MEDNET CLIMATE CHANGE COASTAL OBSERVATION NETWORK: TRACKING AND ASSESSING CHANGES ON THERMAL REGIMES AND THEIR EFFECTS IN MEDITERRANEAN COASTAL ECOSYSTEMS

Abstract
T-MEDNet is a long-term collaborative initiative devoted to the building of a pan-Mediterranean observation network on climate change effects in marine coastal ecosystems (www.t-mednet.org). T-MEDNet has been fostering international cooperation between marine scientists and Marine Protected Areas managers (MPAs). Over the past two decades it has supported the implementation of cost-effective monitoring protocols on seawater temperature conditions in coastal areas as well as on biological indicators on the onset of mass mortalities and shifts in native and exotic fish species distribution. To date, the network gathers managers from more than 25 Marine Protected Areas and more than 80 researchers from 15 countries. Seawater temperature time-series are being acquired in more than 70 sites covering all Mediterranean ecoregions. In T-MEDNet, seawater temperature is being measured continuously at high frequency (every hour) using data loggers deployed by divers at standard depth levels, every 5 m from the surface down to 40 m depth or more. Observations, back to 1997 for the oldest, are managed in a centralized way and continuously updated, resulting in a harmonized and quality-checked database of over 20 million in situ T° measurements. These data have proved key for the characterisation of thermal regimes in the highly dynamic coastal zone and trend analysis at climatic time scales (e.g. warming and marine heatwaves). Regarding the mass mortality events, T-MEDNet provides the most updated comprehensive inventory of mass mortality events in the Mediterranean with about 2000 records encompassing more than 90 species from 9 different phyla. Finally, T-MEDNet hosts the results of the monitoring efforts to track shifts in the distribution of fishes encompassing more than 3000 transects including the information on the abundance of 15 indicator species. Overall, the information provided by T-MEDNet contributes support to adaptive management strategies from local to regional scale face to climate change.

Key-words: Climate change, marine heatwaves, mass mortality events, indicator species, alien species

Introduction
The Mediterranean Sea is warming at an unprecedented rate, faster than the global ocean, and there is an increasing need to understand and manage this rapid transformation that affects marine ecosystems and the services they provide to our societies (Garrabou et al., 2022a). Besides the complexity of these changes, we are witnessing today a number of macroscopic and measurable impacts, a novel scenario, which in its most extreme manifestation is driving the collapse of native biodiversity.
Despite that the ongoing changes are affecting most coastal Mediterranean key habitats, the coralligenous and other calcareous bio-concretions (e.g. vermetid reefs, *Cladocora caespitosa* banks) are among the most affected habitats. After the observation of the

unprecedented mass mortality in 1999 affecting mainly the coasts of the NW Mediterranean and realizing the lack of coastal temperature series, a monitoring strategy on the thermal conditions using temperature data loggers was setup (Bensoussan et al. 2019). This was the origin of the T-MEDNet network devoted to track climate change effects in the Mediterranean coastal ecosystems (www.t-mednet.org). Over the past two decades, T-MEDNet has been supporting the implementation of cost-effective monitoring protocols on seawater temperature conditions in coastal areas, in parallel monitoring protocols devoted to track biological indicators on the onset of mass mortalities and shifts in native and exotic fish species distribution have been implemented. In this communication, we present the main outcomes of this successful collaborative monitoring network.

Materials and methods

T-MEDNet network has developed a harmonized monitoring strategy to track climate change effects across the Mediterranean Sea with the support of research teams and MPAs managers. A landmark of this effort is the development of a web platform (www.t-mednet.org) and the preparation of complete toolkits for each monitoring protocols to ensure an effective and efficient implementation. All together, these materials provide a system to support the entire process, from the sampling design and data collection (field activities), to the analysis and interpretation of data, up to the final assessment of climate change impacts in the monitored areas as well as at more global level (Figure 1).

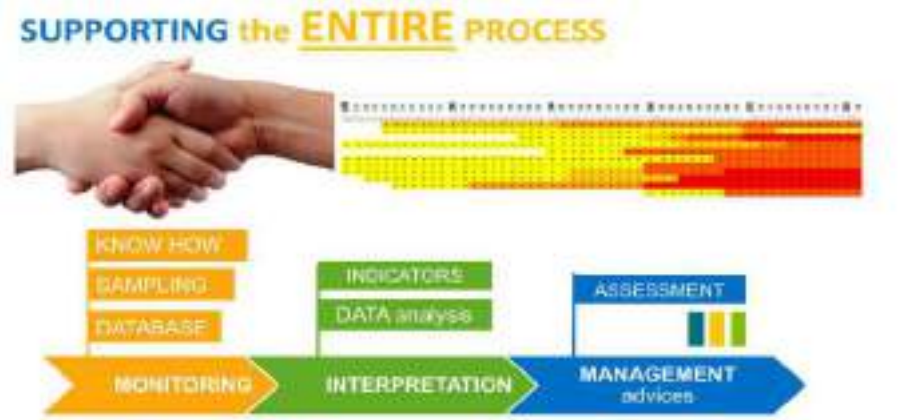


Fig. 1: Conceptual scheme of the T-MEDNet monitoring strategy. This is aimed to assist participants in tracking Climate Change impacts, from data-collection during fieldwork to data analysis and assessment.

T-MEDNet has fully implemented three monitoring protocols, the description of these protocols and all related materials are available in the T-MEDNet platform and in the monitoring protocols booklet (Garrabou et al. 2022b).

Temperature conditions. Temperature protocol is designed to acquire long-term and high-resolution information on temperature conditions along the depth gradient in coastal waters. In this protocol we propose characterizing sea water temperature conditions recording temperature every hour using data loggers (HOBO Tidbit v2 and HOBO U22) deployed and recovered over an annual or a semi-annual basis. Data loggers are placed every 5 m from surface down to 40 m or deeper in order to acquire information about seasonal stratification dynamics and temperature conditions at depth. Run over the long-term these data series build robust baselines and track hydrological changes (e.g. warming, marine heatwaves, shifts in seasonality, stratification) to better understand the impacts of climate warming on marine coastal biodiversity.

Mass mortality. The mass mortality protocol stems from the scientific and field experience gathered during the impact assessment of mass mortality events in different areas of North-Western Mediterranean. The protocol has been successfully applied to monitor the effects of mass mortality events in macrobenthic species such as gorgonians, sponges and bryozoans, but can be adapted to other benthic species. The mass mortality protocol provides quantitative information on the impact on local populations. We consider a local population as a group of colonies/individuals of the same species (ranging from tens to thousands colonies/individuals depending on the species) dwelling in a specific geographic location defined by spatial coordinates and depth range. The surveys quantified the percentage of affected colonies/individuals for each species either directly in the field or from photographic/video sampling. The observations on mortality across taxonomic groups may depend on the timing of the surveys and the duration of the specimens' structures (e.g. soft vs hard skeletons) attached to the substratum after their death. In the case of clonal species (e.g., gorgonians, bryozoans, sponges), we considered an individual/colony to be affected by mortality when it showed recent tissue necrosis over 10% of its surface (Garrabou et al. 2009, 2019).

Climate Fish protocol. The Climate Fish protocol focuses on a group of target species chosen on the basis of their responsiveness to temperature conditions (thermal affinity), widespread distribution and easy identification. These criteria were discussed within a large network of Mediterranean scientists. The species monitored include: *Epinephelus marginatus*, *Thalassoma pavo*, *Sparisoma cretense* – indigenous warm affinity species with documented northward expansions (Milazzo et al. 2016); *Coris julis* and *Sarpa salpa* – indigenous temperate species, for which there is evidence of shrinking of their preferred habitat (Milazzo et al. 2016). We also included the native *Serranus scriba* and *S. cabrilla*, because of their ecological similarity and taxonomic relatedness, associated with a different thermal affinity. Besides the indigenous, the protocol includes eight Lessepsian fishes (which entered the Mediterranean through the Suez Canal) which are currently expanding from the Eastern Mediterranean, namely: *Fistularia commersonii*, *Siganus luridus*, *Siganus rivulatus*, *Pterois miles*, *Stephanolopis diaspros*, *Parupeneus forskali*, *Pempheris rhomboidea* and *Torquigener flavimaculosus*. Fish counts were performed along standard visual census transects of 5 minutes at a standard speed of 10 $m \cdot min^{-1}$ (corresponding to an approximate area of 5 × 50 m).

Results

Seawater temperature time-series are being collected in more than 70 sites across all Mediterranean ecoregions, from Gibraltar straight to the West, to S-Turkey to the East. Observations, back to 1997 for the oldest (>20 years data series), are managed in a centralized way and continuously updated, resulting in a harmonized and quality-checked database of over 20 million in situ T° measurements (Figure 2). The temperature data series allowed to characterize coastal thermal regimes and the trend analysis at climatic time scales (e.g. warming and marine heatwaves). Besides, these data are being key to analyze biological responses to warming, considering episodic events, in particular the onset of mass mortality events affecting the benthic biota, but also changes in species distribution and phenology (see below).

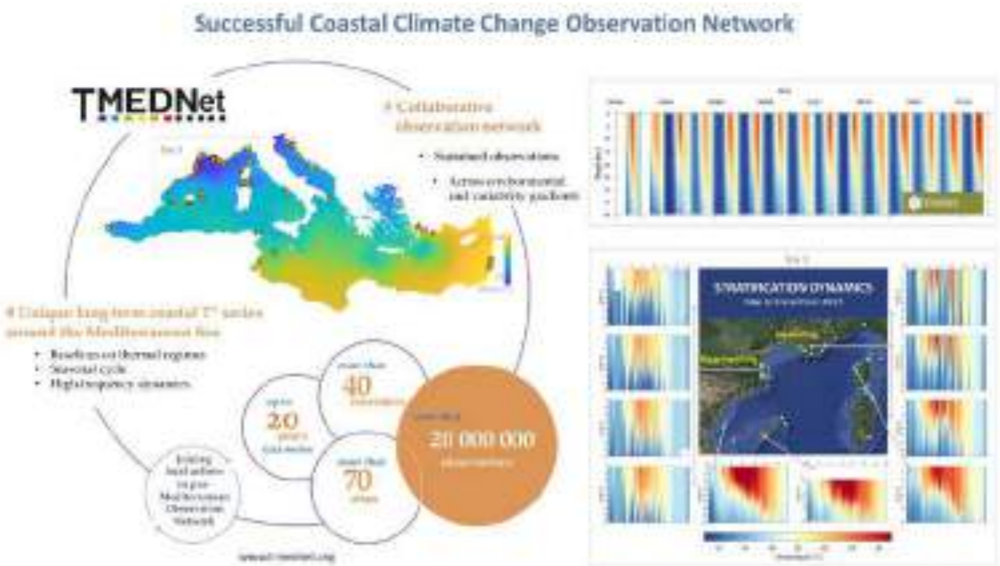


Fig. 2: Overview on the implementation of monitoring protocol on temperature conditions in the coastal areas: sites, years, number of data as well as temporal and spatial patterns.

The implementation of the mass mortality protocol provided the most updated comprehensive inventory of mass mortality events in the Mediterranean, with almost 2000 records encompassing more than 90 species from 9 different phyla. The most affected taxa are cnidarians, sponges and bryozoans from the coralligenous habitats. The most widespread mass mortality events were recorded in 1999, 2003 and during the five year period 2015-2019. While the 1999 and 2003 mass mortality events mainly affected the western Mediterranean, in the 2015-2019 all Mediterranean ecoregions were affected. In all events, populations from surface down to >45 m depth suffered mortality impacts. Different analysis with the temperature conditions recorded during the mass mortality clearly indicated the relationship between the onset of the events and the exposure to high temperature conditions (T max and marine heatwaves) (Garrabou et al. 2022a).
The Climate Fish protocol already provided 3142 underwater observations from different Mediterranean ecoregions. For some areas, up to 9 consecutive years of census are available. Overall, 101,771 individuals belonging to the 15 target species were counted. The most represented species were *S. salpa* (38,201), *C. julis* (26,620), and *T. pavo* (12,718). The database also contains observations on 8 non-indigenous species (NIS). These species, mostly distributed in the eastern sectors of the Mediterranean, are currently underrepresented in the database, but counts of non indigenous species are expected to grow along with the future implementation of the Climate Fish protocol in the eastern sector of the Mediterranean.

Discussion and conclusions

The T-MEDNet can be considered a successful collaborative observation network initiative. The main pillar for this success is to promote the implementation of harmonized monitoring actions by local actors across the Mediterranean to provide a a general picture on climate change effects. Thanks to the trust and collaboration of research teams and MPA managers from 15 Mediterranean countries and the data validation and reporting by the scientific coordination team, T-MEDNet is providing key information on climate change effects across the basin.

The T-MEDNet monitoring tools respond to the principles of the Ecosystem Approach undertaken under the auspices of UNEP/MAP Barcelona Convention and share many commonalities with the implementation of the EU Marine Strategy Framework Directive (MSFD; Directive 2008/56/EC) (EC 2008a), which aims at reaching the good environmental status (GES) through informed management decisions. The monitoring protocols and their associated indicators have been chosen on the basis of their scientific relevance, feasibility, and cost effectiveness.
The amount and quality of results obtained through T-MEDNet are able to reconstruct past changes, set baselines and to regularly quantify climate-related changes and impacts. The monitoring protocols are also valued for surface and model validation in the coastal zone, contributing to more realistic information for vulnerability assessment in support to adaptive management strategies from local to regional scale. The chosen approach of proposing cost-effective protocols and support to participants over the entire implementation process, from field implementation, data management and validation and informing management options, proved to be solid. This was possible thanks to the development of adapted tools including the organization of trainings, preparation of related documents, video tutorials, data reports and user-friendly web platform. Besides the three protocols presented here, other protocols have been developed to track other dimensions of climate change impacts. For the development of these new protocols the same philosophy was applied (Garrabou et al. 2022b). We expect to be able to fully implement them in the T-MEDNet platform as we did for the three protocols presented here.
T-MEDNet is seeking for support and collaboration to continue and enlarge the network representativeness. Ensuring recurrent funding of such international collaborative initiatives both at local and for the network coordination is identified as the main challenge to continue T-MEDNet activities. In the future, T-MEDNet priority is integrating more Marine Protected Areas to the observation network. Since other human activities are restricted in the MPAs, these areas are privileged sentinel zones to track climate change. Bearing in mind the current environmental and conservation framework on marine ecosystems, i) the commitments at EU and Barcelona convention on the protection targets, 30% by 2030, and ii) to reach the Good Environmental Status in the Mediterranean (see above), we contend that the proposed T-MEDNet protocols can support both processes. In fact, the adoption of this view, with the proposed protocols and others developed under the same philosophy, may represent an excellent opportunity to support long-term observation schemes. To promote this vision, we propose to launch the “100×30 MPA challenge” which seeks by 2030 to have 100 MPAs implementing harmonized monitoring protocols as those developed within T-MEDNet.

Acknowledgements
The authors consider all participants in T-MEDNet activities as co-authors of this contribution. Their names are not listed because of space restrictions. Request an authorship certificate if you need it. During the last 5 years T-MEDNet activities were funded by Interreg MED projects MPA-Adapt, MPA-Engage and AmarePlus and the H2020 Futuremares.

Bibliography
BENSOUSSAN N. CEBRIAN E., DOMINICI J.-M., KERSTING D. K., KIPSON S., KIZILKAY Z., OCAÑA Ó., PEIRACHE M., ZUBERER F., LEDOUX J. B., LINARES C., ZABALA M., BUONGIORNO NARDELLI B., PISANO A., GARRABOU J. (2019) -

Using CMEMS and the Mediterranean Marine Protected Areas sentinel network to track ocean warming effects in coastal areas, *Journal of Operational Oceanography* 12, pp. S65.

GARRABOU J., COMA R., BENSOUSSAN N., BALLY M., CHEVALDONNÉ P., CIGLIANO M., DIAZ D., HARMELIN J. G., GAMBI M. C., KERSTING D. K., J. B. LEDOUX, LEJEUSNE C., LINARES C., MARSCHAL C., PÉREZ T., RIBES M., ROMANO J. C., SERRANO E., TEIXIDO N., TORRENTS O., ZABALA M., ZUBERER F., CERRANO C. (2009) - Mass mortality in Northwestern Mediterranean rocky benthic communities: Effects of the 2003 heat wave. Glob. Chang. Biol. 15 (5), 1090–1103.

GARRABOU, J., GÓMEZ-GRAS, D., LEDOUX, J.-B., LINARES, C., BENSOUSSAN, N., LÓPEZ-SENDINO, P., BAZAIRI, H., ESPINOSA, F., RAMDANI, M., GRIMES, S., BENABDI, M., SOUISSI, J. B., SOUFI, E., KHAMASSI, F., GHANEM, R., OCAÑA, O., RAMOS-ESPLÀ, A., IZQUIERDO, A., PERGENT-MARTINI, C., ROUANET, E., TEIXIDÓ, N., GATTUSO, J.-P., GEROVASILEIOU, V., SINI, M., BAKRAN-PETRICIOLI, T., KIPSON, S. & HARMELIN, J. G. 2019. Collaborative Database to Track Mass Mortality Events in the Mediterranean Sea. *Front. Mar. Sci.*, 6, 707.

GARRABOU J., GÓMEZ-GRAS D., MEDRANO A., CERRANO C., PONTI M., SCHLEGEL R., BENSOUSSAN N., TURICCHIA E., SINI M., GEROVASILEIOU V., TEIXIDO N., MIRASOLE A., TAMBURELLO L.,CEBRIAN E., RILOV G., LEDOUX J., SOUISSI J., KHAMASSI F.,GHANEM R., BENABDI M.,GRIMES S., OCAÑA O., BAZAIRI H., HEREU B., LINARES C., KERSTING D., ROVIRA G., ORTEGA J., CASALS D., PAGÈS-ESCOLÀ M., MARGARIT N., CAPDEVILA P., VERDURA J., RAMOS A., IZQUIERDO A., BARBERA C., RUBIO-PORTILLO E., ANTON I., LÓPEZ-SENDINO P., DÍAZ D., VÁZQUEZ-LUIS M., DUARTE C., MARBÀ N., ASPILLAGA E., ESPINOSA F., GRECH D., GUALA I., AZZURRO E., FARINA S., GAMBI M., CHIMIENTI G., MONTEFALCONE M., AZZOLA A., MANTAS T., FRASCHETTI S., CECCHERELLI G., KIPSON S., BAKRAN-PETRICIOLI T., PETRICIOLI D., JIMENEZ C., KATSANEVAKIS, S., KIZILKAYA Z., INCI T., KIZILKAYA Z., SARTORETTO S., ELODIE R., RUITTON S., COMEAU S., GATTUSO J. HARMELIN J. (2022a) - Marine heatwaves drive recurrent mass mortalities in the Mediterranean Sea, *Global Change Biology*. pp. 1–18.

GARRABOU J., BENSOUSSAN, N., AZZURRO E. (2022b) - Monitoring Climate-related responses in Mediterranean Marine Protected Areas and beyond: ELEVEN STANDARD PROTOCOLS. 74 pp. DOI: https://doi.org/10.20350/digitalCSIC/14672

MILAZZO M., QUATTROCCHI F., AZZURRO E., PALMERI A., CHEMELLO R., DI FRANCO A., GUIDETTI P., SALA E., SCIANDRA M., BADALAMENTI F., GARCÍA-CHARTON J. A. (2016) - Warming-related shifts in the distribution of two competing coastal wrasses. *Marine Environmental Research* 120, 55–67.

Giulia GATTI, BARTH L., GRANCHER T., BASTHARD-BOGAIN S., BLONDEAUX V., BIANCHIMANI O., ESTAQUE T., MONFORT T., RICHAUME J., CHEMINÉE A.
Septentrion Environnement, France
E-mail: giulia.gatti@septentrion-env.com

CIGESMED FOR DIVERS: A SUCCESSFUL APPROACH COMBINING SCIENCE AND CITIZEN INVOLVEMENT FOR THE MONITORING OF NW MEDITERRANEAN CORALLIGENOUS REEFS

Abstract
CIGESMED for divers is a citizen science program developed in 2016 by an international scientific team. It aimed to provide a scientifically-based simplified protocol for recreational divers to get involved in the monitoring of coralligenous reefs. Between 2016 and 2021, about 150 observations were collected by volunteer divers in and around the area of the Calanques National Park (Marseilles, France). The data collected allowed the qualitative and semi-quantitative description of the benthic communities of 27 diving sites and the assessment of some natural and anthropic pressures. Data were analysed by gathering observations over three consecutive years to get enough data to reduce the observer bias, and to allow temporal comparisons of the most frequented diving sites. It was then possible to characterise the abundance of the main taxa, as well as the pressures that occurred in this habitat. Their variation over time was also highlighted. Considering the limitations imposed by scuba diving to citizens' involvement, as well as the lack of knowledge from recreational divers and diving instructors regarding coralligenous communities, those results were only made possible because of the enthusiastic coordination of a local network. Indeed, a diving and scientific organisation (Septentrion Environnement) proposed, every year, training sessions (theory and practice) and scheduled dives dedicated to CIGESMED for divers. By encouraging a feedback flow with the participants, it promoted the long-term involvement of citizens. CIGESMED for divers has proved to be an effective tool for the long-term monitoring of coralligenous reefs, particularly for local management purposes. It has also demonstrated to be a great tool for educational and training activities.

Key-words: long-term monitoring; coralligenous reefs; pressures; citizen science; local network

Introduction

Over the past decade, the active participation of volunteer divers has greatly assisted researchers in the inventory and monitoring of marine biodiversity (Thiel *et al.*, 2014) and it still continues. In the Mediterranean Sea, some notable examples of Citizen Science (CS) programs focused on marine biodiversity concern the study and monitoring of non-indigenous species (Giovos *et al.*, 2019; Zenetos *et al.*, 2013), vulnerable emblematic species (Bramanti *et al.*, 2011), aggregates of jellyfish and other gelatinous plankton (e.g. www.jellywatch.org), fish populations (Arvanitidis *et al.*, 2011), gorgonians and corals mortality and/or reproduction (e.g. Coral Alert! Observadores del Mar platform), or long-term variations in marine benthic rocky communities linked to climate change (Turicchia *et al.*, 2021).

Although a multitude of CS projects concern tropical coral reefs on a global scale, few focus on their Mediterranean counterparts: the coralligenous reefs. This is likely due to the depth at which this biocenosis usually develops, which requires more experienced scuba divers than for observing shallow water reefs. At the same time, the complex structure and remarkable biological and functional diversity contribute significantly to the high aesthetic value of coralligenous reefs (Tribot *et al*., 2016). Thus, they are extremely popular among scuba divers and are, without a doubt, among the most valued dive sites of the Mediterranean Sea.

In the framework of CIGESMED SeasEra (ERAnet) international project, the citizen science initiative "CIGESMED for divers" was launched in 2016 in France, Greece and Turkey. A simplified scientific protocol based on observation was created and theoretical training material was provided.

This initiative was launched to involve enthusiastic divers in the study and monitoring of Mediterranean coralligenous assemblages. It also aimed to introduce citizen to the gathering of basic information regarding the spatial occurrence and the assemblage structure of coralligenous reefs, as well as it participates to the awareness concerning pressures or threats that may be encountered (Gerovasileiou *et al.*, 2016). One of the objectives of CIGESMED for divers was to provide tools for recreational divers to continue to study and monitor coralligenous reefs after the official end of the CIGESMED project (2016). Willing to make divers aware of the ecological concerns in regard to coralligenous reefs and to promote their privileged position as the first observers of environmental changes, this initiative hand over the coordination to local actors and while maintaining a context of strong collaboration with scientists.

In this context, the partnership between Septentrion Environnement, *via* its citizen science platform POLARIS (Barth, 2020), and CIGESMED for divers has proven to be coherent and fruitful since its beginnings in 2016. POLARIS has become increasingly involved in the theoretical and practical training of diver-observers. It has developed a training process that is now autonomous and operational, which has proven to be essential for the effective application of the coralligenous habitat observation protocol. Two to three dive sessions per diving season are entirely dedicated to CIGESMED for divers which enable POLARIS to collect data and monitor coralligenous reefs year after year, particularly in the Calanques National Park (Gatti & Barth, 2020).

Six years after the beginning of this program, the data collected by volunteers have provided many information about coralligenous reefs communities in Marseilles' Bay, and the long-term monitoring of the most frequented diving sites has been initiated. This study aimed to discuss the initial objectives and the implementation strategy of CIGESMED for divers. More precisely, it identified which goals have been achieved, and discussed how to improve the dissemination strategy to support coralligenous reefs monitoring elsewhere in the Mediterranean Sea.

Materials and methods

The study area included 27 dive sites in the marine side of the Calanques National Park (Marseilles, France), in the NW Mediterranean Sea. With only two exceptions from the "buffer zone" (PNCAL-A-87, -64, and -141), most of the study sites was located in the "restricted zone" of the Park.

Data collection was supported by submersible slates provided to the volunteer divers. The slates contained all the required information for the characterization and assessment of coralligenous assemblages. More precisely, was observed a) the basic topographic and abiotic features for the preliminary description of each site; (b) the semi-quantitative abundance (abundance ranks: 0 - absent; 1 - rare; 2 - common; 3 - very common) of 23 typical conspicuous species distributed throughout the whole Mediterranean; and c) the semi-

quantitative abundance (abundance ranks: 0 - absent; 1 - limited; 2 - extended) of pressures and imminent threats (see Gerovasileiou *et al.*, 2016 for more details about the protocol).
Prior to their first dive considered in this study, all volunteers have participated to a theoretical and practical training provided by POLARIS' team. After the dive, each participant shared their data *via* the POLARIS' mobile application.
After checking the validity of the data, the number of observations collected in each diving site was computed in order to highlight the most frequented dive sites, which will be selected for long-term monitoring.
Data were analysed by gathering observations over three consecutive years (T0: 2016-2018; T1: 2018-2021) to reduce the observer bias, and to ensure that long-term monitoring of the most frequently visited sites was possible.
For coralligenous assemblage characterization, species were grouped according to their higher taxonomic affinity (Algae, Porifera, Cnidaria, Bryozoa, Crustacea, Echinodermata and Osteichthyes); endangered and protected species (according to IUCN Red List and local conservation measures) where grouped as well. The average abundance of each group (taxonomic and endangered/protected) per site was calculated as the sum of the average abundance of the species in each group. The temporal comparison of the assemblage composition and of the endangered/protected species was possible only for sites that presented sufficiently high and similar number of observations in the two periods (T0 and T1). The average abundance rank of each pressure and threat was computed taking into consideration all the study sites, in order to get an overview of their overall contribution and temporal variation in the Calanques National Park.

Results

Globally, 151 observations were collected between 2016 and 2021, including about 10% of non-exploitable contributions. The observed depth range varied from 11 m to 38 m. The observations were not evenly distributed among the study sites. In most of the sites, less than 5 observations were registered over T0+T1, while only 4 study sites had more than 10 observations (PNCAL_C_106, 103, 007 and PNCAL_A_087) (Fig. 1). The site PNCAL_C_106 was the only one that accounted for more than 20 observations almost evenly distributed between T0 and T1 (12 and 15, respectively). It was therefore selected for the temporal comparison of coralligenous assemblages that follows. The coralligenous reef of PNCAL_C_106 (Les Pharillons) developed on vertical walls from 14 m to 38 m depth and were exposed to all cardinal points. The bioconstruction was discontinuously distributed over an horizontal extent of more than 20 m and have shown medium to small crevices. Whatever the depth and time, the community was dominated by Cnidaria, followed by Algae (calcareous red algae and *Peyssonnelia* spp.), Porifera, Bryozoa and Osteichthyes; Echinodermata and Crustacea which were less represented (Fig. 2a). The temporal comparison between T0 and T1 highlighted negligible changes in protected/endangered species abundance (Fig. 2b) and in the majority of taxa, with the exception of Porifera which increased their abundance rank of more than 1 unit over time (Fig. 2a).
Pressures and threats over all study sites were mostly represented by "Organisms necrosis" and "Mucilaginous aggregations" at both T0 and T1, and did not changed over time. "*Asparagopsis* spp." was the second major pressure in T0, but dramatically decreased in T1. "*Caulerpa cylindracea*", "Fishing gear" and "Divers recklessness" contribution was less important, both showing a slight reduction over time. "Sedimentation" was also low, but lightly increased in T1. Finally, "Anchoring" and "Litter" have shown negligible abundance and temporal variation.

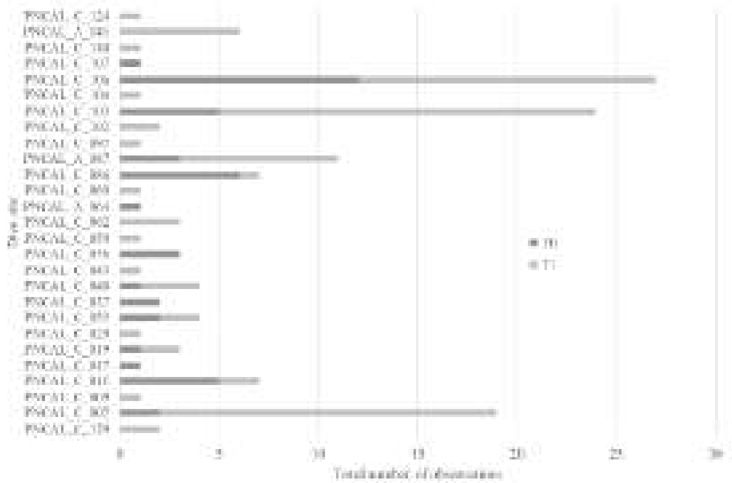


Fig. 1: Total number of observations collected in the Calanques National Park over 27 diving sites, and their distribution between T0 (dark grey) and T1 (light grey).

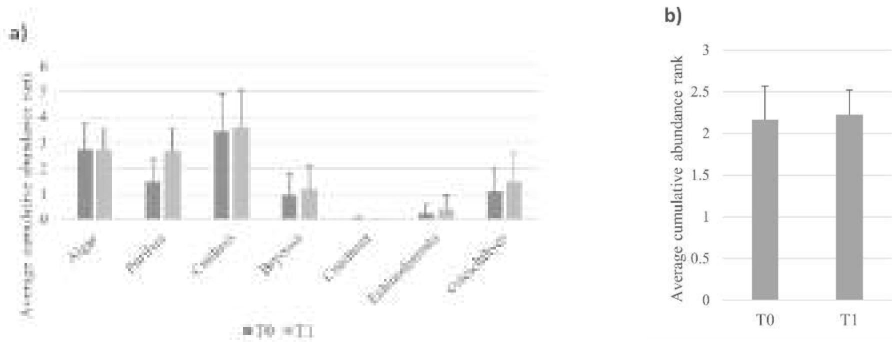


Fig. 2: Site PNCAL_C_106 (Les Pharillons) - a) Average (+SD) taxa abundance at T0 (dark grey) and T1 (light grey); b) average (+SD) abundance of protected/endangered species at T0 and T1.

Discussion and conclusion

The spatial distribution of the observations highlighted a very dispersed sampling effort. Since now, no limits were imposed to the participants on the choice of diving site. However, opting for a large set of sites reduced the number of observations in a site, as the replication process was then limited. The data acquired wasn’t sufficient to be analysed in a different way than descriptive purposes, or a long-term monitoring. At the same time, the results highlighted that a handful of sites were regularly frequented, because of their strategic position, protected from the prevailing winds in the area (NW and SE winds). A temporal analysis was possible in only one site: observations were carried out regularly at T0 and T1, which was not the case for the other sites. For these latest sites, it would be necessary to wait until T2 (2021-2024 data) to start a long-term monitoring. Then, from a scientific point of view, it would be useful to concentrate the dives dedicated to CIGESMED for divers (three per diving season, at Septentrion Environnement) on these few sites, in order to obtain enough data to continue monitoring. This strategy would be in agreement with the feedback received from other diving facilities that we have been trained to the protocol: most of them usually dive on the same sites (four to five at the most). It will therefore be useful to encourage them to choose a couple of sites to do CIGESMED for divers, in order to concentrate the sampling effort and obtain useful data for the long-term monitoring and statistical analyses. Nonetheless, during autonomous dives, volunteer observers will still have the opportunity to choose the observation site. Such information will feed the participative coralligenous database even if it is scattered.

The minimal changes observed for taxa between T0 and T1 were in agreement with the general characteristics of the coralligenous biocenosis, dominated by long-lived and slow-growing organisms (Ballesteros, 2004). The positive variation observed for Porifera could be traced to an improvement in the identification of *Agelas oroides* and *Cliona* spp. Volunteer divers have often shown difficulty in identifying those species, and this has led us to particularly insist on this issue during the training sessions. The same problem was encountered for the "Sedimentation" pressure, which however remained a particularly difficult element to identify for voluntary observers.

The overview of pressures and threats indicated “Organisms necrosis” as the most abundant at both T0 and T1 (Fig. 3). In fact, as in other areas of the NW Mediterranean Sea, the populations of gorgonians in the Calanques National Park are regularly affected by episodes of necrosis due to summer heat waves (Coma *et al.,* 2009). Some “Mucilaginous aggregations” were also observed each year. This pressure causes necrosis in several taxa of ecosystem engineers and an increase in algal turf, affecting the ecological state of the coralligenous biocoenosis (Piazzi *et al.*, 2018). The participative observation of these phenomena has contributed concretely to their long-term monitoring in the area. In the meantime, recreational divers have become aware of the impact of seawater warming on their favorite playground.

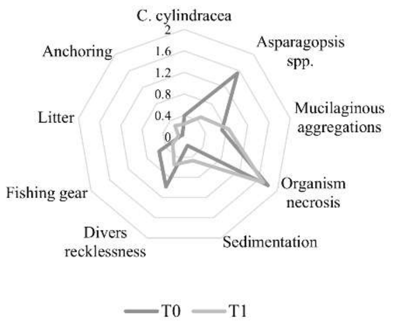


Fig. 3: Average abundance of each pressure and threat observed over all study sites at T0 (dark grey) and T1 (light grey).

CIGESMED for divers has proved to be an effective tool for the long-term monitoring of coralligenous reefs, particularly for local management purposes. It has also demonstrated to be a great tool for educational and training activities.

Considering the limitations imposed by scuba diving to citizens’ involvement, as well as the lack of knowledge from recreational divers and diving instructors regarding coralligenous communities, those results were only made possible because of the enthusiastic coordination of a local network, by the ONG Septentrion Environnement and its POLARIS platform, in constant interaction with the scientific team of CIGESMED for divers. By encouraging a feedback flow with the participants, the training sessions and the submersible slate were regularly improved and adapted according to their suggestions, reducing the observer bias and promoting the long-term involvement of citizens (Cerrano *et al.,* 2017).

CIGESMED for divers successfully took over the CIGESMED project in the monitoring of coralligenous reefs in France, as its implementation along the French Mediterranean coasts is now encouraged by the French Biodiversity Office through the MarHa Life project (2020-2022).

Bibliography

BARTH L. (2020) - *POLARIS - Plateforme d'Observation du Littoral Appliqué à la Recherche, à l'Information et à la Sensibilisation: Contribution aux programmes de recherche.* Septentrion Environnement, Marseille: 24 pp.

BRAMANTI L., VIELMINI I., ROSSI S., STOLFA S., SANTANGELO G. (2011) - Involvement of recreational scuba divers in emblematic species monitoring: The case of Mediterranean red coral (*Corallium rubrum*). *J Nat Conserv*, 19(5): 312-318.

CERRANO C., MILANESE M., PONTI M. (2017) - Diving for science-science for diving: volunteer scuba divers support science and conservation in the Mediterranean Sea. *Aquat Conserv*, 27(2): 303-323.

COMA R., RIBES M., SERRANO E., JIMÉNEZ E., SALAT J., PASCUAL J. (2009) - Global warming-enhanced stratification and mass mortality events in the Mediterranean. *PNAS*, 106(15): 6176-6181.

GATTI G., BARTH L. (2020) - *Présentation de résultats issus de données collectées à travers la plateforme de sciences participatives POLARIS dans le cadre du programme de recherche CIGESMED*. Septentrion Environnement, Marseille: 45 pp.

GEROVASILEIOU V., DAILIANIS T., PANTERI E., MICHALAKIS N., GATTI G., SINI M., DIMITRIADIS C., ISSARIS Y., SALOMIDI M., FILIOPOULOU I., DOĞAN A., THIERRY DE VILLE D'AVRAY L., DAVID R., ÇINAR M.E., KOUTSOUBAS D., FÉRAL J.P., ARVANITIDIS C. (2016) - CIGESMED for divers: establishing a citizen science initiative for the mapping and monitoring of coralligenous assemblages in the Mediterranean Sea. *Biodiver Data J*, 4: e8692.

GIOVOS I, KLEITOU P., POURSANIDIS D., BATJAKAS I., BERNARDI G., CROCETTA F., DOUMPAS N., KALOGIROU S., KAMPOURIS, T.E., KERAMIDAS I., LANGENECK J., MAXIMIADI M., MITSOU E., STOILAS V.-O., TIRALONGO F., ROMANIDIS-KYRIAKIDIS G., XENTIDIS N.-J., ZENETOS A., KATSANEVAKIS S. (2019) - Citizen-science for monitoring marine invasions and stimulating public engagement: a case project from the eastern Mediterranean. *Biol Invasions*, 21: 3707–3721.

PIAZZI L., ATZORI F., CADONI N., CINTI M.F., FRAU F., CECCHERELLI G. (2018) - Benthic mucilage blooms threaten coralligenous reefs. *Mar Environ Res*, 140: 145-151.

TURICCHIA E., PONTI M., ROSSI G., MILANESE M., DI CAMILLO C.G., CERRANO C. (2021) - The Reef Check Mediterranean Underwater Coastal Environment Monitoring Protocol. *Front Mar Sci*: 8:620368

ZENETOS A., KOUTSOGIANNOPOULOS D., OVALIS P., POURSANIDIS D. (2013) - The role played by citizen scientists in monitoring marine alien species in Greece. *Cah Biol Mar*, 54: 419-426.

Raouia GHANEM, BEN SOUISSI J., GARRABOU J.
Biodiversity, Biotechnology and Climate Change Laboratory (LR11ES09), Faculty of Sciences of Tunis, 2092 Tunis, University of Tunis El Manar, Tunisia.
Email : raouia-ghanem@hotmail.fr

REVIEW OF THE GEOGRAPHIC AND BATHYMETRIC DISTRIBUTION OF MAËRL BEDS IN TUNISIAN WATERS

Abstract
Maërl beds are aggregations of living and dead of free-living calcareous rhodophytes. These slow growing organisms that cover a wide benthic marine areas and are recurrent in fossil deposits are threatened by numerous anthropogenic activities particularly dredging, eutrophication and by changes in the dynamics of currents on the seafloor. Tunisian maërl communities have been poorly studied due to lack of taxonomic expertise and regular surveys. According to the scientific, grey literature, technical reports available, studies on the specific diversity and bathymetric distribution of these biogenic habitats in Tunisia are fragmentary, rare or even absent for many areas. In order to fill this gap, this study aimed to provide an overview of the geographic and bathymetric distributions of maërl beds of the Tunisian coast. Information was collected from literature review, local ecological knowledge surveys of divers and scuba diving between 2021 and 2022. The presence of Maërl beds is documented in the northern coasts at depths between 1-60 m. Nine maerl-forming algal species were identified in Tunisia; 8 Corallinaceae: Lithothamniom corallioides (P.Crouan & H.Crouan) P.Crouan & H.Crouan, 1867, Lithothamnion minervae Basso, 1995, Lithothamnion valens Foslie, 1909, Phymatolithon calcareum (Pallas) W.H.Adey & D.L.McKibbin ex Woelkering & L.M.Irvine, 1986, Neogoniolithon brassica-florida (Harvey) Setchell & L.R.Mason, 1943, Lithophyllum racemus (Lamarck) Foslie, 1901, Mesophyllum alternans (Foslie) Cabioch & M.L.Mendoza, 1998 and Mesophyllum lichenoides (J.Ellis) Me.Lemoine, 1928; and one Peyssonneliaceae: Peyssonnelia sp Rhodolith shape varied from non-spherical to spherical and rhodolith morphotypes ranged from rhodoliths with very thin and fine branches to rhodoliths having short finger-like branches. Information obtained in this work provides a first baseline for future monitoring and hope of guiding future conservation and management actions for maërl beds in Tunisia.

Key-words: *Maërl beds, Tunisia, Central Mediterranean, Coralline algae, Bioconcretion*

Introduction
Maërl beds are aggregations of free-living coralline algae that constitute habitats with a high species diversity over broad geographical and depth ranges and cover extensive benthic areas of subtidal environments worldwide (Sciberras *et al.*, 2009; Neves *et al.*, 2021). Rhodoliths could be unattached on the seabed (Bosence, 1983) or may form substantial beds in coarse, fine and muddy sediments (Foster 2001), from the tropics to polar waters and from the low intertidal zone down to more than 100 m deep (Foster 2001; Riosmena-Rodríguez *et al.*, 2017).
Due to their important longevity and their high biodiversity, the conservation importance of maërl beds is increasingly recognized. In addition and because these habitats can provide a variety of ecological niches for a highly diverse range of species, they constitute potential benefits for commercial fisheries (Hall-Spencer *et al*., 2008).

Although maërl beds are both of economic importance and conservation interest, data on their biogeography and their associated communities are lacking. Mapping these habitats is a basic step required to implement effective management and conservation measures. In general, there is a knowledge gap in the geographic and bathymetric distribution of maërl beds in the Mediterranean. However, information on the distribution of these assemblages along the southern Mediterranean coasts is very scarce. The information available in Tunisian marine waters was compiled over four decades ago by Azouz (1973) during investigations of dredged bottoms in northern Tunisia or extracted from benthic bionomics studies (Ben Mustapha *et al.*, 2002 a and b) or from some biodiversity inventories (Afli *et al*., 2005; Ben Mustapha & Afli, 2007; Ramos-Esplá *et al*., 2011).
The main goal of this work was to provide an updated overview of the distribution of maërl beds found in Tunisian marine waters.

Materials and methods

The study was carried out along Tunisian coasts including the main islands. To present the information on the distribution of maërl beds along Tunisian coasts, three sectors were considered:

- Sector 1, from the Algerian border to Kélibia, which covers 393 km of coastline and is part of the western basin of the Mediterranean Sea (WMED);
- Sector 2 comprises the area between Kélibia and Ras Kapudia (261 km of coastline) and;
- Sector 3 from Ras Kapudia to the Libyan border, including the Gulf of Gabès (482 km coastline).

A literature survey was carried out using several bibliographic databases for the period from 1950 to the present. The research was done using different combinations of keywords, such as Mediterranean, maërl beds, bioconcretion, benthic biocenoses, and Tunisia. In addition, information was obtained from technical reports published by Tunisian national institutions. The site coordinates were taken from either the references or the maps included in the publications. Species occurrences were also obtained from the LEK approach via interviews with professional and recreational divers. A total of 9 interviews were conducted. To ensure the quality of the information acquired, the interviews were performed by showing photographs of the maërl beds. A total of 5 localities were surveyed for the presence of maërl beds using scuba diving. The sites were selected after analyzing the literature and the results of the LEK surveys of divers, and were based on information on the nature of the bottom. The surveys were conducted also in insular areas (Table 1). Diving surveys were carried out to a maximum depth of 40 m and for each site, GPS coordinates were recorded.

Results

Maërl beds are almost present in the northern coasts at depths between 1-60 m. Nine maërl-forming algal species were identified in Tunisia; 8 Corallinaceae: *Lithothamniom corallioides* (P.Crouan & H.Crouan) P.Crouan & H.Crouan, 1867, *Lithothamnion minervae* Basso, 1995, *Lithothamnion valens* Foslie, 1909, *Phymatolithon calcareum* (Pallas) W.H.Adey & D.L.McKibbin ex Woelkering & L.M.Irvine, 1986, *Neogoniolithon brassica-florida* (Harvey) Setchell & L.R.Mason, 1943, *Lithophyllum racemus* (Lamarck) Foslie, 1901, *Mesophyllum alternans* (Foslie) Cabioch & M.L.Mendoza, 1998 and *Mesophyllum lichenoides* (J.Ellis) Me.Lemoine, 1928; and one

Peyssonneliaceae: *Peyssonnelia sp* (Tab.1). Rhodolith shape varied from non-spherical to spherical and rhodolith morphotypes ranged from rhodoliths with very thin and fine branches to rhodoliths having short finger-like branches.

Table 1. Maërl beds distribution in Tunisian waters with geographic position, depth range and source of information

Sector	Locality	GPS Coordinates	Depth (m)	Species	Source
Sector 1	Tabarka	36°58’646”N 8°44’499”E	15-25	*Lithothamniom corallioides, Mesophyllum sp*	This study
		36°58’505”N 8°45’216”E	25	*Lithothamniom corallioides*	This study
	Galite Island	37°29’53”N 8°53’09”E	35- 62	*Lithothamnion valens, L. minervae, Lithophyllum racemus, Phymatolithon calcareum*	Andromède (2010a)
	Cap Serrat Cap Negro	37°14’32”N 9°13’22”E	15- 20	Peyssonneliacea and Corallinacea	PNUE/PAM-CAR/ASP, 2016
	Bizerte	37°15’10”N 9°59’30”E	0.5- 3	*Lithothamniom corallioides*	This study
	Cani Island	37°21’220”N 10°07’450”E	25-40	---	LEK Survey
	Banc Esquerquis	37°45’200”N 10°48’620”E	15-60	---	LEK Survey
	Zembra Island	37°08'441"N 010°47'736"E	5- 15	*Lithothamniom corallioides, Mesophyllum sp, Phymatolithon calcareum*	Andromède (2010b) &This study
		37°08'200"N 010°48'160"E	0 -15	*Lithothamniom corallioides, Mesophyllum sp*	Andromède (2010b) &This study
	Haouaria	37°02’607”N 11°04’650”E	15-18	*Mesophyllum sp*	This study
		37°03’11”N 10°58’51”E	3-5	*Lithothamniom corallioides, Phymatolithon calcareum*	This study
		37°03’48”N 11°00’19”E	7	*Mesophyllum sp*	This study
Sector 2	Banc Korba	36°31’870”N 11°05’810”E	25-35	*Mesophyllum sp*	This study
	Banc Hallouf	35°34’650”N 11°32’050”E	39- 45	*Lithothamnion* sp.	Ben Mustapha & Afli, 2007
	Kuriat Islands	35°46’12”N 11°00’07”E	0.5-7	*Lithothamnion sp, Lithophyllum sp, Mesophyllum sp*	CAR/ASP - PNUE/PAM, 2014
		35°48’21”N			

		11°02’03”E			
Sector 3	Kerkennah Island	34°33’48”N 11°19’54”E	21-45	*Lithothamnion corallioides, L. minervae, Phymatolithon calcareum* et *Mesophyllum alternans*	Ramos Espla *et al.*, 2011
	Bibane Lagoon	33°18’15”N 11°11’53”E	---	*Neogoniolithon brassica-florida*	Langar *et al.*, 2011

Discussion and conclusions

In this study, we have provided comprehensive geo-referenced data on the geographic distribution and bathymetric ranges of maërl beds in the Tunisian coastal waters by conducting field work and gathering all published information. This effort provided a compilation of information and new records for Tunisian waters for several species in different areas. A total of nine species of rhodoliths were found in Tunisian waters. The depth range of the rhodolith beds described in the present study varied between 0.5 and 62 m even though the depth range for all the sites where rhodolith-forming species were observed/reported is much larger (8–129 m) (Rebelo *et al*., 2018; Otero-Ferrer *et al.*, 2020).

As maërl depend on light interception and absorption for photosynthesis, depth is determined by water turbidity which could explain its presence on high depths in insular sites.

Maërl beds are threatened by numerous anthropogenic activities including dredging, eutrophication, fishing, and mariculture (Ballesteros 2006). In Tunisian coasts, the main threat to maërl beds is from bottom trawling (Ramos Espla *et al*., 2011).

Maërl beds are now receiving local and international protection and some maerl-forming species such as *Lithothamnion corallioides* and *Phymatolithon calcareum* are both included in Annex V of the EC ‘Habitats Directive’ 1992. In fact, the review of the distribution and richness of these biodiversity hotspots in Tunisian waters could be considered a basic step that will contribute to the implementation of management and conservation strategies for these emblematic Mediterranean habitats.

Bibliography

AFLI A., BEN MOSTAPHA K., JARBOUI O., BRADAI N., HATTOUR A., LANGAR H., SADOK S. (2005) - La biodiversité marine en Tunisie. *Ministère de l'Environnement et du Développement Durable. Direction Générale de l’Environnement et de la Qualité de la vie (DGEQV)*. 20 pp.

ANDROMEDE. (2010a) - Etude et cartographie des biocénoses marines de l’archipel de la Galite, Tunisie. Initiative pour les petites îles de Méditerranée. Contrat OEil d’Andromède/Agence de l’eau. 132 pp.

ANDROMEDE. (2010b) - Etude et cartographie des biocénoses marines de l’île de Zembra, Tunisie. Initiative pour les petites îles de Méditerranée. Contrat OEil d’Andromède/Agence de l’eau. 122 pp.

AZOUZ A. (1973) - Les fonds chalutables de la région Nord de la Tunisie. 1: Cadre physique des côtes Nord de la Tunisie. *Bull. Inst. Océanogr. Pêche Salammbô,* 2, 473- 564.

BALLESTEROS E (2006) Mediterranean coralligenous assemblages: a synthesis of present knowledge. Oceanogr Mar Biol Annu Rev 44:123–195

BEN MUSTAPHA K., AFLI A. (2007) - Quelques traits de la biodiversité marine de Tunisie: Proposition d'aires de conservation et de gestion. Report of the MedSudMed Expert Consultation on Marine Marine Protected Areas and Fisheries Management. MedSudMed Technical Documents. Rome (Italy), pp. 32-55.

BEN MUSTAPHA K., RIVEILL S., EL ABED A - (2002) a - Données récentes sur la présence de l'herbier à posidonie, de la biocénose coralligène et des démosponges signalées au golfe de Tunis et dans les zones adjacentes. In « Elaboration d'une étude de création d'aires marines protégées et de récifs artificiels. 1 Le Golfe de Tunis. ». 63-77.

BEN MUSTAPHA K., EL ABED A., KOMATSU T., SOUISSI A., SAMMARI C., ZARROUK S., HATTOUR A. (2002) b - Tunisian mega benthos from infra (Posidonia meadows) and circalittoral (coralligenous) sites. *Bull. Inst. Natn. Scien. Tech. Mer de Salammbô*, 29, 1-15.

CAR/ASP - PNUE/PAM (2014) - Elaboration d'un Plan de Gestion pour l'Aire Marine et Cotiere Protegee des iles Kuriat (Tunisie) - Phase 1: Bilan et Diagnostic. Par Thetis-Cabinet Sami Ben Haj. Ed. CAR/ASP - Projet MedMPAnet, Tunis : 72 p + annexes.

FOSTER MS (2001) Rhodoliths: between rocks and soft places. *Journal of Phycology*, 37:659–667. https://doi.org/10. 1046/j.1529-8817.2001.00195.x

HALL-SPENCER J. M., KELLY J., MAGGS C. A. (2008) - Assessment of maërl beds in the OSPAR area and the development of a monitoring program. Department of the Environment HaLGD, Ireland (ed). 34 p.

LANGAR H., BESSIBES M., DJELLOULI A., PERGENT-MARTINI C., PERGENT G. (2011) - The *Neogoniolithon brassica-florida* (Harvey) Setchell & LR Mason (1943) Reef of Bahiret el Bibane Lagoon (Southeastern Tunisia). *Journal of Coastal Research*, *27*(2), 394-398.

NEVES P., SILVA J., PEÑA V., RIBEIRO C. (2021) - "Pink round stones"—rhodolith beds: an overlooked habitat in Madeira Archipelago. *Biodiversity and Conservation*, 30(12), 3359-3383.

OTERO-FERRER F, COSME M, TUYA F., ESPINO F., HAROUN R. (2020) - Effect of depth and seasonality on the functioning of rhodolith seabeds. Estuar Coast Shelf Sci 235:106579. https://doi.org/10.1016/j.ecss.2019.106579

PNUE/PAM-CAR/ASP (2016) - Cap Negro-Cap Serrat. Cartographie des habitats marins clés de Méditerranée et initiation de réseaux de surveillance. Par Torchia G., Rais C., Pititto F., Langar H., Bouafif C., Abidi A., Trainito E., Romano C., Dragan M., Camisassi S., Tronconi D., Berutti P., Sghaier Y.R. & Ouerghi A. Ed. CAR/ASP - Projet MedKeyHabitats, Tunis. 78 p + Annexes.

RAMOS-ESPLÁ A.A. AYADI H., MOUELHI S. HATTOUR A. DRIRA Z. ELAOUANI J. EL LAKHRACH H. GUERMAZI W. IZQUIERDO A. JIMÉNEZ-ESCOBAR E. VALLE C. VÁZQUEZ M. ZAKHAMA-SRAIED R. AFLI A. BRADAI M.N., DRAIEF M.N., BEN MUSTAPHA K. (2011) - Protection de ressources marines du golfe de Gabès: Inventaire et suivi des espèces lagunaires, marines et introduites. Rapport final, Don Nº : TF054942-TN. Institut National des Sciences et Technologies de la Mer, Banque Internationale pour la Reconstruction et le Développement. 557 p + annexes.

REBELO AC, JOHNSON ME, QUARTAU R., RASSER M. W., MELO C.S., NETO A. I., TEMPERA F., MADEIRA P., ÁVILA S.P. (2018) - Modern rhodoliths from the insular shelf of Pico in the Azores (Northeast Atlantic Ocean). Estuar Coast Shelf Sci 210:7–17. https://doi.org/10.1016/j.ecss. 2018.05.029

RIOSMENA-RODRÍGUEZ R., NELSON W., AGUIRRE J. (eds) (2017) - Rhodolith/Maërl beds: a global perspective. Springer, Cham.

SCIBERRAS M., RIZZO M., MIFSUD J. R., CAMILLERI K., BORG J. A., LANFRANCO E., SCHEMBRI P. J. (2009) - Habitat structure and biological characteristics of a maerl bed off the northeastern coast of the Maltese Islands (central Mediterranean). *Marine biodiversity*, *39*(4), 251-264.

Carlos JIMENEZ, PETROU A., PAPATHEODOULOU M., RESAIKOS V.
Enalia Physis Environmental Research Centre, Acropoleos 2, Aglantzia 2101, Nicosia, Cyprus
E-mail: c.jimenez@enaliaphysis.org.cy

NO ONE IS SAFE: DESTRUCTION OF CORALLIGENOUS CONCRETIONS AND OTHER BENTHIC SCIAPHILIC COMMUNITIES IN THE MPA CAPE GRECO (CYPRUS)

Abstract
In the current state of a changing world, understanding the role of disturbance, anthropogenic or natural, as a driving force behind biodiversity, communities, and habitats and ecosystems is more relevant than ever. On-going mass-mortality events in the marine realm are only surpassed by the consequences of man-made activities. This study assessed the dramatic destruction of coralligenous concretions and benthic sciaphilic communities in the MPA Cape Greco (Cyprus), which was documented a few days after large vessels anchored in the MPA's buffer zone at the beginning of 2021. At 23m depth, more than 30 large boulders (the largest ca. 12m^3) were dislodged or broken off from the rocky sea bottom and displaced far from the detachment points. It was also observed meters-long scars on the bottom, large slabs and sockets from where the broken pieces of rock came from. Anchors and chains from large vessels usually leave this tell-tale type of damage. Sciaphilic communities that originally thrived below the large boulders were directly exposed to sunlight. The absence of clear signs of necrosis and onset of general mortality in those organisms at the time of the initial survey, suggests that the destruction occurred a few days before the visit. In order to document the damage on those communities, the benthic cover was determined with the use of photo-quadrats and assigned to main categories, such as live/necrotic/dead corals, calcareous algae, and sponges. The preliminary results suggest that important sciaphilic biodiversity was affected and irremediably lost. Given that many of these species are usually confined to dark habitats, mortality is usually the final outcome when exposed to direct sunlight for prolonged periods of time and to predation by biological agents. The damage to the sea bottom and biodiversity was of geological proportions.

Key-words: Disturbance, dark habitat, coral mortality, biodiversity loss, human impact

Introduction
In the actual scenario of a changing world, understanding the role of disturbance, natural or anthropogenic, as a driving force behind selection, resilience, biodiversity, communities, assemblages and entire habitats and ecosystems is more relevant than ever (Coleman & Wernberg, 2020; Gissi *et al.*, 2021). Mass-mortality events in the marine realm, causing a plethora of effects on various time scales, are often exacerbated by the consequences of man-made activities (Newman, 2019; Gissi et al, 2021; Garrabou *et al.*, 2022). Even deep-sea habitats are not spared from ecosystem-scale changes. Coastal areas are particularly affected by disturbances of land and sea origins (Ingrosso *et al.*, 2018). It is crucial to study ecological disturbances and to record their impacts on the marine communities in order to formulate realistic conservation and management activities (Newman, 2019). In the present study, we evaluated the percentage of epibenthic cover in a boulder field area at 23-27m depth in the MPA Cape Greco (Cyprus), before and after the dramatic alteration of the bottom topography due to

anthropogenic activities that dislodged and moved large boulders in January/February 2021. We postulate that the ultimate fate of the coralligenous accretions and sciaphilic communities that originally were under the boulders (dim, semi-dark environments), will be an extensive mortality due to the unnatural position of flipped-over boulders.

Materials and methods

The MPA Cape Greco (Natura 2000, CY3000005), eastern coast of Cyprus in the Levantine Sea (Fig.1), harbours important marine habitats, such as *Posidonia oceanica* meadows, rocky reefs and shores, vermetid platforms, dark habitats including partially submerged caves, coralligenous concretions, and rhodoliths. The specific place of the study is a boulder field within the buffer zone of the MPA (34.973183° Lat., 34.082233° Lon.), which has been monitored by our research team since 2010 and on a systematic way (photo-quadrats) since 2016 (EU project PROTOMEDEA, Towards the establishment of Marine Protected Area Networks in the Eastern Mediterranean) and on a seasonal frequency since 2021 (LIFE-IP Physis, Managing the Natura 2000 network in Cyprus and shaping a sustainable future). The epibenthic communities were recorded with photos taken every 25cm using a 13cm x 19 cm frame along transect lines following the contours of the boulders' exposed (lit) surface (Fig.2). For the purpose of this preliminary study, we concentrate on two surveys (July 2016 and February 2021). From the pool of photos (n=187) positioned over boulders (not on sand, pebbles or crevices), 33 from each survey were randomly selected. The benthic cover was calculated using photoQuad image processing software (Trygonis & Sini, 2012) with a systematic lay-out of 200 points.

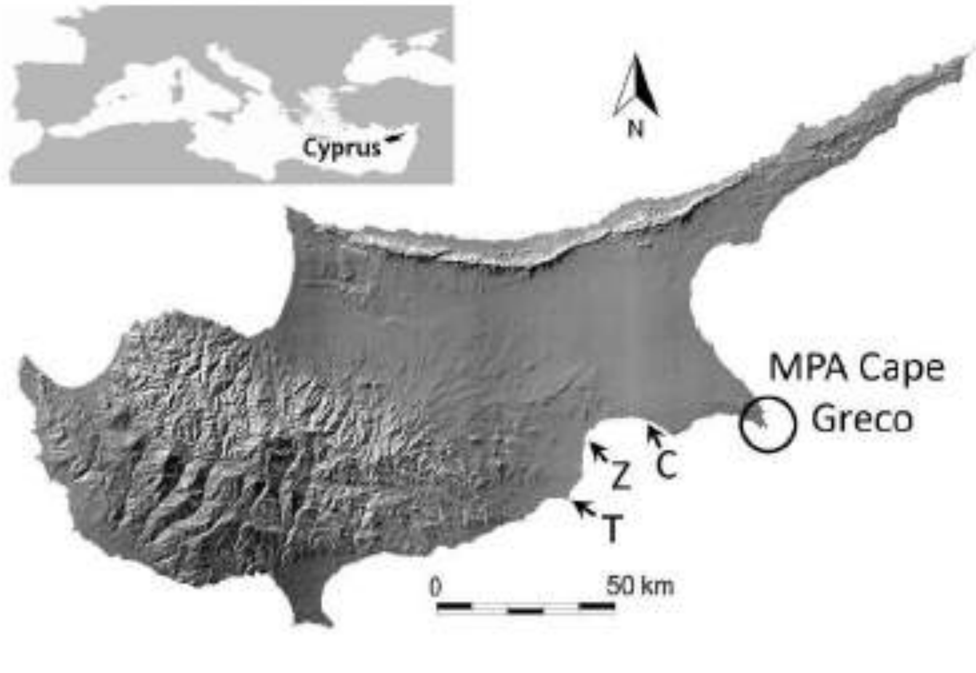


Fig. 1: Location of the MPA Cape Greco (Cyprus, Levantine Sea) where alteration of the sea bottom and extensive destruction of coralligenous concretions and sciaphilic communities were documented in 2021. Position of shipwrecks mentioned in the text: T=Touba, Z=Zenobia, C=Cricket.

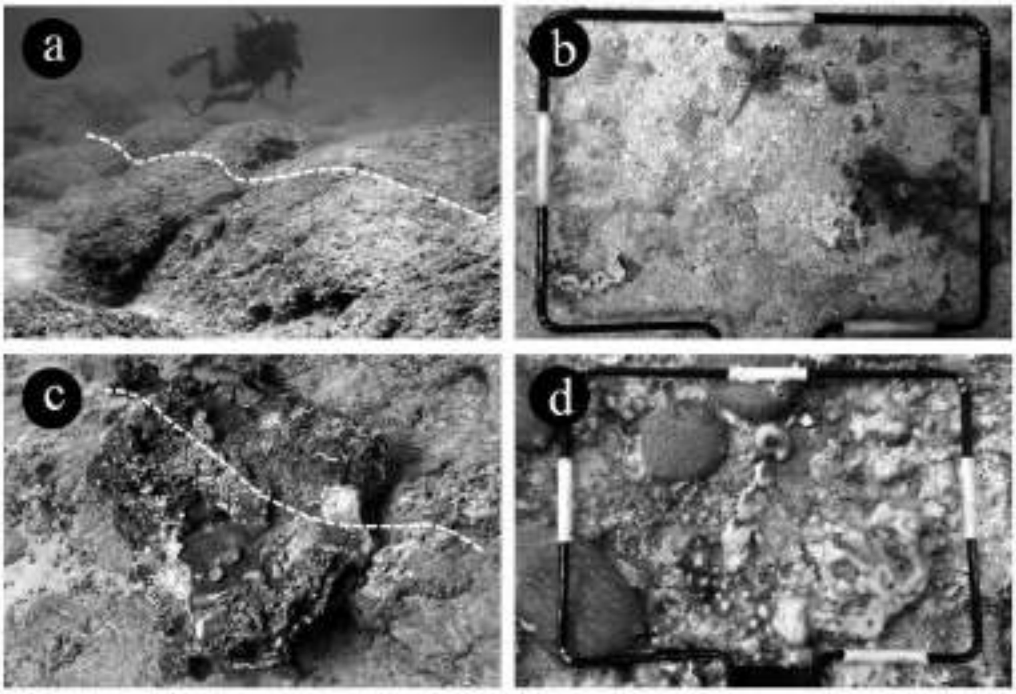


Fig. 2: Epibenthic communities surveys in July 2016 (a, b) and February 2021 (c, d) at the boulder field in MPA Cape Greco. Quadrats (13cmx19cm) where laid along transects (dashed line) following the sea bottom heterogeneity provided by the boulders (23-27m depth). Volume of flipped-over boulder (c) approximately 2m^3.

Sessile organisms (>1mm) were identified to the lowest taxonomic group and percentage of cover was classified into nine main categories (substrate, calcareous algae, macroalgae, bryozoans, cyanobacteria, sessile molluscs, porifera, corals, and other organisms) according to other similar surveys in Cyprus (Jimenez *et al.*, 2017a, 2017b). Here, the analysis of the data will be limited to these categories as a whole; a more detailed description of the data and analysis is in preparation. Diversity among the two surveys (2016, 2021) was examined using Shannon-Wiener diversity index (H'), Species richness (S), and Pielous evenness (P). Statistical analysis for the comparison of the community structures across the two surveys were conducted using the 'vegan' package in the software R, version 4.0.2. Species compositions were clustered into single matrices per session, and plotted using Non-Metric Multi-Dimensional Scaling (NMDS) based on Bray Curtis dissimilarity distance matrices of 0.05, and a stress value of 0.11 (k =2, trymax = 500). To test whether the centroids of the clusters from the NMDS differed, a Permutational Multivariate Analysis of Variance using Distance Matrices known as adonis was performed (permutations = 1000, method = Bray, level = 0.05). Then to identify which of the nine benthic categories, fed into the separation of the clusters a MAVONA and an Analysis of Variance (aov) was run (level = 0.05).

Results

During a particular period of unsettled weather, strong winds and hight swells, large vessels anchored at sheltered areas in the MPA's buffer zone at the beginning of 2021. A few days after, at 23m depth, more than 30 large boulders (the largest ca. 12m^3) were dislodged or broken-off from the rocky sea bottom and displaced far from the detachment points. It was also observed meters-long scars on the bottom, large slabs and sockets from where the broken pieces of rock came from. Sciaphilic communities that originally thrived below the large boulders were directly exposed to sunlight (Fig. 2c). The absence of clear signs of necrosis and onset of general mortality in those organisms at the time of the initial survey (Fig. 2d), suggests that the destruction occurred a few days before the visit. These exposed sciaphilic communities unnaturally increased epibenthic diversity. The indices revealed that the community composition that describes the 2021 survey (H'= 1.625, S=9, P=0.739) has a greater overall diversity compared to 2016 (H'=0.883, S=5, P=0.549). This is a result of a combined increase in the total number of species/categories present in the area, and a more equally distributed species/categories abundance.

The NMDS and adonis (R^2=0.26, p=0.001) have shown that the surveys in 2016 and 2021 were classified with different community compositions (graphics not shown here). The 2016 had a greater abundance in the species categories Macroalgae and Calcareous algae, while the 2021 survey had a higher composition in the species categories Bryozoan, Corals, Porifera, Cyanobacteria and Mollusca. This analysis is further supported by the Analysis of Variance (aov), which revealed that clustering was a result of the categories Macroalgae (F=172.1, p<0.001), Calcareous algae (F=99.6, p<0.001), Cyanobacteria (F=35.8, p<0.001), Mollusca (F=16.06, p<0.001), Porifera (F=131.9, p<0.001), Bryozoan (F=47.2, p<0.001), Corals (F=460.2, p<0.001), and others (F=4.8, p=0.03).

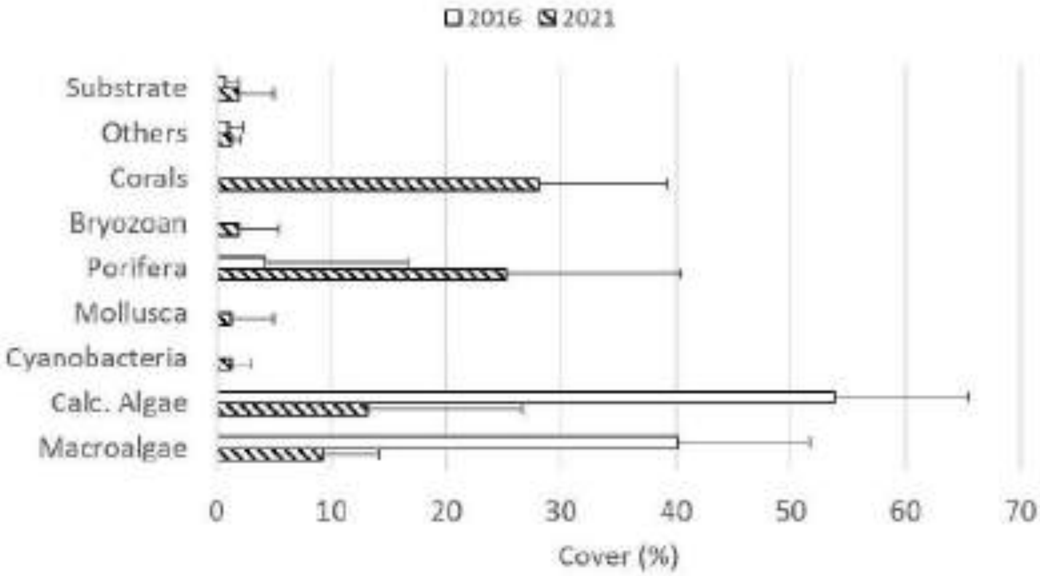


Fig. 3: Percent benthic cover (mean±1SD) at the boulder field in 2016 and 2021 according to nine categories.

The categories and the corresponding mean percentage of benthic cover (Fig. 3) clearly show the unnatural epibenthic composition of the communities found in the 2021 survey. Four of the categories found in 2021 (coral, bryozoan, Mollusca and cyanobacteria) on the surface of the boulders exposed to the light, were absent in 2016. The species in two categories, coral (ca. 28% cover; *Madracis pharencis*) and bryozoan (ca. 2% cover; *Celleporina caminata*), for example, are known members of sciaphilic communities and rarely or almost never are found on flat surfaces exposed directly to light. The composition of species in the other categories that appeared in both surveys, such as Porifera, is also different. The species in the 2021 survey (ca. 25% cover) tend to be more cryptic and abundant in semi-dark habitats (e.g., encrusting *Spirastrella cunctatrix*) than the species in 2016 (e.g., massive *Sarcotragus* sp.).

Discussion and conclusions

We have documented a large-scale destruction of the sea bottom at a boulder field in MPA Cape Greco. Incipient coralligenous accretions and sciaphilic communities were left exposed, on an unnatural position, directly to the light. The percentage of cover from two main components of the sciaphilic communities in the affected area, is not negligible. For illustrative purposes, selected available information of percentage of cover of coral and sponges, from other sciaphilic communities in south-eastern Cyprus (Fig. 1) is presented in Tab.1. The artificial substrates (metallic shipwrecks) are 42 to 74 years old and exhibit well developed sciaphilic communities and incipient biogenic (coralligenous) accretions. The communities that developed in the dim and dark undersides of the boulders, were of unknown age and in comparison, exhibited high percentages of cover. It is necessary to point out that these are communities that developed on natural substrate and are considered important repositories biodiversity.

Table 1: Percentage of cover (mean±SD) of coral and sponge from the shipwrecks Touba, Cricket and Zenobia (Thermistor station), and at the boulder field in the MPA Cape Greco.

Substrate characteristics	Coral	Sponge	Reference
Touba wreck, sunk 1974, 35 m depth	8.6±9	26.9±27	Jimenez *et al.* 2017a
Cricket wreck, sunk 1947, 32 m depth	19.3±13	27.6±26	Jimenez *et al.* 2017a
Zenobia wreck, sunk 1980, 17-42m depth	25.1±6	6.3±7.8	Jimenez *et al.* 2017b
Large boulders, 23-27m depth	29.1±11	25.2±15	This study

Which was the agent of change that modified to such extent the topography of the boulder field? Scars, tracks, ruts and broken slabs of rock all over the boulder field are circumstantial evidence of dragging across and hauling over heavy boulders. Sizable anchors, cables and chains from large vessels usually leave this tell-tale type of damage (e.g., Giglio *et al.,* 2017). We are not making mountains out of mole hills. The extent of the bottom modification (e.g., uprooting, dislodgement, and displacement of boulders) and its associated destruction of coralligenous concretions and other sciaphilic communities, is beyond any reasonable doubt an unprecedented mortality agent in the study area. Sciaphilic communities that originally thrived below the large boulders were directly exposed to sunlight. During subsequent visits to the boulder field in 2021, widespread mortality and necrosis of organisms increased with time (Jimenez, unpublished data). Given that many of these species are usually confined to dark habitats, mortality is usually the final outcome when exposed to direct sunlight (i.e., UV irradiation) for prolonged periods of time and to predation by biological agents.
The type of anthropogenic disturbance (mechanical) and extent of the damage surpassed any other ecological or biological factors of change that would have otherwise regulated the sciaphilic communities at 23-27m depth in the affected area of MPA Cape Greco. It was a sea bottom transformation of an almost geological scale. This poses a challenge for the management and conservation of the high biodiversity found in the coralligenous concretions and sciaphilic communities of MPA Cape Greco. Enforcement of regulatory measures for vessel transit and, in particular, anchoring is necessary to prevent further deterioration of the

boulder field and other areas in the MPA. Lastly, it is only through periodic monitoring and long-time series that changes are easier to detect (Bianchi *et al.*, 2022).

Acknowledgements

This study was possible by funding provided by ProtoMedea Project (MARE/2014/41 [SI2.721917]) and LIFE-IP (Physis LIFE18 IPE/CY/000006) for the 2016 and 2021surveys, respectively. We acknowledge the support of Mr Nick Galea to ENALIA's research program.

Bibliography

BIANCHI C.N., AZZOLA A., COCITO S., MORRI C., OPRANDI A., PEIRANO A., SGORBINI S., MONTEFALCONE M. (2022) - Biodiversity Monitoring in Mediterranean Marine Protected Areas: Scientific and Methodological Challenges. *Diversity* 14:43.

COLEMAN M.A, WERNBERG T. (2020) The Silver Lining of Extreme Events. *Trends Ecol. Evol.* 35: 1065-1067.

GARRABOU J., GÓMEZ-GRAS D., MEDRANO A., CERRANO C., PONTI M., SCHLEGEL R., BENSOUSSAN N., TURICCHIA E., SINI M., GEROVASILEIOU V., TEIXIDO N., MIRASOLE A., TAMBURELLO L.,CEBRIAN E., RILOV G., LEDOUX J., SOUISSI J., KHAMASSI F.,GHANEM R., BENABDI M.,GRIMES S., OCAÑA O., BAZAIRI H., HEREU B., LINARES C., KERSTING D., ROVIRA G., ORTEGA J., CASALS D., PAGÈS-ESCOLÀ M., MARGARIT N., CAPDEVILA P., VERDURA J., RAMOS A., IZQUIERDO A., BARBERA C., RUBIO-PORTILLO E., ANTON I., LÓPEZ-SENDINO P., DÍAZ D., VÁZQUEZ-LUIS M., DUARTE C., MARBÀ N., ASPILLAGA E., ESPINOSA F., GRECH D., GUALA I., AZZURRO E., FARINA S., GAMBI M., CHIMIENTI G., MONTEFALCONE M., AZZOLA A., MANTAS T., FRASCHETTI S., CECCHERELLI G., KIPSON S., BAKRAN-PETRICIOLI T., PETRICIOLI D., JIMENEZ C., KATSANEVAKIS, S., KIZILKAYA Z., INCI T., KIZILKAYA Z., SARTORETTO S., ELODIE R., RUITTON S., COMEAU S., GATTUSO J. HARMELIN J. (2022) - Marine heatwaves drive recurrent mass mortalities in the Mediterranean Sea, *Global Change Biology*. pp. 1–18.

GIGLIO V.J., TERNES M.L.F., MENDES T.C., CORDEIRO C.A.M.M., FERREIRA C.E.L. (2017) - Anchoring damages to benthic organisms in a subtropical scuba dive hotspot. *J. Coast. Conserv*. 21: 311–316.

GISSI E., MANEA E., MAZARIS A.D., FRASCHETTI S., ALMPANIDOU V., BEVILACQUA S., COLL M., GUARNIERI G., LLORET-LLORET E., PASCUAL M., PETZA D., RILOV G., SCHONWALD M., STELZENMÜLLER V., KATSANEVAKIS S. (2021) - A review of the combined effects of climate change and other local human stressors on the marine environment. *Sci. Total Env. 755*: 142564.

INGROSSO G., ABBIATI M., BADALAMENTI F., BAVESTRELLO G., BELMONTE G., CANNAS R., BENEDETTI-CECCHI L., BERTOLINO M., BEVILACQUA S., BIANCHI C.N., BO M., BOSCARI E., CARDONE F., CATTANEO-VIETTI R., CAU A., CERRANO C., CHEMELLO R., CHIMIENTI G., CONGIU L., CORRIERO G., COSTANTINI F., DE LEO F., DONNARUMMA L., FALACE A., et al. (2018) MEDITERRANEAN BIOCONSTRUCTIONS ALONG THE ITALIAN COAST. ADV. MAR. BIOL., 79: 61-136.

JIMENEZ C., HADJIOANNOU L., PETROU A., ANDREOU V., GEORGIOU A. (2017a)- Fouling Communities of Two Accidental Artificial Reefs (Modern Shipwrecks) in Cyprus (Levantine Sea) *Water* 9: 1-11.

JIMENEZ C., ANDREOU V., EVRIVIADOU M., MUNKES B., HADJIOANNOU L., PETROU A., ABU ALHAIJA R. (2017b) - Epibenthic communities associated with unintentional artificial reefs (modern shipwrecks) under contrasting regimes of nutrients in the Levantine Sea (Cyprus and Lebanon). *PLoS ONE*, 12: e0182486.

NEWMAN E. A. (2019) - Disturbance Ecology in the Anthropocene. Front. Ecol. Evol. 7:147.

TRYGONIS V., SINI M. (2012) photoQuad: a dedicated seabed image processing software, and a comparative error analysis of four photoquadrat methods. *J. Exp. Mar. Biol. Ecol*. 424-425, 99-108.

Silvija KIPSON, YAHYAOUI A., AISSI M., OUERGHI A., ROBERT A., TUNESI L., RENDE F., AGNESI S., ANNUNZIATELLIS A., ANGIOLILLO M., GIUSTI M., BADDREDINE A., MAVRIČ B., BERNARDEAU ESTELLER J.A., DÍAZ D., MASSUTÍ E., TAŞKIN E., ÇINAR M.E., GARRABOU J
SEAFAN-marine research & consultancy, Voltino 14, 10000 Zagreb, Croatia
E-mail: silvija.kipson@gmail.com

CORALLIGENOUS AND OTHER CALCAREOUS BIO-CONCRETIONS WITHIN THE INTEGRATED MONITORING AND ASSESSMENT PROGRAMME OF THE MEDITERRANEAN SEA

Abstract
The aim of this work was to assess the implementation status of the Integrated Monitoring and Assessment Programme (IMAP) with the emphasis on two Common Indicators (CIs) related to marine habitats: CI1 - Habitat distributional range and CI2 - Condition of the habitat's typical species and communities. Here we focus on coralligenous and other calcareous bio-concretions (algal platforms/rims, vermetid reefs, Cladocora caespitosa *reefs and rhodolith beds) and elaborate on elements such as scales of monitoring, scales of assessment and assessment criteria as well as threshold and baseline values retrieved from the available data, obtained through extensive literature review and consultation with experts. The analysis revealed that at least one of the selected biogenic habitats was represented in the national monitoring programmes of 70% of the Contracting Parties (CPs) to the Barcelona Convention. The information was unavailable for 15% of CPs. Herein we discuss a way towards a more standardized and coherent monitoring and assessment of the IMAP Common Indicators related to marine habitats in preparation of the 2023 Mediterranean Quality Status Report.*

Key-words: Barcelona Convention, IMAP, GES, biogenic habitats, coralligenous habitat

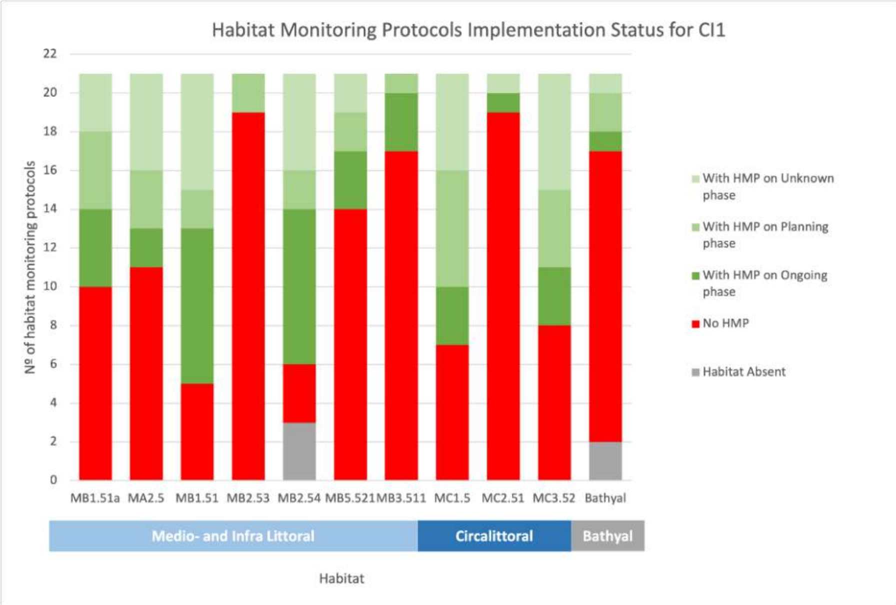
Introduction
The Integrated Monitoring and Assessment Programme (IMAP) of the Barcelona Convention Ecosystem Approach process aims to monitor biodiversity and non-indigenous species, pollution and marine litter, coast and hydrography in an integrated manner (UN Environment/MAP, 2017). As such, IMAP aims to facilitate the implementation of article 12 of the Barcelona Convention and several other monitoring related provisions under different Protocols with the main objective to assess the Good Environmental Status (GES) across the Mediterranean Sea and take measures to achieve it. In the scope of the UNEP/MAP-SPA/RAC Programme of Work (2020-2021 and 2022-2023) and with the financial support of the EU funded project IMAP-MPA, SPA/RAC has been working on the elaboration of assessment criteria, thresholds and baseline values for habitats and species with adequate data availability, following the recommendations of the 2017 Mediterranean Quality Status Report (2017 MED QSR, Decision IG.23/6). In this regard, our goal was to assess the implementation status of two IMAP Common Indicators (CIs) related to marine habitats: CI1 - Habitat distributional range and CI2 - Condition of the habitat's typical species and communities. Here we focus on coralligenous and other calcareous bio-concretions (algal platforms/rims, vermetid reefs, *Cladocora caespitosa* reefs and rhodolith beds).

Materials and methods

Extensive literature review and consultation process were undertaken to gather structured inputs from the key national actors involved in the implementation of the IMAP and the relevant EU Directives i.e. Marine Strategy Framework Directive (MSFD), Water Framework Directive (WFD) and Habitat Directive (HD) as well as marine habitat specialists and the informal Biodiversity Online Woking Group members. These inputs were used to elaborate on scales of monitoring (spatial and temporal resolution), scales of assessment (scale at which the determination of whether GES has been achieved or not takes place) and assessment criteria as well as threshold and baseline values (as defined by UN Environment/MAP, 2016). In this work we report on coralligenous and selected calcareous bio-concretions, included among the priority habitat types by the IMAP (UN Environment/MAP, 2017). We follow the updated Barcelona Convention classification of benthic marine habitat types of the Mediterranean Region (SPA/RAC–UN Environment/MAP, 2019; Montefalcone *et al*. 2021), and consider specifically: MA2.5 Littoral biogenic habitat (MA2.51 Platforms of encrusting Corallinales and MA2.53 Reefs of Vermetidae), MB2.53 Reefs of *Cladocora caespitosa*, MB3.511 Association with maërl or rhodoliths (in infralittoral), MC1.5 Circalittoral rock (MC1.51 Coralligenous cliffs and MC1.52a Coralligenous outcrops), MC2.51 Coralligenous platforms and MC3.52 Coastal detritic bottoms with rhodoliths.

Results

At least one of the selected biogenic habitats was represented in the national monitoring programmes of 70% of the Contracting Parties (CPs) to the Barcelona Convention. The information was unavailable for 15% of CPs. The implementation status of monitoring activities related to CI1 and CI2 differed across habitats (Fig. 1). The highest proportion of CPs include coralligenous and circalittoral rhodolith beds in their national monitoring programmes, i.e. >60% to assess CI1 and >50% to assess CI2 (Fig. 1). However, only 14% of CPs have a clearly ongoing monitoring to assess CI1, whereas the status could not be determined for 25 - 30% of them. To assess the condition of these habitats (CI2), <25% of CPs have confirmed ongoing programmes (Fig. 1). Related to littoral biogenic habitats, algal platforms/rims are monitored by 33% of CPs, most often by the CARLIT method based upon the extensive mapping of the mid-littoral and upper infralittoral of the rocky coastline but this does not imply that in all cases condition of the bioconstructor species is assessed as well. Furthermore, vermetid reefs are included in the national monitoring programmes of 14% of CPs (namely Israel, Lebanon and Tunisia). Notably, condition of *Cladocora caespitosa* reefs was only envisaged for monitoring by Tunisia and infralittoral rhodolith beds are only being monitored by Turkey (Fig. 1). For CI1, spatial and temporal scales of monitoring were rarely defined. In the case of CI2, when scales of monitoring were indicated, they most often referred to <10 sites with ongoing or planned monitoring activities, to be repeated every 2-3 years. Exceptionally, between 101 and 250 coralligenous sites are monitored by Italy and France, and 36 sites are initially planned to be monitored by Croatia. The assessment scale referred to coastal/territorial waters (further subdivided if applied in the scope of WFD/MSFD in the EU Member states). For CI1, the assessment criteria may be identified as the extent of loss of the habitat type, resulting from anthropogenic pressures/physical disturbance. However, related to thresholds, to date no CP has established the maximum allowable extent of habitat being lost or disturbed as a proportion of the total natural extent of considered biogenic habitats in the assessment area (which should take into account regional or subregional specificities). For CI2 the assessment criteria range from alive/dead ratio of the main bioconstructor to elaborated Ecological Quality Ratio (EQR) of indices focused on coralligenous. Whereas there are no clear thresholds in the case of the former CI2 assessment criteria, class boundaries are determined for at least 9 ecological indices used to evaluate the status of the coralligenous habitat. Existing baselines are operational, with rare availability of historical ones.



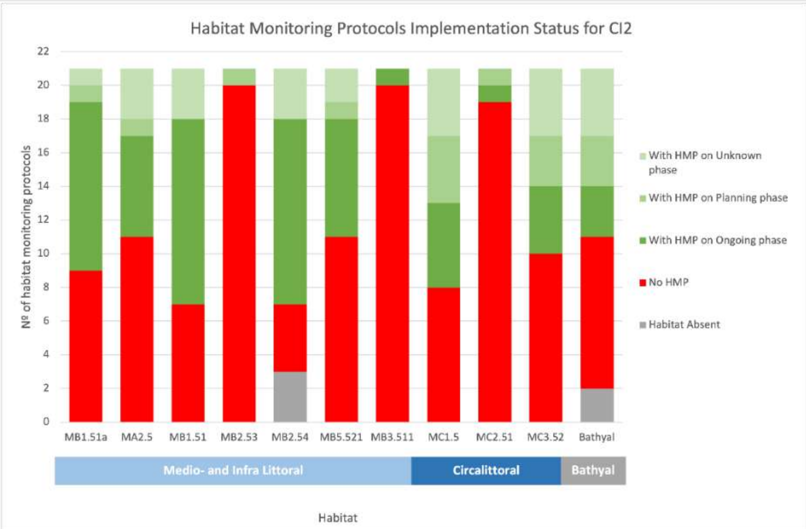


Fig. 1: Implementation status of Habitat Monitoring Protocols (HMP) for the IMAP indicators CI1 (above) and CI2 (down) for the 11 selected habitats covering depth zones from the mediolittoral to the bathyal. Herein, calcareous bio-concretions are represented as: MA2.5 Littoral biogenic habitat, MB2.53 Reefs of *Cladocora caespitosa*, MB3.511 Association with maerl or rhodoliths, MC1.5 Circalittoral rock (as MC1.51 Coralligenous cliffs and MC1.52a Coralligenous outcrops), MC2.51 Coralligenous platforms and MC3.52 Coastal detritic bottoms with rhodoliths.

Discussion and conclusions

This work provides the very first overview of the status of implementation of IMAP regarding benthic habitats at the Mediterranean scale, identifying certain progress but also important knowledge and data gaps, and herein we discuss a way towards a more standardized and coherent monitoring and assessment of the IMAP Common Indicators related to marine habitats in preparation of the 2023 MED QSR. Recommendations include but are not limited to the need for: i) improving channels to share information and data relevant to implementation of CI1 and CI2 in different CPs, ii) establishing methodological standards for data collection at the Mediterranean level, in order to foster consistent datasets, iii) enhancing habitat mapping efforts and adjusting reporting formats on habitat range and extent to benefit from other monitoring schemes, iv) defining clear thresholds for achieving GES both related to the maximum allowable habitat being lost or disturbed and related to the condition of bioconstructions other than coralligenous outcrops and v) validation and inter-calibration of existing ecological indices among different regions.

Bibliography

MONTEFALCONE M., TUNESI L., OUERGHI A. (2021) - A review of the classification systems for marine benthic habitats and the new updated Barcelona Convention classification for the Mediterranean. *Mar Environ Res* (169): 105387.

SPA/RAC–UN Environment/MAP (2019) - Updated Classification of Benthic Marine Habitat Types for the Mediterranean Region. UNEP/MAP-SPA/RAC publ., Tunis.

UN Environment/MAP (2016) - Integrated Monitoring and Assessment Guidance (UNEP(DEPI)/MED IG.22/Inf.7). Athens, Greece, 162 p + annexes.

UN Environment/MAP (2017) - Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria. Athens, Greece, 25 p + annexes.

Cristina LINARES, FIGUEROLA-FERRANDO L., GÓMEZ-GRAS D., PAGÉS-ESCOLÀ M., OLVERA A., AUBACH A., AMATE R., FIGUEROLA B., KERSTING D.K., LEDOUX J.B., LÓPEZ-SANZ A., LÓPEZ-SENDINO P., MEDRANO A., ZENTNER Y., GARRABOU J.
Departament de Biologia Evolutiva, Ecologia i Ciències Ambientals, Institut de Recerca de la Biodiversitat (IRBio), Universitat de Barcelona, Barcelona, Spain.
Email: cristinalinares@ub.edu

CORMEDNET: BUILDING A DATABASE ON THE DISTRIBUTION, DEMOGRAPHY AND CONSERVATION STATUS OF SESSILE SPECIES FROM MEDITERRANEAN CORALLIGENOUS ASSEMBLAGES

Abstract
Coralligenous assemblages are one of the biodiversity-richest ecosystems in the Mediterranean Sea, hosting up to 10% of the Mediterranean marine biodiversity; however, it is increasingly affected by several local and global stressors. Besides the recognition of the relevance of Mediterranean coralligenous assemblages at European and regional levels as well as the increasing research efforts to study this key habitat, there is a lack of updated and comprehensive information about basic data on coralligenous species. Here, we present CorMedNet, an initiative that aims to gather information on distribution, demography and conservation status of key coralligenous species, such as octocorals, bryozoans and sponges. At present, this dataset has gathered information, obtained between 1882 and 2019, from published scientific papers, grey literature and technical reports using different search strategies in the ISI Web of Knowledge and Google Scholar, introducing distinct sets of keywords, and contacts with researchers across the Mediterranean. Now, the database includes 4656 records for more than 230 species covering all Mediterranean ecoregions, but with a strong bias towards the north-western basin. CorMedNet is being developed as a collaborative database to promote a continuous update from research efforts conducted by the scientific community. Gathering all the available information is crucial to guide management strategies to enhance the conservation of coralligenous assemblages across the entire Mediterranean Sea.

Key-words: Coralligenous, Sessile invertebrates, Distribution, Demography, Conservation

Introduction
Coralligenous reefs are one of the biodiversity-richest ecosystems in the Mediterranean Sea, hosting more than 1600 species (up to 10% of the Mediterranean marine biodiversity) (Ballesteros, 2006). In fact, they represent a mosaic of different habitats allowing the development of assemblages ranging from the dominance of calcareous algae to invertebrates such as corals, sponges, bryozoans or tunicates. Beyond the inherent natural value of their exceptional biodiversity, coralligenous assemblages provide highly valuable ecosystem services and benefits and have a fundamental role in supporting human wellbeing (Paoli *et al.*, 2017). These habitats provide humans with several services belonging to provisional (i.e., food, pharmaceutical molecules), regulating (i.e., carbon sequestration, nutrient recycling), and cultural ecosystem services, including numerous services (i.e., high biodiversity, fish abundance) that enhance the quality and the enjoyment of underwater recreation activities (Ville

d'Avray *et al.*, 2019). The relevance of Mediterranean coralligenous assemblages has been recognised in different international, European, and national conservation frameworks (e.g., Habitats Directive; European Water Framework Directive). Despite the research efforts to study this habitat (e.g., Ballesteros, 2006; Gómez-Gras *et al.*, 2021), there is a lack of updated and comprehensive information about basic aspects such as distribution, demography or they conservation status (Kipson *et al.*, 2011). Such information is vital to guide management strategies to ensure the conservation of coralligenous assemblages in the Mediterranean Sea (Çinar *et al.*, 2020), specially bearing in mind the increasing threats affecting this habitat such as the recurrent impact of marine heatwaves (Garrabou *et al.*, 2019). To fill this gap, here we present the CorMedNet dataset, which was created to compile data on geographic and depth distribution, demography and mortality of different habitat-forming invertebrate species dwelling in Mediterranean coralligenous assemblages, such as octocorals, bryozoans, and sponges, among others.

Material and methods

The CorMedNet completed database is deposited in https://www.emodnet-biology.eu/toolbox/en/download/occurrence/dataset/6462 and updated in the online version https://cormednet.medrecover.org, where users can visualize, download, and update data to enhance collaboration and interoperability. The CorMedNet database includes published scientific papers, grey literature, and technical reports from both in situ SCUBA sampling and video-photo surveys. A literature survey was conducted by using different search strategies in the ISI Web of Knowledge and Google Scholar, combining the word "Mediterranean" and different key-words, such as the names of the specific target species from the phyla Cnidaria, Bryozoa, and Porifera (e.g., *Paramuricea clavata, Eunicella singularis, Corallium rubrum, Pentapora fascialis, Spongia officinalis*). The last date of our literature search was October 2020.

Database description

One database record corresponds to the observation or sampling of a local population in a specific geographic location (site), depth range, and time (or period). A local population is considered as a group of colonies, specimens, or individuals of the same species, ranging from tens to thousands, depending on the species.

For each database record, the following distribution and demographic information are provided:

<u>Distribution information</u>

- Site name;
- Taxa/species;
- Ecoregion (following Spalding *et al.*, 2007), country;
- Geographic position (latitude and longitude in decimal degrees, datum WGS84);
- Depth range in meters of the sample record (upper and lower limits);
- Year of the survey (starting and ending year);
- Habitat type if available (boulders, cave, overhangs, vertical walls);
- Protection level of the database record at the time of the sampling (protected and unprotected), and marine protected area identification;
- Species habitat map (species habitat map reported: yes/no);
- Demography (demographic data reported: yes/no);

- Genetics (genetic data reported: yes/no);
- Other type of study or description;
- Data availability (public/private);
- Publication id (identification of the corresponding scientific publication and/or data source).

Demographic information

- Year of the survey;
- Sampling technique of the database record (in situ, photo or video surveys, living specimen, material sample);
- Sampling strategy of the database record (permanent or random survey);
- Date of the survey (following the ISO 8601);
- Colonies density per square meter of the database record;
- Colonies height measures of the database record in mm (sample size, mean, standard deviation, maximum, minimum, and percentage of *C. rubrum* colonies equal or larger than 100 mm in height);
- Colonies diameter of the database record in mm (sample size, mean, standard deviation, maximum, minimum, and percentage of *C. rubrum* colonies equal or larger than 7 mm in diameter);
- Mortality measures of the database record (mean and standard deviation of the percentage of necrosis, and percentage of colonies affected by necrosis – considering a colony affected by necrosis when it is equal or larger than 10 % of the total tissue);
- Recruitment measures of the database record (mean number of recruits per square meter observed in the population).

Geographic coordinates were extracted from the publication source and standardized to decimal degrees in the World Geographic System 1984 (WGS 84) coordinates system. When geographic coordinates were not specified nor in the publication source nor in the auxiliary information, latitude and longitude were estimated whenever possible using figures and maps provided in the publication. When the position was inaccurate, we removed the data from the database.

The protection level is assigned using Marine Protected Areas in the Mediterranean GIS database (MAPAMED; Marine Protected Areas in the Mediterranean www.mapamed.org). MAPAMED integrates information about both Marine Protected Areas and the more general sites of interest to the conservation of the marine environment. MAPAMED latest version is incorporated into the CorMedNet database in order to visualize the most updated version of the protection level.

The CorMedNet database was integrated into the EMODnet Biology catalogue. It is linked to the Ocean Biodiversity Information System (OBIS, 2020), so our database is also introduced to this international open access platform. This helps us to use different international system protocols to standardize the CorMedNet database, as the Darwin Core Archive (DwC-A) standards for the biodiversity informatics data – recommended by GBIF (2022) – the species validation using WoRMS matched tool, or the use of international dates following the ISO 8601 standard. Moreover, it helps us to revise all the database records with the LifeWatch and EMODnet-Biology Quality Control tool, the BioCheck (https://rshiny.lifewatch.be/BioCheck/), which uses for example bathymetric layers to check all the depth range parameters.

Results

The CorMedNet dataset includes 4656 records from more than 230 species covering all Mediterranean ecoregions, but with a strong bias towards the northwest basin (Figure 1). Most of the available information belongs to the 3 major taxonomic groups, in order of importance: Cnidaria, Porifera and Bryozoa (Fig. 1). Regarding the type of information, density is the parameter estimated in most of the studies, followed by size of colonies and mortality (Fig. 2). Most information concerns the northern Mediterranean coast while there is almost a complete lack of reports from the southern and eastern Mediterranean coasts, from Morocco to Lebanon (Fig. 1 and 2).

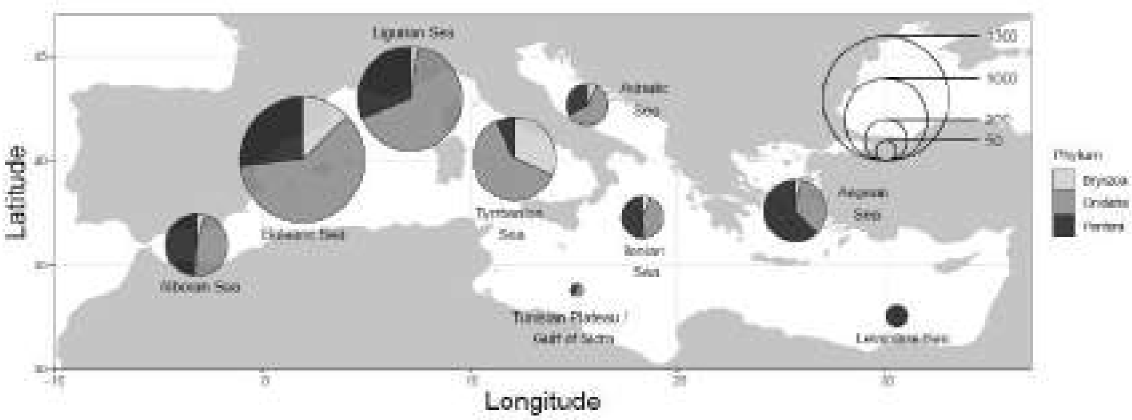


Fig. 1: Taxonomic coverage of the CorMedNet database across Mediterranean ecoregions. Note that the Western Mediterranean was divided into three sub-ecoregions: Balearic Sea, Ligurian Sea, and Tyrrhenian Sea. The number of occurrences is expressed by bubble width.

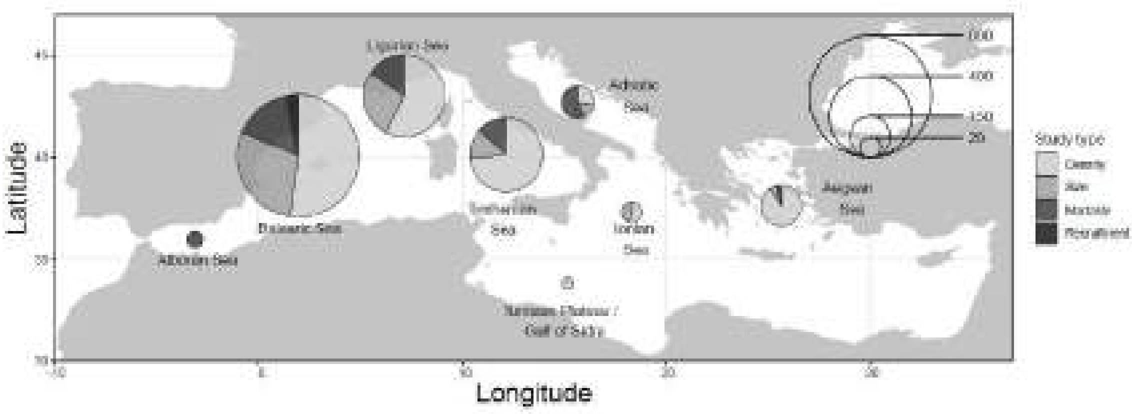


Fig. 2: Distribution of the type of information reported in CorMedNet database across Mediterranean ecoregions. Note that the Western Mediterranean was divided into three sub-ecoregions: Balearic Sea, Ligurian Sea, and Tyrrhenian Sea. The number of occurrences is expressed by bubble width.

Discussion and conclusions

We contend that this collaborative initiative is a unique opportunity to build a regional map of distribution and conservation status of coralligenous species while identifying knowledge gaps (e.g., geographic, depth ranges, species) to be incorporate in the future. CorMedNet is being developed as a collaborative database to promote a continuous update from research efforts conducted by the scientific community. Gathering all the available information is crucial to guide management strategies to enhance the conservation of coralligenous assemblages across the entire Mediterranean Sea (Giakoumi *et al.*, 2013; Doxa *et al.*, 2016). We expect researchers and managers of Marine Protected Areas, technical staff of environmental to contribute with non-published information. Besides, the database will benefit from including the information gathered by citizen science actions such as Observadores del Mar and ReefCheck. In the next future, the database will include data from genetics and species traits.

Acknowledgments

This research has been partially funded by the Spanish Ministry of Economy and Innovation through the Smart project (CGL2012-32194), the HEATMED project (RTI2018-095346-B-I00, MCIU/AEI/FEDER, UE). CL gratefully acknowledges the financial support by ICREA under the ICREA Academia program. JG acknowledges the funding of the Spanish government through the 'Severo Ochoa Centre of Excellence' accreditation (CEX2019-000928-S). LF was supported by FI SDUR grant (2020 FISDU 00482) from the "Generalitat de Catalunya". All researchers are part of the Marine Conservation research group - MedRecover (2017 SGR 1297) from the "Generalitat de Catalunya".

Bibliography

BALLESTEROS, E. (2006) - Mediterranean coralligenous assemblages: A synthesis of present knowledge. *Oceanogr. Mar. Biol. Ann. Rev.* 44, 123-195.

ÇINAR M.E., FÉRAL J.P., ARVANITIDIS C., DAVID R., TAŞKIN E., SINI M., DAILIANIS T., DOĞAN A., GEROVASILEIOU V., EVCEN A., CHENUIL A., DAĞLI E., AYSEL V., ISSARIS Y., BAKIR K., NALMPANTI M., SARTORETTO S., SALOMIDI M., SAPOUNA A., AÇIK S., DIMITRIADIS C., KOUTSOUBAS D., KATAĞAN T., ÖZTÜRK B., KOÇAK F., ERDOGAN-DERELI D., ÖNEN S., ÖZGEN Ö., TÜRKÇÜ N., KIRKIM F., ÖNEN M. (2020) - Coralligenous assemblages along their geographical distribution: Testing of concepts and implications for management. *Aquat. Conserv. Mar. Freshw. Ecosyst.* 30 (8), 1578-1594.

DOXA, A., HOLON, F., DETER, J., VILLÉGER, S., BOISSERY, P., MOUQUET, N. (2016) - Mapping biodiversity in three-dimensions challenges marine conservation strategies: The example of coralligenous assemblages in North-Western Mediterranean Sea. *Ecol. Indic.* 61, 1042-1054.

GARRABOU J., COMA R., BENSOUSSAN N., BALLY M., CHEVALDONNÉ P., CIGLIANO M., DIAZ D., HARMELIN J. G., GAMBI M. C., KERSTING D. K., J. B. LEDOUX, LEJEUSNE C., LINARES C., MARSCHAL C., PÉREZ T., RIBES M., ROMANO J. C., SERRANO E., TEIXIDO N., TORRENTS O., ZABALA M., ZUBERER F., CERRANO C. (2009) - Mass mortality in Northwestern Mediterranean rocky benthic communities: Effects of the 2003 heat wave. Glob. Chang. Biol. 15 (5), 1090–1103.

GIAKOUMI S., SINI M., GEROVASILEIOU V., MAZOR T., BEHER J., POSSINGHAM H.P., ABDULLA A., ÇINAR M.E., DENDRINOS P., GUCU A.C., KARAMANLIDIS A.A., RODIC P., PANAYOTIDIS P., TASKIN E., JAKLIN A., VOULTSIADOU E., WEBSTER C., ZENETOS A., KATSANEVAKIS S. (2013) - Ecoregion-based conservation planning in the Mediterranean: dealing with large-scale heterogeneity. *PloS one* 8 (10), e76449.

GÓMEZ-GRAS D., LINARES C., DORNELAS M., MADIN J.S., BRAMBILLA V., LEDOUX J.B., LÓPEZ-SENDINO P., BENSOUSSAN N., GARRABOU J. (2021) - Climate change transforms the functional identity of Mediterranean coralligenous assemblages. *Ecol. Lett.* 24 (5), 1038-1051.

KIPSON S., FOURT M., TEIXIDÓ N., CEBRIAN E., CASAS E., BALLESTEROS E., ZABALA M., J. GARRABOU (2011) - Rapid biodiversity assessment and monitoring method for highly diverse benthic communities: A case study of Mediterranean coralligenous outcrops. *PLoS one* 6 (11), e27103.

OBIS (2020) - Ocean Biodiversity Information System. Intergovernmental Oceanographic Commission, UNESCO.

PAOLI C., MONTEFALCONE M., MORRI C., VASSALLO P., BIANCHI C.N. (2017) - Ecosystem functions and services of the marine animal forests. In: *Marine animal forests: The ecology of benthic biodiversity hotspots* (Rossi, S., Bramanti, L., Gori, A., Orejas, C., Eds). Springer International Publishing, Cham, Switzerland, 1271-1312.

SPALDING M.D., FOX H.E., ALLEN G.R., DAVIDSON N., FERDAÑA Z.A., FINLAYSON M., HALPERN B.S., JORGE M.A., LOMBANA A., LOURIE S. A., MARTIN K.D., MCMANUS E., MOLNAR J., RECCHIA C.A., ROBERTSON J. (2007) - Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. *BioScience* 57 (7), 573-583.

VILLE D'AVRAY T., AMY L., CHENUIL A., DAVID R., FERAL J.P. (2019) - Application of the ecosystem service concept at a small-scale: The cases of coralligenous habitats in the North-western Mediterranean Sea. *Mar. Poll. Bull*. 138, 160-170.

Massimo PONTI, CERRANO C., GHETTA M., ABBIATI M., TURICCHIA E.
Department of Biological, Geological and Environmental Sciences, University of Bologna, UO CoNISMa, Via S. Alberto 163, 48123 Ravenna, Ravenna, Italy
E-mail: massimo.ponti@unibo.it

ECOLOGICAL STATUS OF THE LIGURIAN CORALLIGENOUS HABITATS ASSESSED BY THE *MEDSENS* INDEX

Abstract

MedSens *is a biotic index developed to provide information on the environmental status of subtidal rocky coastal habitats, based on data collected by trained scuba diver volunteers using the Reef Check Mediterranean Underwater Coastal Environment Monitoring (RCMed-UCEM) protocol. The index is based on 25 selected species, incorporating their sensitivities to the main pressures indicated by the European Marine Strategy Framework Directive (MSFD) and open data on their distributions and abundances. According to benchmark levels and a literature review, the species' sensitivities were assessed relative to their resistance and resilience against physical, chemical, and biological pressures, and averaged in the study area.*
The large availability of data collected by volunteers using the RCMed-UCEM protocol offers the opportunity to assess the ecological status of the coralligenous habitats in the Ligurian region (Italy). MedSens *index was applied to the coralligenous habitats belonging to the different municipalities in this region, providing the mean sensitivity of the assemblages to the pressure categories.* MedSens *can help conservationists and decision-makers identify the main pressures acting in coralligenous habitats, as required by the MSFD, supporting them in implementing appropriate marine biodiversity conservation measures and better communicating the results of their actions.*

Key-words: Temperate reef, impact assessment, environmental monitoring, human pressures, anthropogenic disturbances

Introduction

In the Mediterranean Sea, coralligenous reefs are among the most threatened marine habitats (Micheli *et al*., 2013). Environmental quality assessment tools for these habitats, based on the integrity of marine communities, are not only urgent but also essential to fulfil the European Marine Strategy Framework Directive (MSFD, 2008/56/EC). Marine citizen science (MCS) projects may provide community-based ecosystem monitoring, expanding our ability to collect data across space and time. However, the data from MCS are often not effectively integrated into institutional monitoring programs and/or not effectively used for conservation purposes. This limitation is partially due to difficulties in accessing the data and the lack of tools and indices for proper management application at intended spatial and temporal scales. The growing need to assess the environmental status of Mediterranean habitats and the large availability of data collected by Reef Check Mediterranean Sea volunteers in coralligenous reefs (Turicchia *et al*., 2021b) offers the opportunity to use innovative and reliable indices that may support decision-makers in applying conservation strategies, particularly important for Marine Protected Areas (MPAs). *MedSens* is a biotic index developed to provide information on the ecological status of subtidal rocky coastal habitats, including coralligenous reefs, filling a gap between MCS and coastal management in the Mediterranean Sea (Turicchia *et al*., 2021a).

The Ligurian region (Italy) represents a narrow strip of land bordered by the Alps and the Apennine Mountains, overlooking the homonymous sea in the north-western Mediterranean Sea. Along its 350 kilometres of coastline, the continental shelf is very narrow and often suddenly drops to considerable depths. Rocky cliffs, shoals and shelf outcrops are rich in coralligenous habitats that attract numerous diver tourists (Canessa *et al*., 2017, and reference therein). Part of these habitats are included in the 26 sites of community importance and the 6 national or regional marine protected areas (established, i.e., Portofino, Cinque Terre and Bergeggi Island, or in the process of being established). In this region, many protected area managers and dive centres have long collaborated on marine conservation and actively promoted citizen science programs, including the Reef Check Mediterranean Underwater Coastal Environment Monitoring (RCMed U-CEM) protocol, since its establishment (Cerrano *et al*., 2017). The aims of this study are to provide an overview of the commitment over the years of volunteers in applying the RCMED U-CEM protocol in the Ligurian region and to assess the ecological status of the area by using the *MedSens* biotic index from 2006 to 2021.

Materials and Methods

Since 2006 trained snorkelers, freedivers, and scuba diver volunteers (hereafter called as EcoDivers) have made independent observations along random swim. collecting data on the occurrence, distribution, abundance, prevailing habitat, and bathymetric range of selected key marine species along the Ligurian coasts by using the RCMed U-CEM protocol (www.reefcheckmed.org). Not encountered but actively searched taxa are reported as absent, while no data are provided for not searched taxa (Cerrano *et al*., 2017; Turicchia *et al*., 2021c).

The included algae, invertebrates, and fishes were selected by a combination of criteria, such as ease of identification and being key indicators of ecological shifts in Mediterranean subtidal habitats due to local pressures and climate change. Following the ten principles of Citizen Science (Kelly *et al*., 2020) and the FAIR (findable, accessible, interoperable, and reusable) data principles (Wilkinson *et al*., 2016), the dataset obtained using the RCMed U-CEM protocol is openly accessible across different platforms (Turicchia *et al*., 2021b; Turicchia *et al.*, 2021c).

The *MedSens* index is based on a subset of 25 species, among the 43 available in the RCMed U-CEM protocol, incorporating their sensitivities to the main pressures indicated by the European Union's Marine Strategy Framework Directive (MSFD, 2008/56/EC) and open data on their distributions and abundances, collected by the EcoDivers (Cerrano *et al.*, 2017; Turicchia *et al*., 2021b; Turicchia *et al*., 2021c). The species' sensitivities were assessed relative to their resistance and resilience against physical, chemical, and biological pressures, according to benchmark levels and a literature review following the marine evidence-based sensitivity assessment approach (Tyler-Walters *et al*., 2018). The *MedSens* index was calibrated on a dataset of 33,021 observations carried out by 569 volunteers from 2001 to 2019 along Croatian, French, Greek, Italian, Spanish, and Tunisian coasts (Turicchia *et al*., 2021a). A free and user-friendly QGIS plugin was developed to allow easy index calculation for areas and time frames of interest (https://plugins.qgis.org/plugins/medsens).

The *MedSens* index provides the mean sensitivity of the species assemblages recorded by EcoDivers within a territorial unit and time frame. It can be calculated for the physical ($MedSens_{phy}$), chemical ($MedSens_{che}$), biological ($MedSens_{bio}$), and overall pressures ($MedSens_{tot}$) on the species, based on the corresponding mean sensitivity values derived from the sensitivity assessment, weighted for the abundance of the taxa (Turicchia *et al*., 2021a).

The *MedSens* index was calculated for each municipality along the Ligurian coast for the overall fifteen years period, from 2006 to 2021. Only data from predominantly rocky bottoms within 5 km from the coastline were used.

Results

The number of EcoDivers involved in monitoring the Ligurian coralligenous habitats has shown a fluctuating trend over the years. Between 2006 and 2021, an average of 25 ± 4 EcoDivers per year (± standard error, se) took part in the surveys, with peaks of involvement in 2014 and 2021 (Fig. 1a). Overall, 844 ± 247 mean observations per year were carried out (with a maximum of 3953 in 2014; Fig. 1b), and the EcoDivers dedicated 37 ± 2 minutes per survey (Fig. 1c).

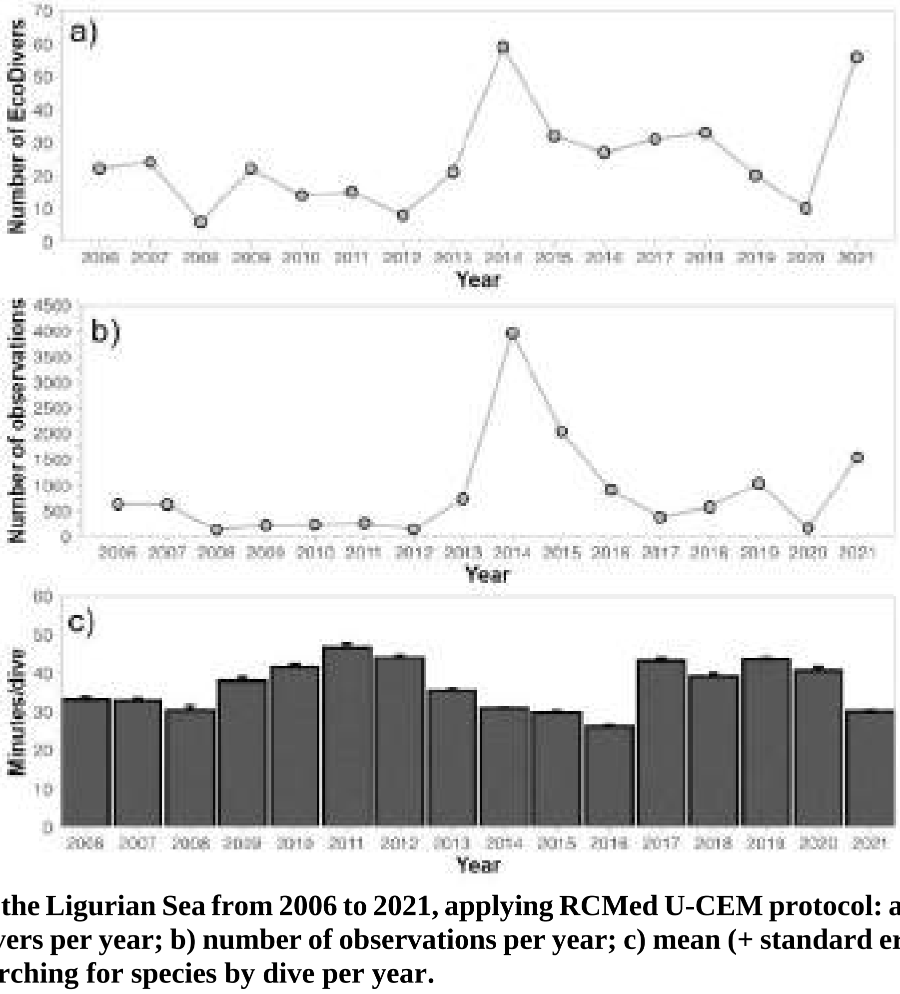


Fig. 1: In the Ligurian Sea from 2006 to 2021, applying RCMed U-CEM protocol: a) number of EcoDivers per year; b) number of observations per year; c) mean (+ standard error) time spent searching for species by dive per year.

Between 2006 and 2021, the most searched species was the yellow cluster anemone *Parazoanthus axinellae* (Fig. 2a, b), followed by the invasive algae *Caulerpa cylindracea*, and the gorgonians *Paramuricea clavata*, *Corallium rubrum* and *Eunicella cavolini*.

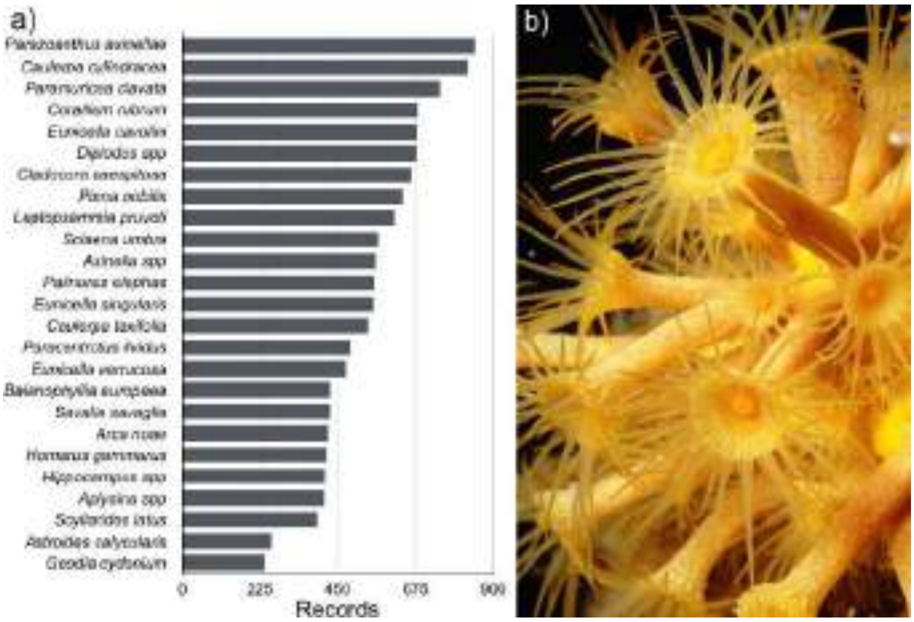


Fig. 2: a) Number of records (including absences) for each target species searched in the Ligurian region from 2006 to 2021; b) the most searched species, *Parazoanthus axinellae*.

Based on the data available, the *MedSens* index was calculated for 17 out of 70 municipalities. In the period 2006-2021, the mean overall sensitivity of the assemblages varies from very high (at Vado Ligure) to low (at Albenga) and very low (at Genova; Fig. 3a). Assemblages with high sensitivities were observed in many municipalities both on the eastern side (Portofino, Sestri Levante) and western side (e.g., Bergeggi, Noli, Diano Marina, Santo Stefano al Mare) of the Ligurian region. The sensitivity of the assemblages to physical pressures follows a similar pattern, with better assemblages at Vado Ligure and Santo Stefano al Mare, and those worse in Genova and Albenga; however, here the sensitivity did not reach the value "very low" (Fig. 3b).
Assemblage's sensitivity toward chemical pressures, including for example pollution and organic enrichment, ranged from very low (at Genova) to very high sensitivity (Vado Ligure), meanwhile Imperia and Santa Margherita Ligure showed low sensitivity (Fig. 3c). The sensitivity of the assemblages toward biological pressures (e.g., invasion of non-indigenous species) resulted very high at Vado Ligure and Noli, whereas at Genova and Albenga, it was very low (Fig. 3d).

Discussion and conclusions

The present study provides a broad overview of the ecological status of the Ligurian coralligenous habitats based on the data provided by scuba diver volunteers. As could be expected, coralligenous habitats close to major cities such as Genova and Imperia showed possible effects of pollution. In general, municipalities that have protected areas perform a little better; however, signs of attention are coming from different areas that have been hit in the past years by the invasion of *Caulerpa cylindracea* (see *Bianchi et al*., 2018; Montefalcone *et al*., 2015; Morri *et al*., 2019).
Marine citizen science is a promising and powerful tool to enhance engagement in marine conservation worldwide, as envisaged by the United Nations Decade of Ocean Science for Sustainable Development Goals 2021–2030 (SDG 14, Life Below Water).

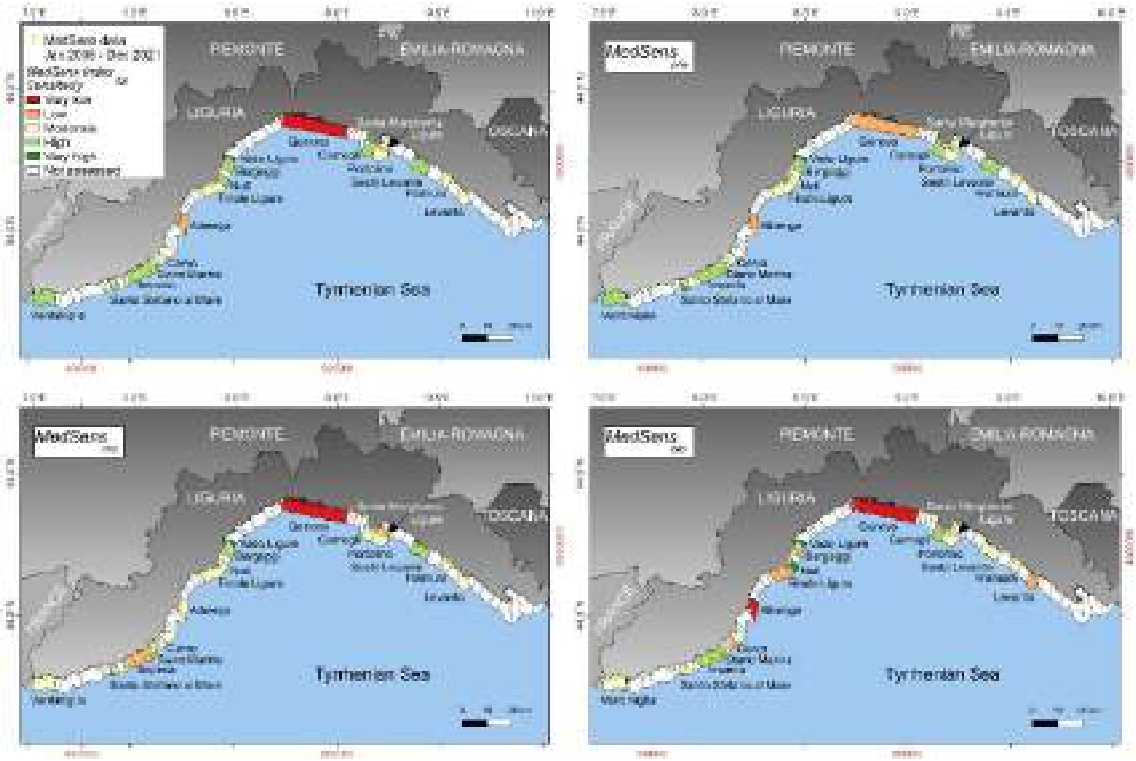


Fig. 3: Coralligenous assemblage sensitivities in the Ligurian region: a) overall assessment (*MedSens*$_{\mathbf{tot}}$) and physical pressures (*MedSens*$_{\mathbf{phy}}$), b) chemical pressures (*MedSens*$_{\mathbf{che}}$), and c) biological pressures (*MedSens*$_{\mathbf{bio}}$). Yellow dots display the included Reef Check Mediterranean Sea MedSens data points (EPSG:32632 - WGS84/UTM zone 32N).

In particular, the RCMed U-CEM protocol is a simple but effective visual census with species that encompass the key ecological aspects of the Mediterranean subtidal habitats. It can provide a large amount of timely, up-to-date geo-referenced data. Its data quality is ensured by rigours participant training courses (subject to learning tests), numerous surveys by independent observers, and quality control procedures. Similarly, the *MedSens* index can provide a proxy of the mean sensitivity of the coralligenous assemblages to natural and anthropic pressures listed by MSFD. Higher average assemblage sensitivities are associated with low disturbance level, indicating good environmental conditions. It is particularly suitable for monitoring marine protected areas or specific dive spots and represents a bridge between MCS and coastal management in the Mediterranean Sea, allowing the effective integration of lasting community-based environmental monitoring into ecosystem-based management policies. It can help conservationists and decision-makers identify the main pressures acting in these habitats, as required by the MSFD, supporting them in implementing appropriate marine biodiversity conservation measures and better communicating the results of their actions.

Acknowledgments

We thank all the EcoDivers and their trainers who provided and continue to provide data. A special thanks goes to the managers of the marine protected areas who believe and invest in participatory science and to the diving centres that make their resources available.

Bibliography

BIANCHI C.N., COCITO S., DIVIACCO G., DONDI N., FRATANGELI F., MONTEFALCONE M., PARRAVICINI V., ROVERE A., SGORBINI S., VACCHI M., MORRI C. (2018) - The park never born: Outcome of a quarter of a century of inaction on the sea-floor integrity of a proposed but not established Marine Protected Area. *Aquat. Conserv.*, 28(5): 1209-1228.

CANESSA M., MONTEFALCONE M., BAVESTRELLO G., POVERO P., COPPO S., MORRI C., BIANCHI C.N. (2017) - Fishery maps contain approximate but useful information for inferring the distribution of marine habitats of conservation interest. *Estuar. Coast. Shelf Sci.*, 187: 74-83.

CERRANO C., MILANESE M., PONTI M. (2017) - Diving for science - science for diving: Volunteer scuba divers support science and conservation in the Mediterranean Sea. *Aquat. Conserv.*, 27(2): 303–323.

KELLY R., FLEMING A., PECL G.T., VON GÖNNER J., BONN A. (2020) - Citizen science and marine conservation: a global review. *Philos. Trans. R. Soc. B*, 375(1814): 20190461.

MICHELI F., HALPERN B.S., WALBRIDGE S., CIRIACO S., FERRETTI F., FRASCHETTI S., LEWISON R., NYKJAER L., ROSENBERG A.A. (2013) - Cumulative human impacts on Mediterranean and Black Sea marine ecosystems: Assessing current pressures and opportunities. *PLoS ONE*, 8(12): e79889.

MONTEFALCONE M., MORRI C., PARRAVICINI V., BIANCHI C. (2015) - A tale of two invaders: Divergent spreading kinetics of the alien green algae *Caulerpa taxifolia* and *Caulerpa cylindracea*. *Biol. Invasions*, 17(9): 2717–2728.

MORRI C., MONTEFALCONE M., GATTI G., VASSALLO P., PAOLI C., BIANCHI C.N. (2019) - An alien invader is the cause of homogenization in the recipient ecosystem: A simulation-like approach. *Diversity*, 11(9): 146.

TURICCHIA E., CERRANO C., GHETTA M., ABBIATI M., PONTI M. (2021a) - MedSens index: The bridge between marine citizen science and coastal management. *Ecol. Indic.*, 122: 107296.

TURICCHIA E., PONTI M., ROSSI G., CERRANO C. (2021b) - The Reef Check Med Dataset on Key Mediterranean Marine Species 2001–2020. *Front. Mar. Sci.*, 8(1714).

TURICCHIA E., PONTI M., ROSSI G., MILANESE M., DI CAMILLO C.G., CERRANO C. (2021c) - The Reef Check Mediterranean Underwater Coastal Environment Monitoring protocol. *Front. Mar. Sci.*, 8(8): 620368.

TYLER-WALTERS H., TILLIN H.M., D'AVACK E.A.S., PERRY F., STAMP T. (2018) - *Marine Evidence-based Sensitivity Assessment (MarESA) – A Guide*. Marine Biological Association of the UK, Plymouth (UK): 91 pp.

WILKINSON M.D., DUMONTIER M., AALBERSBERG I.J., APPLETON G., AXTON M., BAAK A., BLOMBERG N., BOITEN J.-W., DA SILVA SANTOS L.B., BOURNE P.E., BOUWMAN J., BROOKES A.J., CLARK T., CROSAS M., DILLO I., DUMON O., EDMUNDS S., EVELO C.T., FINKERS R., GONZALEZ-BELTRAN A., GRAY A.J.G., GROTH P., GOBLE C., GRETHE J.S., HERINGA J., 'T HOEN P.A.C., HOOFT R., KUHN T., KOK R., KOK J., LUSHER S.J., MARTONE M.E., MONS A., PACKER A.L., PERSSON B., ROCCA-SERRA P., ROOS M., VAN SCHAIK R., SANSONE S.-A., SCHULTES E., SENGSTAG T., SLATER T., STRAWN G., SWERTZ M.A., THOMPSON M., VAN DER LEI J., VAN MULLIGEN E., VELTEROP J., WAAGMEESTER A., WITTENBURG P., WOLSTENCROFT K., ZHAO J., MONS B. (2016) - The FAIR Guiding Principles for scientific data management and stewardship. *Scientific Data*, 3(1): 160018.

Martina RADICIOLI, ANGIOLILLO M., GIUSTI M., PROIETTI R., FORTIBUONI T., SILVESTRI C., TUNESI L.
Istituto Superiore per la Protezione e Ricerca Ambientale (ISPRA), Via Vitaliano Brancati, 60, 00144, Rome, Italy
Email: Martina.radicioli@gmail.com

MONITORING CORALLIGENOUS REEFS IN ITALIAN COASTAL WATERS WITHIN THE MARINE STRATEGY FRAMEWORK DIRECTIVE

Abstract
Coralligenous reefs are one of the most relevant and endemic assemblages of the Mediterranean Sea, supporting high levels of biodiversity. Due to their functional role and importance for ecosystems conservation, Italy has included coralligenous habitat in the monitoring activities of the Marine Strategy Framework Directive (MSFD, 2008/56/EC) to assess the maintenance or achievement of good environmental status (GES). For this purpose, an extensive monitoring program has been conceived for the Italian coastal waters within the three MSFD Mediterranean sub-regions. The national approach, coordinated by the National System for the Environmental Protection (SNPA), which includes all Italian Regional Environmental Protection Agencies (ARPA) and ISPRA, planned the application of a standardised protocol based on multibeam echosounder, side-scan sonar, and Remotely Operated Vehicle surveys. This study synthesises the data collected during the first cycle of MSFD implementation (2015-2019) in the seventy-three monitored areas at depths ranging from 42 to 127 m. To organise the data, a specific ArcGIS Geodatabase (GDB) was designed, implementing a series of tables with feature classes and attributes to obtain spatial and biological information about the coralligenous reefs, such as species composition, abundance and health status of habitat-forming species, marine litter distribution and its impact. The data analysis provides the first baseline for an initial assessment of the health status of coralligenous reefs in the Italian sub-regions, allowing future comparisons and thus evaluating the effectiveness of the measures undertaken in the framework of the MSFD to enable the achievement of the GES.

Key-words: Coralligenous, Marine Strategy Framework Directive, ROV-imaging, Mediterranean Sea, baseline

Introduction
Coralligenous is an endemic biogenic benthic assemblage of the Mediterranean Sea formed by the stratification of calcareous, encrusting algae (Rhodophyceae), later consolidated by the growth of structuring taxa such as bryozoans, sponges and cnidarians, mainly anthozoans (Ballesteros, 2006; Gori *et al.*, 2017). It develops between 25 and 200 m in depth in special environmental conditions such as low and relatively constant temperature, clear water, moderate hydrodynamics, moderate sedimentation rate and low luminosity. Coralligenous represents one of the most important "hot spots" of Mediterranean biodiversity and one of the main marine ecosystems in terms of distribution, biomass and role played in the carbonate cycle, but it is also one of the most sensitive and vulnerable habitats to environmental alterations, both on a local and global scale (Angiolillo and Fortibuoni, 2020; Ingrosso *et al.*, 2018). Hence the need to implement activities according to the specific "Action Plan for the

Conservation of the Coralligenous and Other Calcareous Bio-concretions in the Mediterranean", adopted under the Barcelona Convention, to investigate the distribution and health status of coralligenous habitat in order to promote its protection. At the European level, the Marine Strategy Framework Directive (MSFD) 2008/56/EC (European Commission, 2008) (implemented in Italy by Legislative Decree 190/2010) promotes an integrated approach to ensure that European marine waters are in good environmental status (GES). To pursue this goal, each state must implement a specific strategy by undertaking monitoring activities and implementing a specific program of measures. In this context, Italy has identified the coralligenous as a benthic assemblage to be monitored precisely because of its ecological importance and vulnerability to human activities. The activities of the Marine Strategy made it possible to assess the distribution and condition of coralligenous reefs and the pressures to which they are exposed in the studied areas, linking three MSFD descriptors, namely D1 (Biodiversity), D6 (seafloor integrity), and D10 (marine litter). These descriptors are considered together to assess, within the Italian context, the health status of the coralligenous habitat. All these activities are fully in line with the requirements of the ecosystem approach (EcAp) of the Barcelona Convention (UNEP-MAP, 2008) and with the IMAP guidelines (Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast) (UNEP-MAP, 2016).

Materials and methods

The data analysed in this study are related to the first cycle of Italian MSFD monitoring (2015-2019) on coralligenous habitats. The monitoring activities were conducted by ARPAs (Regional Environmental Protection Agencies) in each Italian region where the presence of coralligenous habitat was known, namely Abruzzo, Calabria, Campania, Lazio, Liguria, Puglia, Sardinia, Sicily, and Tuscany. The monitored areas were identified on bibliographic data within 12 Mn from the Italian coasts and/or 100 m depth, selecting those that are as representative as possible of the different environmental conditions of each Italian region, including Natura 2000 sites or Marine Protected Areas. The data collected included preliminary surveys carried out using two sophisticated sonars (Multibeam and Side Scan Sonar) to acquire bathy-morphological data on the nature and conformation of the substrate over areas large 25 km^2, to obtain high-resolution digital terrain models (DTMs) and backscatter maps of the seafloor. These maps were used to identify rocky areas where to verify the presence and extent of coralligenous habitats through Remotely Operated Vehicles (ROVs) following an *ad-hoc* MSFD protocol (MATTM-ISPRA, 2019). In each area, three sites were identified, and, in each of them, three 200 m long transects were carried out on the coralligenous reefs. Data on coralline algae cover, sedimentation, biocoverage, bottom type, exposition and slope, species richness, size structure, density, rate of mortality and epibiont covers were collected for 22 target habitat-forming species to allow coralligenous characterisation. In addition, the quantity, composition, and spatial distribution of marine litter and its impact on habitat-forming species (entanglement) were assessed. The collected data were edited and validated by the Italian Institute for Environmental Protection and Research (ISPRA). The geo-referenced tabular and cartographic data acquired were organised within a geodatabase in the ArcGIS environment to provide a tool for data storage, organisation and management. The geodatabase is populated by feature class and by four feature datasets containing data on all the areas, sites, and transects organised by year and region. The geodatabase also contains several object classes related to environmental and biological parameters. All feature and object classes are related to each other through relationship classes.

Results

Overall, 73 areas (Fig. 1), 214 sites, and 620 transects (each covering an area of 100 m²) were monitored between 2015 to 2019, afferent to the three sub-regions of the Mediterranean Sea on which Italy is facing, for a total of 62,000 m² of explored seafloor. The higher number of sites monitored in the WME sub-region is explained by the greater presence of coralligenous seabed areas, whereas soft bottoms mostly characterize the Adriatic coasts.

Fig. 1: Areas investigated with monitoring activities in the 3 sub-regions of the Mediterranean Sea

The ROV-imaging analysis revealed the presence of more than 100 taxa per sub-region belonging to the following phyla: Rhodophyta, Chlorophyta, Ochrophyta, Magnoliophyte, Porifera, Cnidaria, Annelida, Mollusca, Bryozoa, Arthropoda, Echinodermata, and Chordata (Tab. 1). Porifera and cnidarians were the dominant recorded taxa.

In the survey areas, 22 target species were identified, 5 demosponges (*Axinella cannabina, A. polypoides, Spongia lamella, Sarcotragus foetidus, Calyx nicaeensis*), 15 anthozoans (*Antipathella subpinnata, Callogorgia verticillata, Cladocora caespitosa, Corallium rubrum, Dendrophyllia cornigera, D. ramea, Eunicella cavolini, E. singularis, E. verrucosa, Leptogorgia sarmentosa*, *Paramuricea clavata, P. hirsuta, P.*

macrospina, *Savalia savaglia*, *Ellisella flagellum*) and 2 gymnolaemata (*Pentapora fascialis* and *Myriapora truncata*).
The most occurring and abundant target species were *P. clavata* and *E. singularis*, with an average density of 12 and 2 colonies m^{-2}, respectively. Both species are most abundant in the Sicily region (Fig. 2). The geodatabase contains a total of 74,821 records, including all parameters considered.

Tab. 1: Coralligenous Species Richness derived from ROV-imaging analysis by Italian region

Phylum	Abruzzo	Calabria	Campania	Lazio	Liguria	Puglia	Sardegna	Sicilia	Toscana
Rhodophyta	2	11	4	5	0	4	1	20	1
Chlorophyta	0	7	8	4	0	9	4	11	5
Ochrophyta	3	5	3	4	0	1	1	5	1
Magnoliophyta	0	1	0	1	0	0	0	0	0
Porifera	10	20	20	27	13	30	12	47	1
Cnidaria	6	21	11	25	19	20	15	16	8
Annelida	3	11	3	4	4	4	4	11	0
Bryozoa	1	11	7	9	7	9	5	25	6
Echinodermata	1	14	9	5	4	11	7	16	0
Chordata	3	3	3	12	1	4	5	54	0
Mollusca	2	7	0	3	2	3	0	7	0
Arthropoda	1	1	0	1	2	1	1	2	0
Tot. Taxa	**32**	**112**	**68**	**100**	**52**	**32**	**55**	**115**	**6**
Structural Species	**2**	**11**	**8**	**15**	**10**	**9**	**3**	**11**	**6**

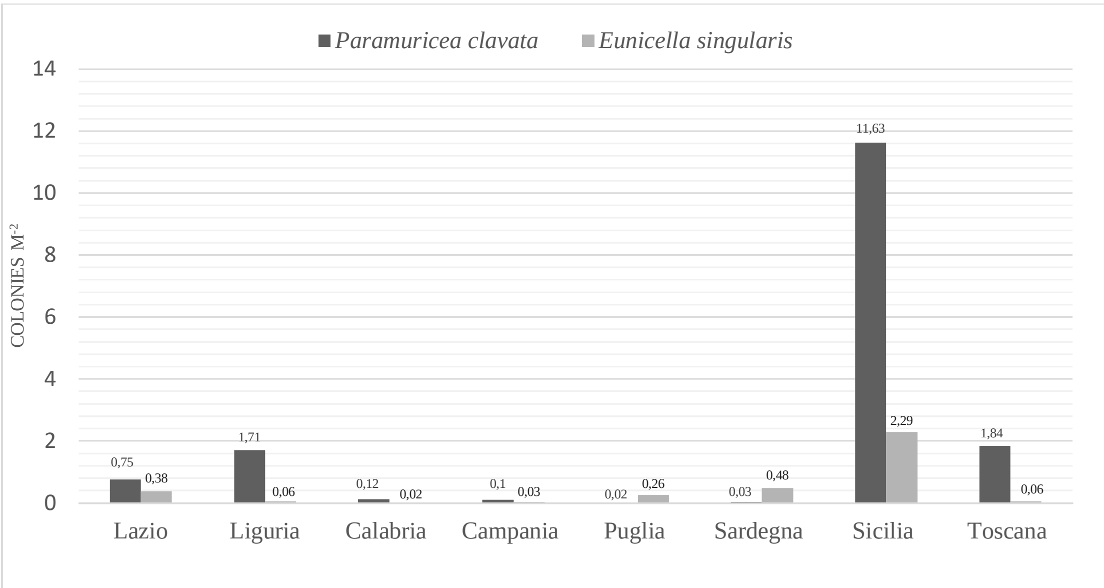


Fig. 2: Species abundance distributions of *Paramuricea clavata* and *Eunicella singularis* in Italian regions

Overall, 4,316 litter items were recorded along Italian coralligenous reefs. The most common category was artificial polymer materials (89.5%), followed by undefined (5.3%), metal (1.6%) and glass/ceramics (1.5%). Fishery-related litter (lines, ropes and nets) was the most abundant type (86.5%). Plastic bags, glass and metal objects, tyres, anchors and oil barrels were other recorded items. The mean litter density was 5.5 items

100 m^{-2} (range: 0–120 items 100 m^{-2}). The Adriatic Sea presented the lowest litter densities (average = 1.9 items 100 m^{-2}; min-max = 0-17 items 100 m^{-2}), whereas the Western Mediterranean Sea was the most polluted (average = 6.7 items 100 m^{-2}; min-max = 0–120 items 100 m^{-2}). Abandoned, Lost or otherwise Discarded Fishing Gear (ALDFG, i.e. lines, ropes, and nets) affected rocky reefs in almost all monitored areas (94%), particularly in the Western Mediterranean Sea. The entanglement was not recorded in all regions, so it was not considered in the analysis.

Discussion and conclusions

The data collected provide the baseline information for conducting a more in-depth assessment of the ecological status of the coralligenous in the different sites studied. They will be useful for comparing the data collected to date, with those that will be acquired during the next MSFD cycles.

This will then provide reference values for future monitoring activities so that the effectiveness of the management measures introduced by the MSFD can be assessed. Overall, the combination of geo-technology with geomorphological analysis, video and position data provided by the ROV, resulted in a powerful tool for the assessment of the distribution and the health status of the coralligenous habitats (i.e. Pierdomenico *et al.*, 2021; Enrichetti *et al.*, 2019). Nevertheless, despite initial difficulties in applying an innovative protocol for monitoring the coralligenous, a large amount of validated and standardised data has been collected on a large scale. The creation of a referenced archiving system in the ArcGIS environment, designed within the GES scenario, is a valuable tool for archiving and analysing environmental data on benthic habitats. It allows datasets to be implemented and updated over time with data collected during future monitoring campaigns. Data analysis is in progress, and the multi-parameter Mesophotic Assemblages Conservation Status (MACS) index (Enrichetti *et al*., 2019) will be used to define the environmental status, allowing further assessments and the basis for defining a "threshold value" to distinguish areas in good from those in poor environmental status. This integrated approach will provide important feedback on the extent and diversity of these bio-constructions, providing stakeholders with appropriate management measures to ensure the sustainable development of coastal areas and the conservation of valuable ecosystems (Pierdomenico *et al.*, 2021).

Acknowledgements

The authors would like to thank all the staff of the National System for Environmental Protection involved in Descriptor 1 and 10 implementations. A special thank goes to the ARPA staff involved in data collection on coralligenous and seafloor litter.

Bibliography

ANGIOLILLO M., FORTIBUONI T. (2020) – Impact of Marine Litter on Mediterranean Reef Systems: From Shallow to Deep Waters. *Frontiers in Marine Science.*

BALLESTEROS E. (2006) – Mediterranean coralligenous assemblages: a synthesis of present knowledge. *Oceanography and Marine Biology: an annual review.*, 44: 123-195.

GORI A., BAVESTRELLO G., GRINYÓ J., DOMINGUEZ-CARRIÓ C., AMBROSO S., BO M. (2017) – *Animal forests in deep coastal bottoms and continental shelf of the Mediterranean Sea*. In: Rossi, S., Bramanti, L., Gori, A., Orejas, C. (Eds.), Marine Animal Forests: The Ecology of Benthic Biodiversity Hotspots. Springer International Publishing, Cham, Switzerland, pp. 207–233.

ENRICHETTI F., BO M., MORRI C., MONTEFALCONE M., TOMA M., BAVESTRELLO G., TUNESI L., CANESE S., GIUSTI M., SALVATI E., BERTOLOTTO M.R., BIANCHI C.N. (2019) – Assessing the environmental status of temperate mesophotic reefs: A new integrated methodological approach. *Ecological Indicators*, 102: 218–229.

ENRICHETTI F., DOMINGUEZ-CARRIÓ C., TOMA M., BAVESTRELLO G., BETTI F., CANESE S., AND BO M. (2019) - Megabentic communities of the Ligurian deep continental shelf and shelf break (NW Mediterranean Sea). *PloS ONE*, 14: e0223943.

EUROPEAN COMMISSION (2008) – Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008. Establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). *Off. J. Europ. Union L1*, 64: 19–40.

INGROSSO G., ABBIATI M., BADALAMENTI F., BAVESTRELLO G., BELMONTE G., CANNAS R., … BOERO F. (2018) – Mediterranean Bioconstructions along the Italian Coast. Adv. *Mar. Biol.*, 79: 61–136. doi: 10.1016/bs.amb.2018.05.001

MATTM-ISPRA (2019) – *Schede Metodologiche per l'attuazione delle Convenzioni stipulate tra Ministero dell'Ambiente e della Tutela del Territorio e del Mare e Agenzie Regionali per la protezione dell'Ambiente. Modulo 7 Habitat Coralligeno*. Programmi di Monitoraggio per la Strategia Marina, Art. 11, D. lgs. 190/2010.

PIERDOMENICO M., BONIFAZI A., ARGENTI L., INGRASSIA M., CASALBORE D., AGUZZI L., VIAGGIU E., LE FOCHE M., CHIOCCI F.L. (2021) – Geomorphological characterization, spatial distribution and environmental status assessment of coralligenous reefs along the Latium continental shelf. *Ecological indicators*, 131.

UNEP-MAP (2008) – *Decision IG.17/06: Implementation of the ecosystem approach to the management of human activities that may affect the Mediterranean marine and coastal environment*. UNEP(DEPI)/MED IG.17/10. 15th Ordinary Meeting of the Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its Protocols.

UNEP/MAP (2016) – *Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria*. UNEP (DEPI)/MED IG.22/28. Decision IG.22/7.

Sandra RAMIREZ-CALERO, BENSOUSSAN N, LÓPEZ-SENDINO P, GÓMEZ-GRAS D, MONTERO-SERRA I, PAGÈS-ESCOLÀ M, MEDRANO A, LÓPEZ-SANZ A, FIGUEROLA, L, LINARES C, LEDOUX JB, GARRABOU J.
Institute of Marine Sciences, ICM-CSIC, Pg. Marítim de la Barceloneta 37-49, 08003, Barcelona, Spain
E-mail: sandraramirezcalero@gmail.com

TEMPORAL VARIABILITY IN THE RESPONSE TO THERMAL STRESS IN THE RED GORGONIAN, *P. CLAVATA*: INSIGHTS FROM COMMON GARDEN EXPERIMENTS

Abstract
Recurrent mass mortality events (MMEs) linked to marine heatwaves (MHWs) have been observed in the Mediterranean Sea affecting thousands of kilometers of coastline. Coralligenous habitats were among the most impacted during these events. Information on how the exposure to recurrent MHWs is affecting the coralligenous is critical to anticipate the consequences of climate change and implement actions to enhance their resilience. Combining field surveys with experiments in controlled conditions allowed to dilucidate the differential responses to thermal stress among species, populations and individuals and to explore the spatial and taxonomic variability response to thermal stress linked to MHWs. Yet, the temporal variability in the response to thermal stress remains to be characterized. Thus, we aim to fill this gap focusing on the temporal variability in the response to thermal stress of the coralligenous key habitat-forming species Paramuricea clavata (Plexauridae). We replicated thermal stress experiments during 3 consecutive years following a common garden setup (control vs. thermal stress) involving the same individuals from the same three populations. Considering different phenotypic responses including the level of tissue necrosis during the time of the experiment and the survival of the individuals, we found that the average percentage of tissue necrosis per population variated greatly across years while the probability of survival was considerably reduced in 2017. During the experiments, several individuals from the 3 populations systematically showed reduced level of tissue necrosis suggesting resistance to thermal stress. Overall our data will contribute to help better inform further conservation strategies of habitat-forming coral species in the Mediterranean Sea.

Key-words: Marine heat-waves, octocorals, temporal series, population genetics, conservation.

Introduction
The Mediterranean Sea, considered as a hotspot of marine biodiversity and climate change (Cramer *et al*., 2018), has been affected by recurrent mass mortality events (MMEs) linked to marine heat waves (MHWs) with differential impacts among species, populations and individuals (Garrabou *et al.*, 2022). Habitat-forming octocorals such as *Paramuricea clavata* (Risso, 1827) were strongly impacted with up to 80% of individuals affected in some localities (Cerrano *et al*., 2000; Garrabou *et al*., 2009; 2021; 2022). This Mediterranean octocoral is characterized by slow population dynamics and restricted dispersal abilities (Linares, *et al*., 2008; Arizmendi-Mejía *et al*., 2015), thus, the high mortality rates induced by MMEs question its evolutionary trajectory. Moreover, *P. clavata* has a key ecological role increasing habitat complexity in biogenic coralligenous communities. Thus, its decline owing to MMEs may have cascading effects on associated communities and related ecosystem functioning (Gómez-Gras *et al.*, 2021).

Differential responses to MMEs among individuals and populations have been reported from the field and from experimental approaches in this species (Garrabou & Harmelin, 2002; Crisci *et al*., 2011; Linares *et al*., 2015), suggesting spatial variability in the response to thermal stress with some individuals/populations able to better resist to MMEs. Yet, these studies have not included observations across consecutive years. Accordingly, the level of temporal variability in the response to thermal stress is totally unknown. This study aims to analyze the differential response to thermal stress between individuals and populations of *Paramuricea clavata* across three consecutive years, to: i) characterize the yearly temporal response variability; ii) refine estimation regarding the response variability at local scale (1 km^2) and iii) explore the potential underlying genetic and environmental factors.

Materials and methods

Samples of *P. clavata* were collected yearly from 2015 to 2017 in early September from three different localities at the Medes Island (Spain, 42°02'60.00" N 3°12'60.00" E). Thirty healthy adult colonies (>50 cm) were initially tagged in 2014 at each location within a depth range of 15-20 m. From each marked colony, apical fragments were collected every year and allocated in the Aquarium Experimental Zone (ZAE) of the Institut de Ciències del Mar (ICM-CSIC) in Barcelona. After one week of acclimation in an open aquarium system at 17-18 °C, each colony branch was divided into two and the common garden experiments were conducted with one control (18 °C) and one stress treatment (25 °C).

For control treatment, seawater temperature was maintained between 16-18 °C during the whole experiment. For the stress treatment, the temperature was increased stepwise from 18 to 25 °C over a period of 3 days. Once the temperature reached 25 °C, thermal conditions were maintained for 25 days following Crisci *et al*., (2017). Feeding was carried out three times per week in each tank.

Phenotypic response and Statistical analysis

Firstly, the percentage of tissue necrosis (extent of injury) was used as a proxy of colony response to thermal stress. Each individual was monitored visually every day until the end of the experiment. Then, we estimated the mean (and SD) extent of injury for each population and each year by using the average of injured tissue across all individuals. Secondly, the survival probabilities for each colony and population during the time of the experiment (*i.e.* having less than 100% of injured surface) was evaluated using a series of COX models under the *survival* R-package (Therneau *et al.*, 2022). Finally, since we sampled the same individuals every year, we also reported the daily trajectory of tissue necrosis for each colony each year separately in order to look for temporal variability at the population and individual levels. Following Garrabou *et al*., 2022, we identified individuals as potentially “resistant” if the levels of tissue necrosis were between 0 and 30% at the end of the experiment of any of the tested years. Remaining individuals were considered as “sensitive”.

Results

Tissue necrosis was observed for all populations in the three experiments. In 2015 and 2016, the extent of injury was below 40% at the end of the experiment (day 25^{th}). In contrast for 2017, colonies were totally affected (100% of tissue necrosis) by the 18^{th} day, except for Pota del Llop where a 100% of tissue necrosis was reached at day 24th.

(Fig. 1a). In addition, there were no significant differences in the survival probability comparing between localities for any given year. Significant differences in the survival probability of colonies from the three localities were found across years (*$p<0.001$*). In 2015 and 2016, the probability of surviving slightly decreased only after day 15. In contrast, in 2017, the probability of survival sharply decreased after day 10. The probability of surviving in 2015 and 2016 was higher in comparison with 2017 (Fig. 1b).

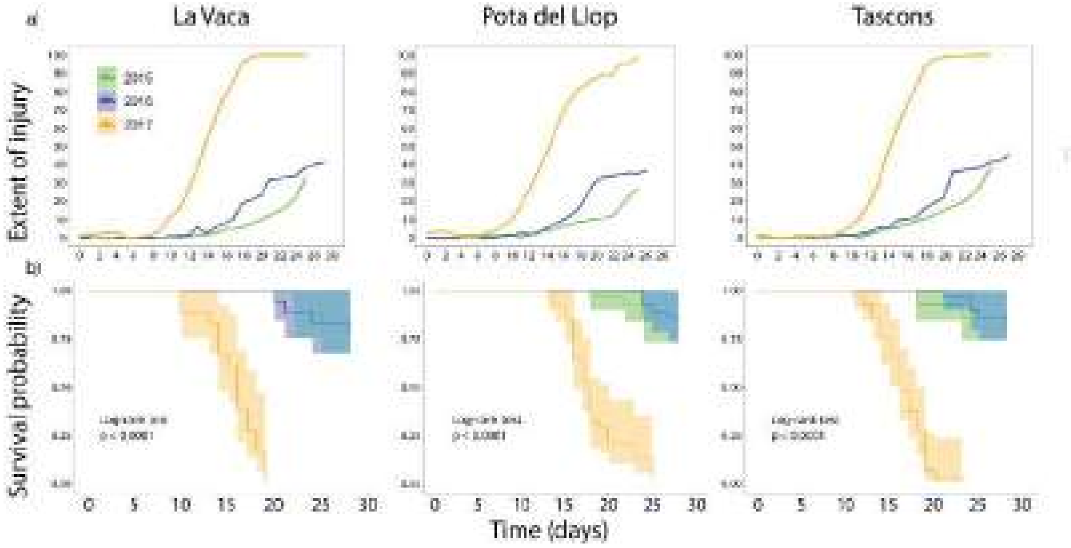


Fig. 1:. a) Average tissue necrosis in common garden experiments in La Vaca, Pota del Llop and Tascons from 2015 to 2017. b) Differences in survival probability (*i.e.* mortality) across years in *P. clavata* when exposed to thermal stress Kaplan-Meier survival curve (*$p<0,0001$*).

Figure 2 shows the temporal variability of individual tissue necrosis among the three years. In each population, the level of tissue necrosis varied greatly among individuals. Considering the three years, around 40% of the total individuals (black arrows) in each population show between 0-30% of tissue necrosis in at least one of the tested years at the beginning of the second week of the experiment (~13 day). Thus, they were considered as potentially more resistant.

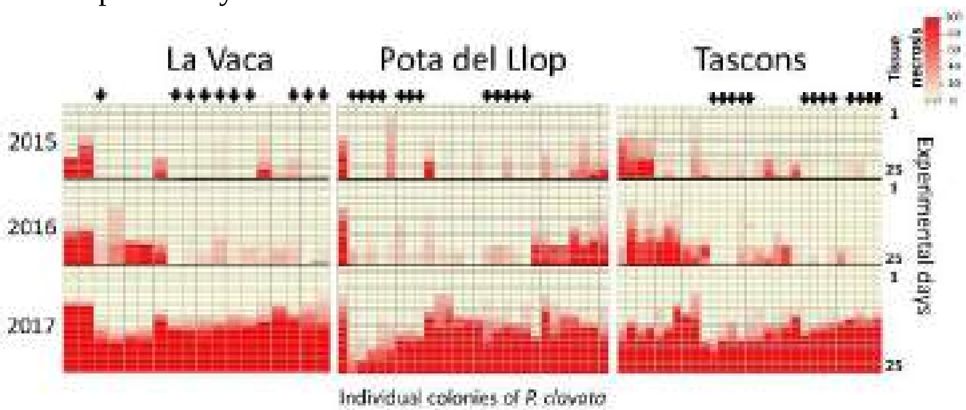


Fig. 2: Trajectory of tissue necrosis in every experimental year for individual colonies of *P. clavata* at each locality. Each column represents the tissue necrosis in one individual during the 25 days of the experiment for each year. Black arrows indicate potential "resistant" individuals.

Discussion

In this study we conducted the characterization of the spatial and temporal variability in the responses to thermal stress between individuals and populations of the red gorgonian *P. clavata*. We considered a local scale within 1 km^2 with three populations, while the temporal scale accounts for three consecutive years. We found no significant response to thermal stress when comparing the survival probability among populations for any given year. These results are in line with previous thermal stress experiments with the same species. In fact, as in our study, the response of populations from the same geographic area were not significantly different (Crisci *et al.*, 2017). The factors and processes underlying this level of spatial variability remain poorly understood in *P. clavata*. Nevertheless, the influences of local thermal environment and recent thermal history on the spatial variability to thermal stress seem to be low (Gomez-Gras *et al*., 2022). This result contrasts with different studies conducted in tropical corals species and point towards the implication of other processes, in particular genetic drift, driving the differential response among populations (Crisci *et al.*, 2011; Linares *et al*., 2013;Howells *et al*., 2012; Palumbi *et al.*, 2014).

We demonstrate a high variability in the percentage of tissue necrosis among individuals from the same population for a given year. This result is also in line with previous studies with *P. clavata* (Crisci *et al.*, 2017). For instance, physiological aspects, including reproductive status (male vs. female) of the colonies were also suggested as important drivers controlling the differential response among individuals (Coma *et al.*, 2009; Arizmendi-Mejía *et al.*, 2015). In the present case, all the sampled colonies were adults (> 50cm), and they were feed during all the experiments, most likely buffering the impact of physiological and reproductive status. Therefore, on-going population genetics and transcriptomics studies should provide further insights into this level of variability. Noteworthy, this individual sensitivity has been proposed as a fuel for adaptation and directional selection of resistant individuals to new thermal regimes in other coral populations over time (Morikawa & Palumbi, 2019).

Finally, we demonstrate a strong temporal variability in the response to thermal stress for all three populations. We found that the survival probability of colonies was strongly reduced in 2017 experiment. Even though, we found several potentially resistant individuals of *P. clavata* at every locality, we observed that mortality is reached faster at year 2017 in at least two of the three populations (100% tissue necrosis by day 18^{th}). Two non-exclusive hypotheses may potentially explain this result: i) impact of past thermal conditions (*i.e.* years before the experiment); ii) impact of recent thermal conditions (*i.e.* summer before the experiment). In 2017, the study area suffered a severe marine heatwave in the sea surface (Bensoussan *et al.*, 2019). Besides preliminary results comparing 2017 with 2015 and 2016 thermal conditions at the depth where the populations dwell (15-20m) point toward a stronger and longer thermal disturbance (>23°C) observed during June to September of 2017 in comparison with 2015 and 2016. In any case, the populations in the field were slightly affected by mortality (Hereu *et al*., 2020). This study indicates that determining the thermal response of populations and individuals may not be straightforward, as we showed that it may depend on the yearly environmental conditions. Despite of this, we also found some potential sensitivity/resistance patterns that may support climate adaptation conservation measures.

Bibliography

ARIZMENDI-MEJÍA R., LEDOUX JB., CIVIT S., ANTUNES A., THANOPOULOU Z., GARRABOU J., LINARES C. (2015) - Demographic responses to warming: reproductive maturity and sex influence vulnerability in an octocoral, *Coral Reefs,* 34(4), pp. 1207–1216.

BENSOUSSAN N., CEBRIAN E., DOMINICI JM., KERSTING DK., KIPSON S., KIZILKAYA Z., OCANA O., PEIRACHE M., ZUBERER F., LEDOUX JB., LINARES C., ZABALA M., NARDELLI BB., PISANO A., GARRABOU J (2019) - Using CMEMS and the Mediterranean Marine Protected Areas sentinel network to track ocean warming effects in coastal areas, *Journal of Operational Oceanography,* 12, pp. S65.

CERRANO C., BAVESTRELLO G., BIANCHI C.N., CATTANEO-VIETTI R., BAVA S., MORGANTI C., MORRI C., PICCO P., SARA G., SCHIAPARELLI S., SICCARDI A., SPONGA F. (2000) - A catastrophic mass-mortality episode of gorgonians and other organisms in the Ligurian Sea (North-western Mediterranean), summer 1999, *Ecology Letters*. 3(4), pp. 284–293.

COMA R., RIBES M., SERRANO E., JIMÉNEZ E., SALAT J., PASCUAL J. (2009) - Global warming-enhanced stratification and mass mortality events in the Mediterranean, *Proceedings of the National Academy of Sciences of the United States of America*, 106(15), pp. 6176–6181.

CRAMER W., GUIOT J., FADER M., GARRABOU J., GATTUSO J., IGLESIAS A., LANGE M., LIONELLO P., LLASAT M., PAZ S., PEÑUELAS J., SNOUSSI M., TORETI A., TSIMPLIS M., XOPLAKI E. (2018) - Climate change and interconnected risks to sustainable development in the Mediterranean, *Nature Climate Change 2018 8:11*. 8(11), pp. 972–980.

CRISCI C., BENSOUSSAN N., ROMANO JC., GARRABOU J. (2011) - Temperature anomalies and mortality events in marine communities: Insights on factors behind differential mortality impacts in the NW Mediterranean, *PLoS ONE*. 6(9), p. e23814.

CRISCI C., LEDOUX J.B., MOKHTAR-JAMAÏ K., BALLY M., BENSOUSSAN N., AURELLE D., CEBRIAN E., COMA R., FÉRAL J.P., LA RIVIÈRE M., LINARES C., LÓPEZ-SENDINO P., MARSCHAL C., RIBES M., TEIXIDÓ N., ZUBERER F., GARRABOU J., (2017) - Regional and local environmental conditions do not shape the response to warming of a marine habitat-forming species, *Scientific Reports*, 7(1), pp. 1–13.

GARRABOU J., COMA R., BENSOUSSAN N., BALLY M., CHEVALDONNÉ P., CIGLIANO M., DIAZ D., HARMELIN J.G., GAMBI M.C., KERSTING D.K., LEDOUX J.B., LEJEUSNE C., LINARES C., MARSCHAL C., PÉREZ T., RIBES M., ROMANO J.C., SERRANO E., TEIXIDO N., TORRENTS O., ZABALA M., ZUBERER F., CERRANO C. (2009) - Mass mortality in Northwestern Mediterranean rocky benthic communities: Effects of the 2003 heat wave, *Global Change Biology*. 15(5), pp. 1090–1103.

GARRABOU J., LEDOUX J., BENSOUSSAN N., GÓMEZ-GRAS D., LINARES C. (2021) - Sliding Toward the of Mediterranean Coastal Marine Rocky Ecosystems, in *Ecosystem Collapse and Climate Change*. pp. 291–324.

GARRABOU J., GÓMEZ-GRAS D., MEDRANO A., CERRANO C., PONTI M., SCHLEGEL R., BENSOUSSAN N., TURICCHIA E., SINI M., GEROVASILEIOU V., TEIXIDO N., MIRASOLE A., TAMBURELLO L.,CEBRIAN E., RILOV G., LEDOUX J., SOUISSI J., KHAMASSI F.,GHANEM R., BENABDI M.,GRIMES S., OCAÑA O., BAZAIRI H., HEREU B., LINARES C., KERSTING D., ROVIRA G., ORTEGA J., CASALS D., PAGÈS-ESCOLÀ M., MARGARIT N., CAPDEVILA P., VERDURA J., RAMOS A., IZQUIERDO A., BARBERA C., RUBIO-PORTILLO E., ANTON I., LÓPEZ-SENDINO P., DÍAZ D., VÁZQUEZ-LUIS M., DUARTE C., MARBÀ N., ASPILLAGA E., ESPINOSA F., GRECH D., GUALA I., AZZURRO E., FARINA S., GAMBI M., CHIMIENTI G., MONTEFALCONE M., AZZOLA A., MANTAS T., FRASCHETTI S., CECCHERELLI G., KIPSON S., BAKRAN-PETRICIOLI T., PETRICIOLI D., JIMENEZ C., KATSANEVAKIS, S., KIZILKAYA Z., INCI T., KIZILKAYA Z., SARTORETTO S., ELODIE R., RUITTON S., COMEAU S., GATTUSO J. HARMELIN J. (2022) - Marine heatwaves drive recurrent mass mortalities in the Mediterranean Sea, *Global Change Biology*. pp. 1–18.

GARRABOU J., HARMELIN J. G. (2002) - A 20-year study on life-history traits of a harvested long-lived temperate coral in the NW Mediterranean: Insights into conservation and management needs, *Journal of Animal Ecology*, 71(6), pp. 966–978.

GÓMEZ-GRAS D., BENSOUSSAN N., LEDOUX JB., LÓPEZ-SENDINO P., CERRANO C., FERRETTI E., KIPSON S., BAKRAN-PETRICIOLI T., CRUZ F., GÓMEZ-GARRIDO J., ALIOTO TS., GUT M., SERRAO EA., , PAULO D., BOAVIDA J., COELHO M., PEARSON GA., MONTERO-SERRA I., PAGÈS-ESCOLÀ M., MEDRANO A., LÓPEZ-SANZ A., MILANESE M., LINARES C., GARRABOU J. (2022) Exploring the response of a key Mediterranean habitat-forming gorgonian to heat stress across biological and spatial scales. *In prep.*

GÓMEZ-GRAS D., LINARES C., DORNELAS M., MADIN J., BRAMBILLA V., LEDOUX J., LÓPEZ-SENDINO P., BENSOUSSAN N. GARRABOU J. (2021) - Climate change transforms the functional identity of Mediterranean coralligenous assemblages, *Ecology Letters*. 24(5), pp. 1038–1051.

HEREU B., ROVIRA G. CASALS D., ORTEGA J., MARGARIT N., MEDRANO A., PAGÈS-ESCOLÀ M., ZENTNER Y., LINARES C. (2020) - Seguiment anual de briozous, gorgònia vermella i coves a la Reserva Natural Parcial Marina de les Medes del Parc Natural del Montgrí, les Illes Medes i el Baix Ter. Memòria 2020. Generalitat de Catalunya. Departament de Territori i Sostenibilitat. Direcció General de Polítiques Ambientals i Medi Natural. 96 pp.

HOWELLS E.J., BELTRAN V.H., LARSEN N.W., BAY L.K., WILLIS B.L., VAN OPPEN M.J.H. (2012) - Coral thermal tolerance shaped by local adaptation of photosymbionts, *Nature Climate Change*, 2(2), pp. 116–120.

LINARES C. CEBRIAN E., KIPSON S., GARRABOU J. (2013) - Does thermal history influence the tolerance of temperate gorgonians to future warming?, *Marine Environmental Research*. 89, pp. 45–52.

LINARES C. DOAK D., COMA R., DIAZ D., ZABALA M., DOAK F., MOLL C. (2015) - Life History and Viability of a Long-Lived Marine Invertebrate : The Octocoral *Paramuricea clavata*, *Ecology*, 88(4), pp. 918–928.

LINARES C., COMA R., ZABALA M. (2008) -Effects of a mass mortality event on gorgonian reproduction, *Coral Reefs*, 27(1), pp. 27–34.

MORIKAWA M. K., PALUMBI S. R. (2019) -Using naturally occurring climate resilient corals to construct bleaching-resistant nurseries, *Proceedings of the National Academy of Sciences of the United States of America*. National Academy of Sciences, 116(21), pp. 10586–10591.

PALUMBI S., BARSHIS D., TRAYLOR-KNOWLES N., BAY R. (2014) - Mechanisms of reef coral resistance to future climate change, *Science*, 344(6186), pp. 895–897.

THERNEAU T., LUMLEY T., ATKINSON E., CROWSON C. (2022) - Package ‘survival’ Title Survival Analysis Priority recommended.

Antonietta ROSSO, ALTIERI C., BAZZICALUPO P., BERTOLINO M., BRACCHI V.A., BRUNO F., CIPRIANI M., COSTA G., D'ALPA F., DONATO G., FALLATI L., GALLO A., GUIDO A., LEONARDI R., MUZZUPAPPA M., NEGRI M.P., SANFILIPPO R., SAVINI A., SCIUTO F., SERIO D., TADDEI RUGGIERO E., VARZI A.G., VIOLA A., BASSO D.
Department of Biological, Geological and Environmental Sciences, University of Catania, Catania, Italy
E-mail: rosso@unict.it

BRIDGING TOGETHER RESEARCH AND TECHNOLOGICAL INNOVATION: FIRST RESULTS AND EXPECTED BEARINGS OF THE PROJECT CRESCIBLUREEF ON MEDITERRANEAN CORALLIGENOUS

Abstract
Coralligenous developed off Marzamemi (SE Sicily, Ionian Sea) is being investigated in the frame of the project FISR 04543 "CRESCIBLUREEF - Grown in the blue: new technologies for knowledge and conservation of Mediterranean reefs" aimed at understanding time and mode of its inception and accretion and at developing non-invasive technologies for its sampling. First achievements include: 1) mapping of the coralligenous field; 2) first quantitative characterisation of the internal structure of two bioconstructions (frame builders, cavities and sediment); 3) characterisation of cavity-filling sediments including entrapped bioclasts and micrites; 4) preliminary data about biodiversity associated with the bioconstructions; 5) development of a prototype for underwater non-invasive coring of coralligenous bioconstructions.

Key-words: Benthic diversity, coralligenous reef, priority habitat, non-invasive sampling, Ionian Sea

Introduction
Coralligenous (C) is a relevant habitat in the Mediterranean with high aesthetic, economic and ecological value representing a hot spot of biodiversity seemingly sustained by its complexity and heterogeneity (Hong, 1980; Ballesteros, 2006 and references therein). However, coralligenous accretion rate is slow (vertical estimated values of *ca.* 0.26-0.27mm per year: Di Geronimo *et al*., 2001; Bertolino *et al*., 2020) and constituent organisms are extremely sensitive to natural and anthropogenic environmental changes (e.g. Montefalcone *et al*., 2017). For these reasons, Coralligenous is a relevant but fragile and threatened habitat that has since long time been the object of special interest by the UNEP (United Nations Environmental Plan) RAC/SPA (Regional Activity Centre for Specially Protected Areas) and considered among the priority habitats for monitoring and conservation by the European Community, and currently included in the EU Biodiversity Strategy for 2030. In this context, the 2-years project FISR 04543 "CRESCIBLUREEF - Grown in the blue: new technologies for knowledge and conservation of Mediterranean reefs" aims at: 1) understanding the *tempo* and mode of the Coralligenous inception and development, focusing on its growth rate (also in the framework of the Holocene climate fluctuations), the type of accretionary structures that sustain its biodiversity and the canopy of soft-

bodied engineer species developing on its surface; 2) understanding the role that sponges and microbial communities play in strengthening/weakening these biostructures and seemingly promoting their early diagenesis; 3) developing new non-invasive sampling technologies to complement the existing techniques for remote and direct monitoring. Members of the permanent staff of three universities are involved in the project lead by the University of Milano Bicocca, with the collaboration of the universities of Catania and Calabria. The project also benefits of the collaboration of specialists from other institutions and of several researchers as temporary staff.

Materials and Methods

A field of Coralligenous bioconstructions occurring off Marzamemi, SE Sicily (W Ionian Sea) was selected for this project (Fig. 1).

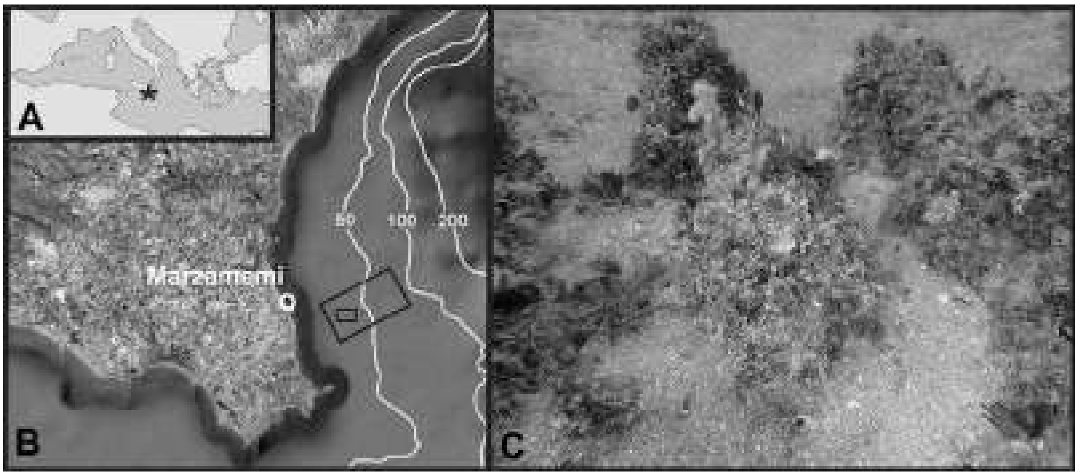


Fig. 1: Location of the study area: (A) In Italy and the Mediterranean Sea. The SE sector of Sicily (asterisk) is enlarged in B; (B) The surveyed area offshore Marzamemi (large rectangle) and the sampling sites (small rectangle); (C) underwater view of some build-ups.

Coralligenous was known in this area since the early 1980 (Violanti *et al*., 1990) and pillar-like bioconstructions were first detected by scuba diving at the end of the 1990s. The associated biodiversity and internal composition and architecture were investigated on a discrete structure (Di Geronimo *et al*., 2001; 2002; Rosso & Sanfilippo, 2009). Dating of the basal part of that bioconstruction at about 2000 years pointed to its recent inception and to a low growth rate in the range of other similar coralligenous structures (see Di Geronimo *et al*., 2001). Many aspects, however, remained to be investigated, including the extension of the biocoenosis in the area and its relationships with the surrounding soft bottoms, the inception of the build-ups and the relationships with the substratum, the possible spatial variability and the role of organisms in its accretion.
Owing to the multiple aims of the project several methods are being employed to fulfil the different challenging investigation topics. To define the extension of the Coralligenous and acquire the marine geomorphology and seascape, multibeam echosounder coupled with ROV surveys has been employed. Photogrammetry was performed on selected clusters of bioconstructions for their remote description and visualization. Chirp profiles were employed to investigate the deep inception of Coralligenous in the area. Coring in selected sites is also planned. Several types of samples were collected by scuba diving, including the use of an airlift suction sampler to collect small vagile fauna, a scraping method on definite surfaces (20x20 cm) to

obtain the canopy and the superficial concretion layer in order to investigate present-day biodiversity, the collection of two discrete bioconstructions, to study the internal structure; the constructional organisms' composition, role and relationships; the sediments filling cavities, their nature and meaning; the microbial communities, early diagenesis and age. Airlift and scraping samples are being routinely processed through stereomicroscopy and scanning electron microscopy (SEM) for the identification of organisms. The two sampled build-ups were investigated through photogrammetry, image analysis and computed axial tomography. Sediments inside cavities are being analysed for the recognition of entrapped biogenic remains of both organisms living in the build-ups and their surroundings. Muds have been investigated through optical microscopy, UV-epifluorescence and SEM to figure out about a direct marker of biological activity or not.

The need to perform minimally invasive sampling on coralligenous build-ups forced the development of a coring device that could be operated both by divers, for shallow depths, and by ROVs, for deeper sites. Various laboratory experiments were conducted to determine the main specifications of the robotic coring system, by using different coralligenous samples. A test bench has been manufactured to determine the system specifications in terms of rotational speed, torque and axial force needed to core the build-ups. The design and prototyping of the coring device was then performed, and a prototype has been assembled and successfully tested in the pool.

Results

After the first year of the project, several results have been reached. A high-resolution bathymetric map of the area was produced (Varzi *et al*., in press) allowing the localisation of the coralligenous outcrop and its extent (ca. 17 km^2) in a belt between ca. 36 and 100 m depth. First interpretation of acquired data point to a good correlation between C distribution and the local terraced seascape (Varzi *et al*., in press).

Image analysis and computed axial tomography applied to two bioconstructions allowed to identify and quantify for the first time the cavities within the structure and the role of the different components on the surface and inside the framework, confirming the main building role of crustose coralline algae in the Mediterranean C (Bracchi *et al*., 2022; Basso *et al*., in press). Other constructional taxonomic groups were subordinate to negligible, except for bryozoans (ca. 3-12%) on the surface of one of the examined build-ups. Preliminary analyses of the communities associated with the canopy, mainly consisting of soft algae (*Flabellia petiolata, Peyssonnelia rubra, Halimeda tuna, Rodrigueziella pinnata, Palmophyllum crassum* and locally *Acrodiscus vidovichii, Osmundaria volubilis* and slender thalli of the invasive alien species *Caulerpa cylindracea*) and occasionally of the large-sized bryozoan *Margaretta cereoides*, point to a high associated biodiversity. Focusing on skeletonised taxa (study still ongoing) bryozoans and serpulids are the most obvious groups, especially with some large-sized species, whereas all other taxonomic groups are very rare and not obvious. Bryozoans account for more than 100 species nearly all with living colonies; few species, among which *Celleporina caminata, Mecynoecia delicatula* and *Scrupocellaria delilii*, dominate. Serpulids occur with about 35 species, most with living specimens; the serpulines *Josephella marenzelleri, Metavermilia multicristata* and *Spirobranchus triqueter* and the spirorbine *Neodexiospira pseudocorrugata* dominate. Molluscs are present with ca. 80 species, but mostly with dead specimens; a couple of vermetids have a role in the construction of the build-up while bivalves show a range of mode of life, from byssate on the surface to boring the algal carbonate (e.g., *Lithophaga lithophaga*) or nesting within cavities (*Gregariella semigranata*). Brachiopods are subordinate, with only three species and few specimens, except for *Argyrotheca cuneata*. *Verruca spengleri* is the only detected barnacle. Among small-sized taxa, foraminifera are numerous with ca. 130 species, several with only dead specimens. Elphidiidae, Hauerinidae and Cibicididae dominate. *Miniacina miniacea* and *Cornuspiramia adherens* directly encrust the build-ups. Ostracods include 20 species nearly all alive; taxa in the genus *Xestoleberis* dominate. Sponges (more than 20 already identified species) are common constituents on both the surface and within cavities; the most abundant species are the massive *Agelas oroides* and the boring *Cliona schmidtii*.

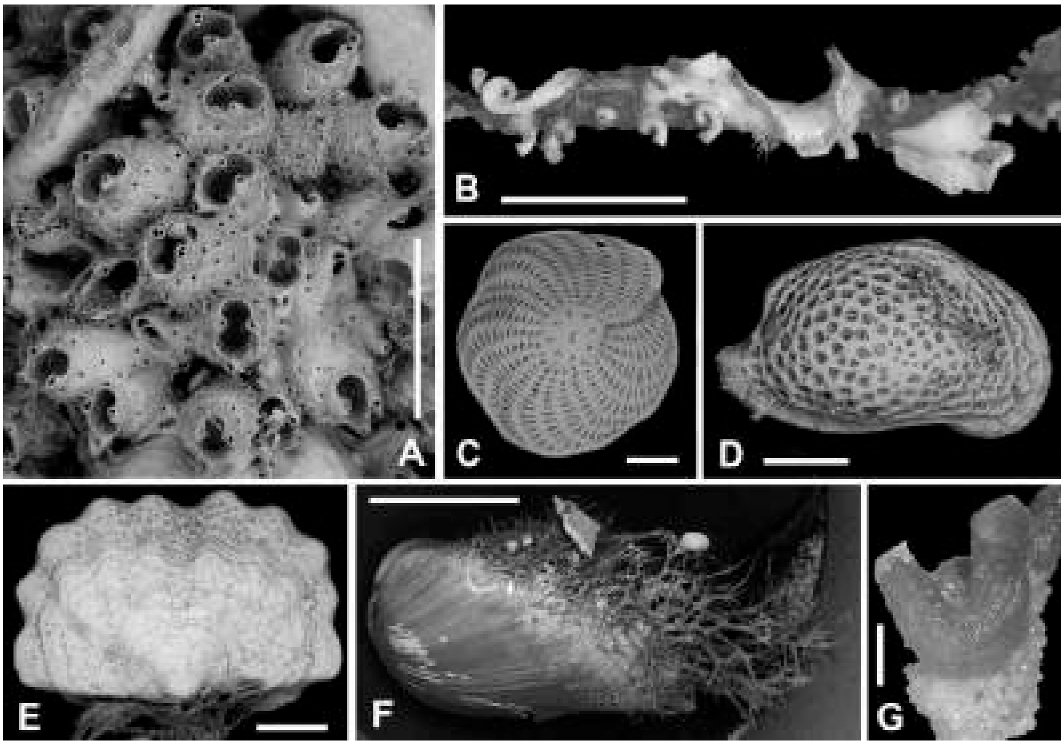


Fig. 2: Representatives of some taxonomic groups. (A) The bryozoan *Celleporina caminata*; (B) the serpuline *Spirobranchus triqueter* and the spirorbine *Pileolaria psudomilitaris*; (C) The foraminifera *Elphidium crispum*; (D) The ostracod *Aurila convexa*; (E) The brachiopod *Argyrotheca cuneata*; (F) The bivalve *Gregariella semigranata*; (G) The gastropod *Vermetus granulatus*. Scale bars: A, F, G: 1 mm; B: 5 mm; C, D: 200 μm; E: 500 μm.

Preliminary results indicate the occurrence of autochthonous and allochthonous micrite strictly associated with skeletal remains. While the former consists of amorphous high-magnesium calcite engulfing sponge spicules and shows bright epifluorescence under UV excitation, the latter consists of sub-euhedral crystals engulfing bioclasts, including insinuating and boring sponge spicules, and small intraclasts and does not show epifluorescence under UV treatment. Coccoliths entrapped within cavities consist of remains of both present-day species and reworked material entrapped in the structure.
The first laboratory testing on the robotic coring system demonstrated that the device is able to extract samples with a diameter of 60 mm, but the main issues to be solved relate to need of its proper anchoring to prevent breakage of the sample.

Discussion and conclusions

Remote analyses allowed identification of different build-up morphologies (*sensu* Bracchi *et al*., 2017) and to hypothesise a relationship between the Coralligenous offshore Marzamemi and the inherited seascape morphology (Varzi *et al*., in press), but more in-depth investigations and new results from dating are needed to understand the particular conditions leading to C inception in the area during the Holocene sea-level raise.

Although subordinate as builders and carbonate production, organisms associated with the build-ups and trapped in the cavities are numerous and ongoing research will contribute improving knowledge about Coralligenous biodiversity, mostly for some previously understudied groups. The identified species of bryozoans and serpulids largely outnumber the figures for these two groups found on a previously studied build-up from shallower waters in the area (9 bryozoans and 7 serpulids: Di Geronimo *et al*., 2001) and those from deeper coralligenous fragments (ca. 100 m depth: 60 bryozoans and 11 serpulids) from a nearby site (Rosso & Sanfilippo, 2009). Though diversified, bryozoans and molluscs show less species than the total numbers reported for the whole Mediterranean, i.e. 219 (Rosso & Di Martino, 2016 and references therein) and ca. 130 species (see Ballesteros, 2006, based on Hong, 1980), respectively. In contrast, foraminifers and ostracods exceed the 61species and 10 species, respectively reported by Ballesteros (2006 and references therein) for the Coralligenous in the whole Mediterranean. Comparisons are more difficult for serpulids usually merged within polychaetes. Preliminary data and literature in the area also suggest a relevant spatial heterogeneity in species distribution to be further investigated.

Further analyses are needed to elucidate the relationship between the high abundance of sponges inhabiting the Coralligenous (e.g., Costa *et al*., 2019) and micrite sediments. Assessing the biomineralization processes involved in the autochthonous micrite deposition will add information about the syndepositional cementation and strengthening of the coralligenous framework, and enable comparison with other bioconstructions, such as cave biostalactites (e.g., Guido *et al*., 2022). The pool trails of the robotic coring system have demonstrated the feasibility of the concept, even if the system still does not implement all the functions that have been designed and some issues are arisen about the anchorage to the seabed. Sea trails will probably give more information about other issues to be solved and then a complete prototype is expected to be manufactured. First data from still under- or un-explored aspects (e.g., biogenics entrapped in the cavities) are also promising in helping to reconstruct the palaeoenvironmental conditions during inception and accretion of the studied biostructures.

Acknowledgements

This work was funded by the Italian Ministry of Research and University – Fondo Integrativo Speciale per la Ricerca (FISR), project FISR2019_04543 “CRESCIBLUREEF - Grown in the blue: new technologies for knowledge and conservation of Mediterranean reefs”. Nunzio Pietralito and the team of SUTTAKKUA Diving Center (Pachino, SR) are thanked for support in field activities. This is the Catania Palaeoecological Research Group contribution n. 490.

Bibliography

BALLESTEROS E. (2006) - “Mediterranean Coralligenous Assemblages,” in Oceanogr. *Mar. Biol. Ann. Rev*. Ed. H. Barners, 123–195.

BASSO D., BRACCHI V.A., BAZZICALUPO P., MARTINI M., MASPERO F., BAVESTRELLO G. (in press) - Living Coralligenous as geo-historical structure built by coralline algae. *Frontiers Earth Science, Paleontology.*

BERTOLINO M., COSTA G., CATTANEO-VIETTI R., PANSINI M., QUARTA G., CALCAGNILE L., BAVESTRELLO G. (2019) - Ancient and Recent Sponge Assemblages from the Tyrrhenian Coralligenous over Millennia (Mediterranean Sea). *Facies* 65 (3), 1–12.

BRACCHI V.A., BAZZICALUPO P., FALLATI L., VARZI A.G., SAVINI A., NEGRI M.P., ROSSO A., SANFILIPPO R., GUIDO A., BERTOLINO M., COSTA G., DE PONTI E., LEONARDI R., MUZZUPAPPA M., BASSO D. (2022) - The main builders of Mediterranean coralligenous: 2D and 3D quantitative approaches for its identification. *Frontiers Earth Science, Paleontology*. 10:910522.

COSTA G., BAVESTRELLO G., MICARONI V., PANSINI M., STRANO F., BERTOLINO M. (2019) - Sponge community variation along the Apulian coasts (Otranto Strait) over a pluri-decennial time span. Does water warming drive a sponge diversity increasing in the Mediterranean Sea? *Journal of the Marine Biological Association of the United Kingdom*, 99(7): 1519–1534.

DI GERONIMO I., DI GERONIMO R., IMPROTA S., ROSSO A., SANFILIPPO R. (2001) - Preliminary Observations on a Columnar Coralline Build-Up from off SE Sicily in Proceedings of the Conference of the Society of Marine Biology, Sharm El Sheikh, May 13–20 2000. *Biol. Mar. Medit.* 8 (1): 1–10.

DI GERONIMO I., DI GERONIMO R., ROSSO A., SANFILIPPO R. (2002) - Structural and Taphonomic Analysis of a Columnar Coralline Algal Build-Up from SE Sicily. *Geobios* 35, 86–95.

GUIDO A**.,** ROSSO A., SANFILIPPO R., MIRIELLO D., BELMONTE G. (2022) - Skeletal *vs* microbialite geobiological role in bioconstructions of confined marine environments. *Palaeogeogr., Palaeoclim., Palaeoecol.*, 593:110920,

HONG J.S. (1980) - Etude faunistique d'un fond de concrétionnement de type coralligène soumis à un gradient de pollution en Méditerranée nord-occidentale (golfe de Fos). Thèse 3ème cycle Océanologie, Université Aix-Marseille II, 137 + 108p.

MONTEFALCONE M., MORRI C., BIANCHI C.N., BAVESTRELLO G., PIAZZI L. (2017) - The two facets of species sensitivity: Stress and disturbance on coralligenous assemblages in space and time. *Mar. Poll. Bull.*, 117: 229–238.

ROSSO A., DI MARTINO E. (2016) - Bryozoan diversity in the Mediterranean Sea: an up-date. *Medit. Mar. Sci.*, 17 (2): 567–607.

ROSSO A., SANFILIPPO R. (2009) - The contribution of bryozoans and serpuloideans to coralligenous concretions from SE Sicily. In: UNEP-MAP-RAC/SPA, Proc. First Symposium on the Coralligenous and other calcareous bio-concretions of the Mediterranean Sea (Tabarka, 15–16 January 2009): 123–128.

VARZI A.G., FALLATI L., SAVINI A., BRACCHI V.A., BAZZICALUPO P., ROSSO A., SANFILIPPO R., BERTOLINO M., MUZZUPAPPA M., BASSO D. (in press) - Geomorphological mapping of Coralligenous reefs offshore southeastern Sicily (Ionian Sea). *Journal Maps*.

VIOLANTI V., DI GERONIMO I., SACCÀ R. (1990) - Foraminiferal thanatocoenoses from the Gulf of Noto (Southeastern Sicily). *Boll. Mus. Reg. Sci. Nat. Torino*, Special Volume: 773–799. Torino.

Nur Eda TOPÇU, GÜRESEN S. O., YILMAZ I.N., STEINUM T., TURGAY E., YARDIMCI E., KARATAŞ S., DOĞAN O., BARRAUD T., SARACOGLU C., AURELLE D.
Istanbul University, Faculty of Aquatic Sciences, Department of Marine Biology, Balabanağa Mah. Ordu cad. No8 Laleli 34134 Istanbul-Turkey.
E-mail: edatopcu@istanbul.edu.tr

SOFT CORAL AND GORGONIAN ASSEMBLAGES EXEMPTED OF THERMAL STRESS BUT THREATENED BY HIGH ANTHROPOGENIC PRESSURES IN THE SEA OF MARMARA

Abstract
The Sea of Marmara, characterized by peculiar oceanography, harbours unique alcyonarian assemblages below the halocline layer (approximately below 20 m), where Mediterranean originated waters flow at dim light conditions, roughly 15 °C, year-round. These conditions allow the co-presence of species with relatively large bathymetric distribution like Eunicella cavolini and Paramuricea clavata together with species with deeper distribution, like P. macrospina and Spinimuricea klavereni, within scuba diving limits. Distribution and density of these assemblages in northeastern Marmara are being monitored since 2013. Demographic and genetic structure of the yellow gorgonian E. cavolini populations were studied in 2016 and 2021. Also, the microbiomes of some alcyonarians were studied in 2018. Alcyonarians, which are among the most impacted and threatened organisms by thermal anomalies that affect Mediterranean assemblages, are eventually protected from climatic threats in more or less constant temperatures of the Marmara lower layer. However, they are threatened by other anthropogenic impacts, mainly fisheries, high sedimentation and pollution, the impacts of which are evidenced in results of our various studies. In Marmara, alcyonarian microbiomes included Endozoicomonas bacteria like most alcyonarians, however notably less abundant than previously reported in Mediterranean gorgonians, possibly due to high anthropogenic stressors. Populations of the yellow gorgonian in Marmara seem well-structured but displayed high proportion of mortality and extent of injury, especially at large size classes, showing a strong impact. These populations were characterized by high genetic structure, low levels of diversity and high private allelic richness. Alcyonarians in Marmara were lately impacted from a severe, basin-wide mucilage event that took place in 2020, that resulted in sharp decreases of colony numbers in northeastern Marmara. Urgent actions to protect the vulnerable assemblages are required and should be considered as part of the recent status of "Special Environmental Protection Area" and the 2021 Marmara Action Plan.

Key-words: Coral assemblages, disturbance, population genetics, demographic structure, microbiomes

Introduction
The Sea of Marmara, with unique oceanography and high nutrient availability, constitutes a favourable environment for suspension feeders including soft corals and gorgonians (Alcyonacea) and supports high biodiversity along with high abundances (Topçu and Öztürk 2015). Soft corals and gorgonians are absent on sea bottom of the brackish upper layer, formed by the Black Sea water mass flowing into the Marmara Sea through the Istanbul Strait. They are present below the halocline layer, at 20 – 22 m shallowest, or deeper, depending on the species. The lower layer is characterized by

dim-light and a year-round roughly 15 °C temperature, conditions that allow several alcyonarians to be found, including species with relatively large bathymetric distribution like *Eunicella cavolini* (Koch, 1887) and *Paramuricea clavata* (Risso, 1826) together with species with deeper distribution (in general below 50 m), like *Paramuricea macrospina* (von Koch, 1882) and *Spinimuricea klavereni* (Carpine and Grasshoff, 1975*)*, at depths that can be reached by regular scuba diving.
Prince Islands where diverse alcyonarian assemblages are present, is a group of islands facing the megacity of Istanbul. Soft corals and gorgonians in the area were monitored and were subject to several studies since 2013. This study briefly summarises results from various recent studies in Prince Islands including (i) octocorals distribution and abundance, (ii) demographic structure of yellow gorgonian populations, (iii) and their genetic diversity, and (iv) microbiome composition of two gorgonian species.

Materials and methods

The materials and methods used in various studies can be summarised as follows.
(i) Octocoral species in Prince Islands were monitored at 9 stations by counting colonies in 20 m^2 transects on more or less horizontal bottoms or in 20 quadrats haphazardly placed in case of steep bottoms (Topçu and Öztürk 2015; Topçu et al. 2019 and unpublished data in 2021). The health status of colonies is also noted, as healthy, showing partial mortality > 10% of colony surface or dead (entirely denuded, bare skeleton).
(ii) Numbers, sizes, and percentage of recent/old necrosis of yellow gorgonian colonies (*Eunicella cavolini*) were studied in haphazardly placed 1 m^2 quadrats for populations' demographic structure at 3 stations in 2016 and 2021 (Fig. 1).
(iii) In order to determine the genetic diversity in populations of the Sea of Marmara and reveal genetic connectivity with populations of the Aegean Sea, four populations in the Sea of Marmara were compared to seven population in the northern Aegean Sea by genotyping five microsatellite loci from 30 colonies/population.
(iv) The bacterial microbiome composition of 2 gorgonian species (*Paramuricea clavata* and *E. cavolini*) were studied by using 16S rRNA amplicon sequencing-based profiling.

Results

The monitoring of octocoral assemblages in Prince Islands indicate significant decreases in all species as response to recent stressors (Fig. 1). Following the excessive sedimentation in 2015 - 2016, soft corals in Prince Islands decreased by 91.6 % (Topçu et al. 2019). Even most common species like *Alcyonium palmatum* Pallas 1766 has become rare at all sites. In 2021, the long-lasting and basin-wide mucilage caused another decrease of soft corals by 76.7 %, leading to an almost suppression of soft corals in Prince Islands.
Considering only those completely denuded, gorgonians were decreased by 66.4 %, following the excessive sedimentation. The mucilage induced another decrease by 19.2 % of gorgonians but not all species were similarly impacted. *Paramuricea macrospina* and *Spinimuricea klavereni* were the most affected species from both stressors.
The demographic structure of the yellow gorgonian populations was characterized by high numbers of small sized colonies along with the presence of large size classes in 2016 (Topçu et al. unpubl. data). In 2021, the number of large size classes highly diminished while the number of necrosed and dead colonies were increased. On the

other hand, the number of small colonies had considerably increased, resulting in a significant shift in populations' demographic structure.

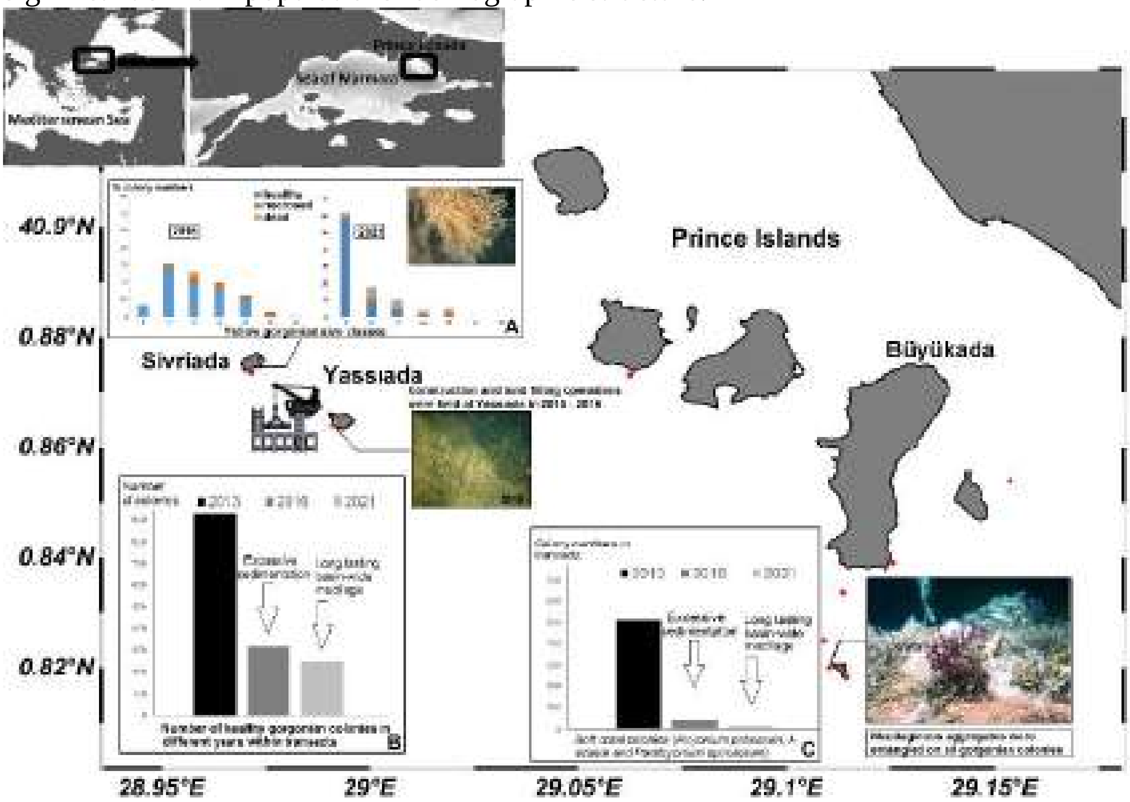


Fig. 1: Location of Prince Islands in the Sea of Marmara and the Mediterranean Sea (at top); diving sites are shown with red dots. Graphics of changes in the demographic structure of the yellow gorgonian in Sivriada (A); changes in colony numbers of gorgonians (B) and soft corals (C) at Prince Islands in different years marked by dramatic events. The pictures show a red gorgonian (right bottom) and a yellow gorgonian (top) covered by mucilaginous aggregates, and yellow gorgonians covered with sediment in 2015 at Yassıada (center).

The results of the genetic study indicate an important genetic differentiation among Marmara and Aegean populations (Doğan et al. unpubl. data). Inside each area, a significant differentiation is observed among populations as well. We found that populations in the Marmara have the least genotypic richness and diversity. STRUCTURE results showed that the Aegean and Marmara populations are clustered regionally. This pattern is confirmed by Fst values and differentiation tests. When we consider the averages of pairwise differences between populations the highest value is observed between Marmara and Aegean populations.
The microbiomes of *Eunicella cavolini* and *P. clavata* were significantly different from each other and their identified core microbiome consisted of twelve bacterial taxa for *E. cavolini* and 19 for *P. clavata* (Steinum et al. unpubl. data).

Discussion and conclusions
Mucilage and sedimentation impact soft corals in similar ways, mainly by covering coenenchyme resulting in suffocation (Airoldi, 2003). Due to coverage by sediment or entanglement of mucilaginous aggregates, gorgonians might die-off, especially at small sizes or show partial mortality of colony surface and recover once the aggregates

disappear (Mistri and Ceccherelli, 1996a; 1996b; Giuliani et al., 2005). In Prince Islands, these two stressors highly impacted alcyonarian assemblages, leading some species to become regionally very rare. Following disturbance, soft corals that do not have an axis (Alcyoniina) disappear from the bottom and leave no traces behind, unlike gorgonians whose bare skeleton can easily be detected and form a substrate for epibiont organisms. Among gorgonians present in the area, those with relatively fast growth, i.e. *S. klavereni* (Topçu and Öztürk 2016) and *P. macrospina* (Bo et al. 2011), were eventually the first to show signs of necrosis and die-off whereas species with slower dynamics showed higher resilience to these disturbances. *P. clavata* colonies in Prince Islands are present at sites highly impacted from industrial fisheries and has a decreasing trend since a long time (Topçu and Öztürk 2015). Several colonies died-off during both disturbances, putting at risk the regional continuity of the species. Currently, large size colonies that survived the mucilage are found only at 2 sites. The yellow gorgonian forms dense forests at 3 sites in Prince Islands and large size colonies seem highly impacted from mucilaginous cover. The increase in the number of small size colonies might be related to higher survival of small sizes thanks to the umbrella effect of large size colonies (Ponti et al. 2018) and a higher recruitment following sedimentation/mucilage due to increased availability of substrates cleared of large sizes.
The Sea of Marmara is an isolated basin and the connectivity of sessile benthic organisms ‘populations with Mediterranean populations is not yet reported in literature and might be highly limited. The yellow gorgonians populations in Prince Islands form locally dense forests but tend to decrease with recent impacts and their demographic structure seems to shift to small sizes, which may impact reproductive output and further recruitment in following years. These populations, restricted and isolated in space, have low genetic diversity. Along with decreasing numbers, they might be at risk of a bottleneck.
As for microbiome composition, environmental factors seemed more important in determining it than host identity. Endozoicomonas bacteria were present as core members but notably less abundant (Steinum et al., unpubl. data) than previously reported in Mediterranean gorgonians (as in Bayer et al. 2013; Vezzulli et al. 2013), which could reflect community shifts in response to anthropogenic stressors in the Marmara.
The Sea of Marmara, with particularly favourable environmental conditions for alcyonarians, e.g. more or less stable temperature as from 20 m, should present a safe haven for macrozoobenthic species, highly impacted from climatic threats in the northwestern Mediterranean (Cerrano et al., 2000; Garrabou et al. 2019) but they are threatened by other anthropogenic impacts, mainly fisheries, high sedimentation and pollution, the impacts of which are evidenced in results of our various studies. Following the severe mucilage in 2020 – 2021, the Ministry of Environment, Urbanization and Climate Change implemented an Action Plan to reduce pollution and increase water quality, and declared the Sea of Marmara as a Special Environmental Protection Area (SEPA) in 2021. Thus, if anthropogenic pressures are minimized through the appliance of the action plan and the consecutive integrated strategic plan for the Sea of Marmara, we can expect a natural recovery of soft coral and gorgonian assemblages, although we should probably envisage tens of years to fully recover habitat complexity and all ecosystem services (Montero-Serra et al. 2018; Cerrano et al. 2019). In order to protect yet healthy assemblages from mechanical damages (caused

by fishing nets, fishing lines, anchoring …) restricted zones should be considered as effective measures.

Acknowledgments
This study summarizes the results from several studies, funded by Istanbul University (grant no 24069, 25360, 24523 and 22324) and TÜBİTAK (grant no 117Y064 and 121G015). The authors thank all volunteer divers that helped during field works.

Bibliography

AIROLDI L. 2003. The effects of sedimentation on rocky coast assemblages. Oceanography and Marine Biology, *An Annual Review*, Volume 41. CRC Press.

BAYER T., ARIF C., FERRIER-PAGÈS C., ZOCCOLA D., ARANDA M., VOOLSTRA C. R. (2013) - Bacteria of the genus *Endozoicomonas* dominate the microbiome of the Mediterranean gorgonian coral *Eunicella cavolini*. *Marine Ecology Progress Series*, 479: 75-84.

BO M., BAVESTRELLO G., CANESE S., GIUSTI M., ANGIOLILLO M., CERRANO C., SALVATI E., GRECO S. (2011) - Coral assemblage off the Calabrian Coast (South Italy) with new observations on living colonies of *Antipathes dichotoma*. *Italian Journal of Zoology*, 78: 231-242.

CERRANO C., BASTARI A., CALCINAI B., DI CAMILLO C., PICA D., PUCE S., VALISANO L., TORSANI F. (2019) - Temperate mesophotic ecosystems: gaps and perspectives of an emerging conservation challenge for the Mediterranean Sea. *The European Zoological Journal*, 86: 370-388.

CERRANO C., BAVESTRELLO G., BIANCHI C.N., CATTANEO-VIETTI R., BAVA S., MORGANTI C., MORRI C., PICCO P., SARA G., SCHIAPARELLI S., SICCARDI A., SPONGA, F. (2000) - A catastrophic mass-mortality episode of gorgonians and other organisms in the Ligurian Sea (North-western Mediterranean), summer 1999. *Ecology Letters*, 3: 284-293.

GARRABOU J., GÓMEZ-GRAS D., LEDOUX J.-B., LINARES C., BENSOUSSAN N., LÓPEZ-SENDINO P., BAZAIRI H., ESPINOSA F., RAMDANI M., GRIMES S., BENABDI M., SOUISSI J.B., SOUFI E., KHAMASSI F., GHANEM R., OCAÑA O., RAMOS-ESPLÀ A., IZQUIERDO A., ANTON I., RUBIO-PORTILLO E., BARBERA C., CEBRIAN E., MARBÀ N., HENDRIKS I.E., DUARTE C.M., DEUDERO S., DÍAZ D., VÁZQUEZ-LUIS M., ALVAREZ E., HEREU B., KERSTING D.K., GORI A., VILADRICH N., SARTORETTO S., PAIRAUD I., RUITTON S., PERGENT G., PERGENT-MARTINI C., ROUANET E., TEIXIDÓ N., GATTUSO J.-P., FRASCHETTI S., RIVETT, I., AZZURRO E., CERRANO C., PONTI M., TURICCHIA E., BAVESTRELLO G., CATTANEO-VIETTI R., BO M., BERTOLINO M., MONTEFALCONE M., CHIMIENTI G., GRECH D., RILOV G., TUNEY KIZILKAYA I., KIZILKAYA Z., TOPÇU E.N., GEROVASILEIOU V., SINI M., BAKRAN-PETRICIOL, T., KIPSON S., HARMELIN J.G. 2019. Collaborative Database to Track Mass Mortality Events in the Mediterranean Sea. *Frontiers in Marine Science*, 6.

GIULIANI S., VIRNO LAMBERTI C., SONNI C., PELLEGRINI D. (2005) -. Mucilage impact on gorgonians in the Tyrrhenian sea. *Sci Total Environ*, 353: 340-9.

MISTRI M. (1995) - Population Structure and Secondary Production of the Mediterranean Octocoral *Lophogorgia ceratophyta* (L. 1758). *Marine Ecology*, 16, 181-188.

MISTRI M., CECCHERELLI V.U. (1996a) - Effects of a mucilage event on the Mediterranean gorgonian *Paramuricea clavata*. I-Short term impacts at the population and colony levels. *Italian Journal of Zoology*, 63, 221-230.

MISTRI M., CECCHERELLI, V.U. (1996b). Effects of a mucilage event on the Mediterranean gorgonian *Paramuricea clavata*. II - Population recovery after two years. *Italian Journal of Zoology*, 63, 231-236.

MONTERO-SERRA I., GARRABOU J., DOAK D.F., FIGUEROLA L., HEREU B., LEDOUX J.B., LINARES C. (2018) - Accounting for life-history strategies and timescales in marine restoration. *Conservation Letters*, 11: e12341.

PONTI M., TURICCHIA E., FERRO F., CERRANO C., ABBIATI M. (2018) - The understorey of gorgonian forests in mesophotic temperate reefs. Aquatic Conservation: *Marine and Freshwater Ecosystems*, 28: 1153-1166.

TOPÇU E.N., ÖZTÜRK B. (2015) - Composition and abundance of octocorals in the Sea of Marmara, where the Mediterranean meets the Black Sea. Scientia Marina, 79, 125-135.

TOPÇU N.E., ÖZTÜRK B. (2016) - First insights into the demography of the rare gorgonian *Spinimuricea klavereni* in the Mediterranean Sea. *Marine Ecology*, 37: 1154-1160.

TOPÇU N.E., TURGAY E., YARDIMC, R.E., TOPALOĞLU B., YÜKSEK A., STEINUM T.M., KARATAŞ S., ÖZTÜRK B. (2019) - Impact of excessive sedimentation caused by anthropogenic activities on benthic suspension feeders in the Sea of Marmara. *Journal of the Marine Biological Association of the United Kingdom*, 99: 1075-1086.

VEZZULLI L., PEZZATI E., HUETE-STAUFFER C., PRUZZO C., CERRANO C. (2013) - 16SrDNA Pyrosequencing of the Mediterranean Gorgonian *Paramuricea clavata* Reveals a Link among Alterations in Bacterial Holobiont Members, Anthropogenic Influence and Disease Outbreaks. *PLoS ONE*, 8: e67745.

Eva TURICCHIA, ABBIATI M., BETTUZZI M., CALCINAI B., MORIGI M.P., SUMMERS A.P., PONTI M.
Department of Biological, Geological and Environmental Sciences, University of Bologna, UO CoNISMa, Via S. Alberto 163, 48123 Ravenna, Ravenna, Italy.
E-mail: eva.turicchia2@unibo.it

NEW INSIGHTS ON BIOEROSION PROCESSES IN THE NORTHERN ADRIATIC CORALLIGENOUS REEFS

Abstract
The northern Adriatic continental shelf hosts many coralligenous reefs rising from the sedimentary bottom and characterized by high spatial heterogeneity. The bioerosion processes have been experimentally studied in the field using calcareous tiles exposed for 12 years in three different sites off Chioggia. Based on their shape and size, the bioeroded volumes of the boring sponges of the genus Cliona *were measured through high-resolution Computed Tomography (CT). The* Cliona *spp. eroded a mass from 3.48 to 15.83 kg* m^{-2} *compared to the initial size of the experimental tiles after 12 years of exposure.*
The distribution of Cliona *spp. in the three experimental sites and surrounding 10 sites was assessed through their superficial evidence (i.e., papillae of the sponges) by means of photographic sampling. Through a regression analysis between measured mass bioeroded and borers abundance, the estimated mass bioerosion of reefs in the whole area off the coast of Chioggia was evaluated. This approach could improve our understanding and ability to quantify bioerosion processes over large areas and possibly relate it to the environment quality, anthropogenic impacts, and climate change.*

Key-words: Mediterranean Sea, ecological processes, biogenic structures, 3D visualization, mesophotic

Introduction
The northern Adriatic continental shelf hosts many mesophotic coralligenous reefs, scattered on the sedimentary bottom (www.marine-geo.org/tools/search/entry.php?id= NorthernAdriatic_Reefs) and characterized by heterogenous benthic assemblages (Ponti *et al.*, 2011). These reefs can be considered as peculiar coralligenous "banks" (sensu Ballesteros, 2006) ranging in size from a few to thousands of square meters and distributed between 15 and 40 m in depth, where twilight conditions occur due to high water turbidity (Ponti *et al.*, 2011). The coralligenous reefs are considered a "hot spot" of species diversity, shaped by bioconstruction and erosion processes, geological events, human impacts, and climate changes (Ballesteros, 2006). Coralligenous assemblages are threatened by anthropogenic disturbances (Claudet & Fraschetti, 2010; Coll *et al.*, 2010), and climate change-related disturbances (Garrabou *et al.*, 2019; Ponti *et al.*, 2021; Teixidó *et al.*, 2013; Turicchia *et al.*, 2018).
The boring sponges of the genus *Cliona* represent one of the leading agents of bioerosion in coralligenous reefs producing a vast system of branched and interconnected galleries in the substrate and communicate with the surface through numerous openings. In particular, *Cliona viridis* (Schmidt, 1862) is regarded as one of the Mediterranean Sea's most abundant and effective borers (Bertolino *et al.*, 2013), especially in the northern Adriatic mesophotic reefs (Ponti *et al.*, 2011; Turicchia *et al.*,

2022). Species from the *Cliona viridis* complex indeed commonly display high bioerosion rates, up to 29.5 kg m^{-2} y^{-1} (Calcinai *et al*., 2007; Schönberg *et al.*, 2017 and references therein). The aim of the present study is to shed light on bioerosion process taking place in the northern Adriatic coralligenous reefs. Starting from the experimental measure of masses eroded by *Cliona* spp. on tiles deployed underwater for 12 years (Turicchia *et al.*, 2022) and the boring sponges' superficial evidence (i.e., papillae of the sponges) on photographic samples, the eroded mass was estimated for ten coralligenous reefs in the area in front of Chioggia.

Materials and methods

In the coralligenous reefs off Chioggia, 3 main typologies of benthic assemblages have been recognized according to their relative abundance of encrusting calcareous rhodophytes (ECRs), algal turf, sponges, and colonial ascidians. As a general pattern, reefs closer to the coast are dominated by algal turfs, while those further away are dominated either by ECRs or by erect sponges (Ponti *et al.*, 2011). Based on these findings, three sites were randomly chosen, each to represent a different assemblages typology (site P204 dominated by algal turfs, P213 dominated by erect sponges, and MR08 dominated by ECRs) to deploy forty-eight rough travertine tiles (15.0 × 11.5 × 1.0 cm = 172.5 cm^3) in August 2005.
Four tiles from each site were randomly retrieved in August 2017 to quantify the bioerosion process. Before collection, each tile was photographed underwater using a Canon PowerShot G15 digital camera, equipped with an aluminum underwater case and an INON D2000 S-TTL strobe (Fig. 1a). The boring sponges bioerosion has been assessed at genus level. Shapes and volumes of the *Cliona* spp. bioerosion traces were non-destructively identified and measured through high-resolution computed tomography (CT) on experimental tiles following the methodology in Turicchia *et al.*, 2022 (Fig. 1b). Moreover, ten photographic samples (21 × 28 cm) of the natural substrate were randomly collected at 6 sites in 2014 and 4 sites in 2017 in the area off Chioggia (Fig. 1c, Tab. 1).
The percent cover of *Cliona* spp. was calculated through their superficial evidence (i.e., papillae of the sponges) and quantified by superimposing a grid of 400 squares of equal size using the PHOTOQUAD freeware software (Trygonis & Sini, 2012) on both the photos of the experimental tiles and those of the natural substrate. The percentage cover was related to the total readable area of each image, obtained by subtracting dark and blurred areas or portions covered by mobile organisms (Ponti *et al.*, 2011).
The possible relationship between the percent cover of *Cliona* on the travertine tiles and the *Cliona* eroded mass in the tiles were explored by the regression linear model. Based on the calculated regression linear model, from *Cliona* eroded mass, the mean *Cliona* bioerosion and the corresponding lower and upper limit values (at 95% confidence interval) have been predicted for each site. The potential bioeroded mass estimation was extended to the entire area through spatial interpolation using the ordinary kriging method (Zhang *et al.*, 2015).

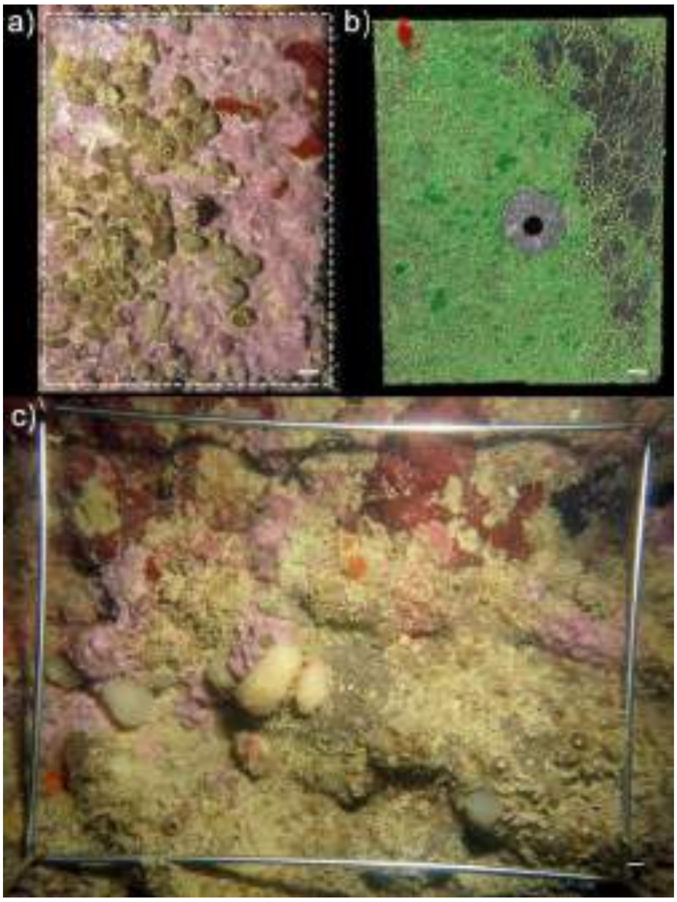


Fig. 1: a) example of travertine tile (delimited by the white dotted line) deployed underwater for 12 years at the MR08 site; b) computed tomography graphic reconstruction of the tile in figure 1A, in which the erosion pattern of the boring sponge *Cliona* is shown in green; c) photographic sampling of the natural substrate at the MR08 site (steel frame 21 x 28 cm). Scale bars are 1 cm long.

Results

Boring sponges from the genus *Cliona* were found in all experimental tiles from the 3 study sites, both inside and on the surface. The percent cover of *Cliona* spp. on the surface of the experimental tiles varied from 1.01% (site P204) to 71.16% (site MR08). Likewise, the corresponding bioeroded mass by *Cliona* spp., as measured through CT image analysis, ranged from 3.48 kg m^{-2} (site P204) to 15.83 kg m^{-2} (site MR08). Regression analysis allowed to calculate the following biomass estimation equation:

$$\text{Bioeroded mass [kg m}^{-2}] = 5.88 + 16.08\ \textit{Cliona}\ \text{surface cover [0..1]}$$
$$(R^2 = 0.69,\ p < 0.001,\ n = 12;\ \text{Fig. 2a})$$

The surface cover of *Cliona* spp. on natural substrate was estimated for ten sites, six photographically sampled in 2014 (MR08, P204, P208b, P213, TM1 and TQS; Tab. 1) and four in 2017 (AL06, East Bike, MR08 and P213; Tab. 1). *Cliona* spp. was present at all the study sites, confirming its wide distribution in the area. Its lowest percent cover was at TM1 site (0.41 ± 0.41%), while the highest at MR08 site in 2017 (10.68 ± 3.45%). The related mean bioeroded mass at the study sites, based on the *Cliona* surface cover assessed from the photographic samples, ranged from 5.95 kg m^{-2} at the TM1 site (with 0.02 kg m^{-2} as lower and 11.88 kg m^{-2} upper prediction limit), to 7.60 kg m^{-2} at the MR08 site in 2017 (with 1.88 kg m^{-2} and 13.32 kg m^{-2} as the lower and upper prediction limit), respectively (Fig. 2b, Tab.1).

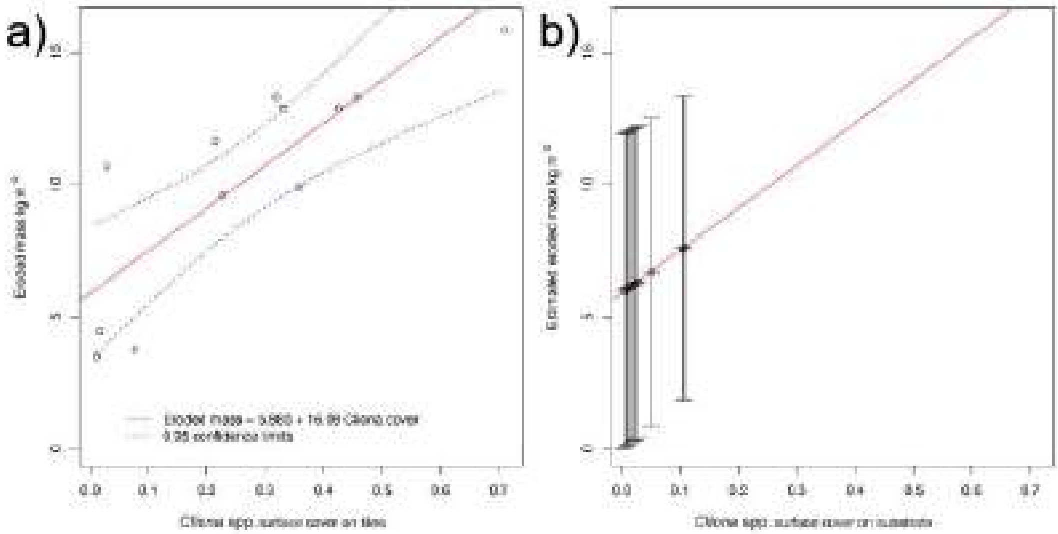


Fig. 2: a) regression linear model between *Cliona* surface cover [0..1] on experimental tiles and corresponding eroded mass, measured by CT analysis; b) estimated mean bioerosion mass at the study sites based on the surface cover of *Cliona*, assessed by photographic sampling.

Tab. 1: Study sites with their geographical coordinates (Latitude and Longitude, Datum WGS84), photographic sampling year, mean percent cover of *Cliona* spp. ± standard error (se), and the corresponding estimated bioerosion including lower and upper prediction limits (95%CL).

Site	Lat [°N]	Lon [°E]	Photographic sampling year	Mean *Cliona* cover [%cover ± se]	*Cliona* Bioerosion [kg m^{-2}]	Lower limit [kg m^{-2}]	Upper limit [kg m^{-2}]
AL06	45.2028	12.4207	2017	2.86 ± 1.92	6.34	0.47	12.21
East Bike	45.1606	12.9486	2017	1.07 ± 0.95	6.05	0.14	11.97
MR08	45.2305	12.4892	2014	2.34 ± 0.63	6.26	0.38	12.14
MR08	45.2305	12.4892	2017	10.68 ± 3.45	7.60	1.88	13.32
P204	45.2111	12.3844	2014	1.65 ± 1.18	6.15	0.25	12.05
P208B	45.1945	12.4247	2014	0.86 ± 0.53	6.02	0.10	11.94
P213	45.1712	12.5169	2014	5.05 ± 1.91	6.69	0.87	12.52
P213	45.1712	12.5169	2017	2.07 ± 1.81	6.22	0.33	12.11
TM1	45.2045	12.4049	2014	0.41 ± 0.41	5.95	0.02	11.88
TQS	45.2891	12.5631	2014	10.54 ± 3.82	7.58	1.86	13.30

The computation of the potential mass bioeroded by *Cliona* spp. was extended to the area off Chioggia through spatial interpolation. The highest value (7.53 kg m^{-2}) was on the north side of the area, close to TQS site; the estimated values tend to decrease following a southward gradient; however, the lower values (5.99 kg m^{-2}) were located both at the east and west extremes of the interpolated area (Fig. 3).

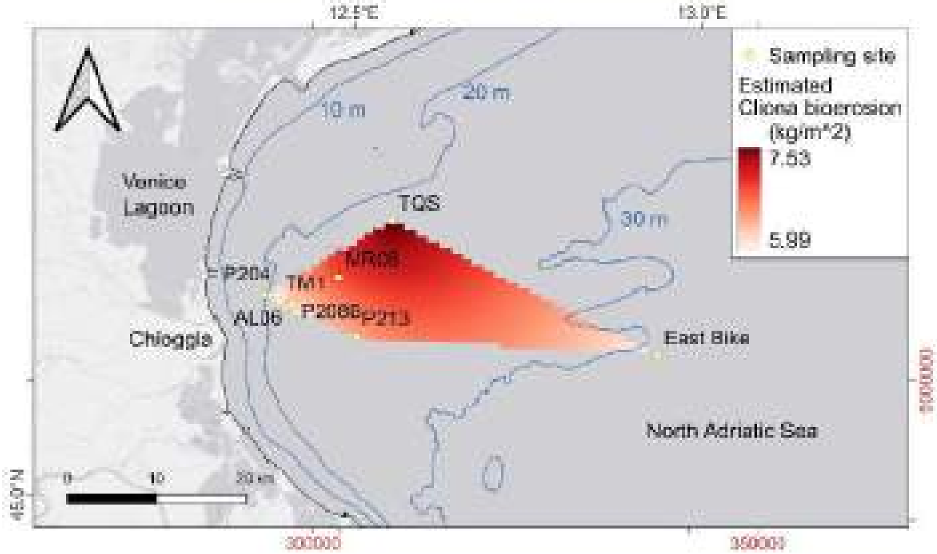


Fig. 3: Map of the potential *Cliona* bioerosion in the study area. Yellow dots represent the study sites (Map projection UTM33N/WGS84).

Discussion and conclusions

The activities of boring sponges shape the coralligenous habitats by eroding the substrate and creating shelters for many organisms (Cerrano *et al*., 2001), but simultaneously, they reduce the mechanical stability of the reefs. Some studies provided allometric equations to estimate boring sponge volumes from surface cover appraisal in tropical coral reefs (Rose & Risk, 1985; Schönberg, 2001), and in the Adriatic Sea (Calcinai *et al*., 2011). Based on experimental evidence, this study provides a rapid method to estimate *Cliona's* erosion, including associated uncertainty. *Cliona* sponges are abundant in the northern Adriatic coralligenous reefs, and their bioerosion activities can mine these fragile systems; therefore, quantifying their bioerosion capacity in space and time is of paramount importance for nature conservation purposes and should be included in environmental monitoring programs. Thus, although with relatively large uncertainty, this type of bioerosion estimation could complement regular photographic monitoring.

Bibliography

BALLESTEROS E. (2006) - Mediterranean coralligenous assemblages: A synthesis of present knowledge. In: Gibson R.N., Atkinson R.J.A., Gordon J.D.M. (Eds.), *Oceanography and Marine Biology: An Annual Review*, Boca Raton 123-195.

BERTOLINO M., CERRANO C., BAVESTRELLO G., CARELLA M., PANSINI M., CALCINAI B. (2013) - Diversity of Porifera in the Mediterranean coralligenous accretions, with description of a new species. *ZooKeys*, 336: 1-37.

CALCINAI B., AZZINI F., BAVESTRELLO G., GAGGERO L., CERRANO C. (2007) - Excavating rates and boring pattern of *Cliona albimarginata* (Porifera: Clionaidae) in different substrata. *In*: *Proceedings of the Porifera Research: Biodiversity, Innovation and Sustainability,* Rio de Janerio, Brazil: Serie Livros 28. Museu Nacional.

CALCINAI B., BAVESTRELLO G., CUTTONE G., CERRANO C. (2011) - Excavating sponges from the Adriatic Sea: description of *Cliona adriatica* sp. nov. (Demospongiae: Clionaidae) and estimation of its boring activity. *Journal of the Marine Biological Association of the United Kingdom*, 91(2): 339-346.

CERRANO C., BAVESTRELLO G., BIANCHI C.N., CALCINAI B., CATTANEO-VIETTI R., MORRI C., SARA M. (2001) - The role of sponge bioerosion in Mediterranean coralligenous accretion. *In*: Faranda F.M., Guglielmo L., Spezie G. (Eds.), *Mediterranean Ecosystems: Structures and Processes*. Springer-Verlag Italia, Milan: 235-240.

CLAUDET J., FRASCHETTI S. (2010) - Human-driven impacts on marine habitats: A regional meta-analysis in the Mediterranean Sea. *Biol. Conserv.*, 143(9): 2195-2206.

COLL M., PIRODDI C., STEENBEEK J., KASCHNER K., BEN RAIS LASRAM F., AGUZZI J., BALLESTEROS E., BIANCHI C.N., CORBERA J., DAILIANIS T., DANOVARO R., ESTRADA M., FROGLIA C., GALIL B.S., GASOL J.M., GERTWAGEN R., GIL J., GUILHAUMON F., KESNER-REYES K., KITSOS M.S., KOUKOURAS A., LAMPADARIOU N., LAXAMANA E., LOPEZ-FE DE LA CUADRA C.M., LOTZE H.K., MARTIN D., MOUILLOT D., ORO D., RAICEVICH S., RIUS-BARILE J., SAIZ-SALINAS J.I., SAN VICENTE C., SOMOT S., TEMPLADO J., TURON X., VAFIDIS D., VILLANUEVA R., VOULTSIADOU E. (2010) - The Biodiversity of the Mediterranean Sea: Estimates, patterns, and threats. *PLoS ONE*, 5(8): e11842.

GARRABOU J., GOMEZ-GRAS D., LEDOUX J.-B., LINARES C., BENSOUSSAN N., LOPEZ-SENDINO P., BAZAIRI H., ESPINOSA F., RAMDANI M., GRIMES S., BENABDI M., SOUISSI J.B., SOUFI E., KHAMASSI F., GHANEM R., OCAÑA O., RAMOS-ESPLA A., IZQUIERDO A., ANTON I., RUBIO-PORTILLO E., BARBERA C., CEBRIAN E., MARBA N., HENDRIKS I.E., DUARTE C.M., DEUDERO S., DIAZ D., VAZQUEZ-LUIS M., ALVAREZ E., HEREU B., KERSTING D.K., GORI A., VILADRICH N., SARTORETTO S., PAIRAUD I., RUITTON S., PERGENT G., PERGENT-MARTINI C., ROUANET E., TEIXIDO N., GATTUSO J.-P., FRASCHETTI S., RIVETTI I., AZZURRO E., CERRANO C., PONTI M., TURICCHIA E., BAVESTRELLO G., CATTANEO-VIETTI R., BO M., BERTOLINO M., MONTEFALCONE M., CHIMIENTI G., GRECH D., RILOV G., TUNEY KIZILKAYA I., KIZILKAYA Z., EDA TOPÇU N., GEROVASILEIOU V., SINI M., BAKRAN-PETRICIOLI T., KIPSON S., HARMELIN J.G. (2019) - Collaborative database to track mass mortality events in the Mediterranean Sea. *Front. Mar. Sci.*, 6(707): 707.

PONTI M., FAVA F., ABBIATI M. (2011) - Spatial-temporal variability of epibenthic assemblages on subtidal biogenic reefs in the northern Adriatic Sea. *Mar. Biol.*, 158(7): 1447-1459.

PONTI M., LINARES C., CERRANO C., RODOLFO-METALPA R., HOEKSEMA B.W. (2021) - Biogenic reefs at risk: facing globally widespread local threats and their interaction with climate change. *Front. Mar. Sci.*, 8.

ROSE C.S., RISK M.J. (1985) - Increase in *Cliona delitrix* infestation of *Montastrea cavernosa* heads on an organically polluted portion of the Grand Cayman fringing reef. *Mar. Ecol.*, 6(4): 345-363.

SCHÖNBERG C. (2001) - Estimating the extent of endolithic tissue of a great barrier reef clionid sponge. *Senckenb. Marit.*, 31(1): 29-39.

SCHÖNBERG C.H.L., FANG J.K.-H., CARBALLO J.L. (2017) - Bioeroding sponges and the future of coral reefs. In: Carballo J.L., Bell J.J. (Eds.), *Climate change, ocean acidification and sponges: Impacts across multiple levels of organization*. Springer International Publishing, Cham: 179-372.

TEIXIDÓ N., CASAS E., CEBRIAN E., LINARES C., GARRABOU J. (2013) - Impacts on coralligenous outcrop biodiversity of a dramatic coastal storm. *PLoS ONE*, 8(1): e53742.

TRYGONIS V., SINI M. (2012) - photoQuad: A dedicated seabed image processing software, and a comparative error analysis of four photoquadrat methods. *Journal of Experimental Marine Biology and Ecology*, 424-425: 99-108.

TURICCHIA E., ABBIATI M., BETTUZZI M., CALCINAI B., MORIGI M.P., SUMMERS A.P., PONTI M. (2022) - Bioconstruction and bioerosion in the northern Adriatic coralligenous reefs quantified by X-ray computed tomography. *Front. Mar. Sci.*, 8.

TURICCHIA E., ABBIATI M., SWEET M., PONTI M. (2018) - Mass mortality hits gorgonian forests at Montecristo Island. *Dis. Aquat. Org.*, 131(1): 79-85.

ZHANG H., LU L., LIU Y., LIU W. (2015) - Spatial sampling strategies for the effect of interpolation accuracy. *ISPRS International Journal of Geo-Information*, 4(4): 2742-2768.

Yanis ZENTNER, ROVIRA G., ORTEGA J., MARGARIT N., CASALS D., MEDRANO A., PAGÈS-ESCOLÀ M., MONTERO-SERRA I., ASPILLAGA E., CAPDEVILA P., FIGUEROLA-FERRANDO L., HEREU B., GARRABOU J., LINARES C.
Departament de Biologia Evolutiva, Ecologia i Ciències Ambientals, Universitat de Barcelona (UB). Av. Diagonal 643, 08028, Barcelona, Espanya
E-mail: yaniszentner@ub.edu

CLIMATE ADAPTATIVE MANAGEMENT IN MARINE PROTECTED AREAS: THE CASE OF MARINE HEATWAVES AND DIVING FREQUENTATION ON THE CONSERVATION OF CORALLIGENOUS HABITAT FORMING SPECIES

Abstract
During the last two decades, different Marine Heatwaves (MHWs) have affected coralligenous assemblages in the Mediterranean Sea, causing catastrophic mass mortalities of several habitat-forming invertebrates such as gorgonians, corals and sponges. Moreover, whether Marine Protected Areas (MPAs) are contributing to effectively protect marine ecosystems from extreme climatic events is currently being challenged. Furthermore, recreational diving represents an important activity in Mediterranean MPAs, which has shown detrimental effects when high number of divers are allowed to visit these areas. Here, we assess if a climate-adaptive management of MPAs can delay the impact of climate change focusing on the case study of the Medes Islands MPA, one of the most visited by divers. To achieve this, we benefit from a 6 year monitoring of permanent transects encompassing six sites with red gorgonian Paramuricea clavata, which combined with data prior to the effects of firsts MHWs in 2016 allowed us to assess the impacts caused by climate change and scuba diving. Besides, based on the empirical dataset, we modelled the long-term viability of this species under different managing and mass mortality scenarios. Overall, our results show a clear decline of the red gorgonian populations and predict a local extinction for shallow depths (<25 m) in the next 20 years, caused by the synergic effect of diver over-frequentation and climate change. However, the simulated scenarios show how a climate-adaptive management of the diving activity under climate change can enhance the long-term viability of this key Mediterranean habitat-forming octocoral. This study provides one of the few quantitative evidences of how an adaptive management is crucial to delay climate change impacts in Marine Protected Areas.

Key-words : Coralligenous, Marine Heatwaves, Marine Reserve, *Paramuricea clavata*, adaptive Management

Introduction
Marine Protected Areas (MPAs) are one of the main management tools to ensure biodiversity conservation and to achieve significant ecological gains in marine ecosystems (Lubchenco & Grorud-Colvert, 2015). However, the accelerated biodiversity loss caused by overexploitation and climate change is raising major concerns about their effectiveness (Hughes *et al.*, 2003). Related to ocean warming, marine heatwaves (MHWs) are increasing their frequency and severity across ecosystems (Smale *et al.*, 2019). In the current context of MHWs, the effectiveness of existing MPAs is under debate as the majority were designed without considering this global warming stressor (Bruno *et al.*, 2018). In view of this concern, a climate-adaptive management of MPAs has been proposed as a tool to face climate change at a local scale (Roberts *et al.*, 2017).

Global stressors such as warming and MHWs are not the only threat for MPAs, as not all protected areas are sustainably managed, and many are still under local stressors (Giakoumi *et al.*, 2017). Even in well-established no-take areas, the presence of SCUBA diving, has been documented to be detrimental (Giglio *et al.*, 2020). Considering the interaction between global and local stressors is especially relevant when enforcing an adaptive management, as they can not only worsen the conditions through an additive effect, but also through a synergistic interaction. Particularly, in shallow depths both affected by MHWs and high diving pressure, a strong synergic relation has been found affecting key habitat-forming gorgonians (Linares & Doak, 2010).
The present study focuses on the interaction of diving and MHWs in The Medes Islands Marine Reserve, which was created in 1983 and currently represents one of the most frequented no-take areas in the Mediterranean Sea. The main goal of the study is to explore how local climate-adaptive measures within MPAs can be crucial to ensure the conservation of a key habitat-forming gorgonian (*Paramuricea clavata*). Firstly, we performed a demographic monitoring to assess the impact of MHWs and diving as well as their interaction. Secondly, we used the field data to predict the long-term viability of this species through size-structured matrix models. Finally, we explored how different climate and local management scenarios can ensure the conservation of marine biodiversity.

Material and methods
We used monitoring data from 2016 to 2021, when unexpected extreme climate events occurred in this area: an anomalous mucilage growth in 2017, causing an outbreak that entangled *P. clavata* branches (visually observed by authors), and the Storm Gloria in 2020, one of the largest historical storms over the western Mediterranean basin (Amores *et al.*, 2020). Moreover, analyzing the in-situ, hourly temperature obtained during the last 20 years, shows that 2017, 2019 and especially 2018 were affected by MHWs that surpassed the red gorgonian thermotolerance.
A total 659 colonies were individually identified and mapped during six years. For each colony, the maximum height was measured and the extend of injury was estimated as the percentage of each colony's total surface that showed either a denuded axis or overgrowth by other organisms (Linares *et al.*, 2005). From this data the following descriptors were obtained: density, biomass, mean height, colony size distribution, partial mortality and total mortality.
We also examined the long-term viability of *Paramuricea clavata* through size-structured matrix populations (Lefkovitch, 1965). For the model, a set of 7 size-defined classes were implemented based on the life cycle of this species (Linares & Doak, 2010). The transition matrixes were constructed by estimating survival, growth, shrinkage and reproduction rates for each class. With the matrixes constructed, deterministic lambdas were estimated (λ) together with a stochastic lambda (λs), obtained from randomly drawing the annual matrices (Caswell, 2000; Morris & Doak, 2002). Finally, to underpin the need of MPA management adapting their conservation strategies to climate change, we estimated the stochastic lambda for a large variety of future combinations between the local (high diving activity) and global (mainly temperature driven MMEs) stressors. To simulate the effect of the local impact of diving, we simulated a reduction and an increase on the mortality of adult colonies corresponding to different levels of diving activity. The effect of the global impact has been simulated by changing the proportion on which the model randomly draws the annual transitions that present climate change impacted growth rates.

Results

During the study period, a clear drop has been recorded on the density and the biomass of the studied colonies (Fig. 1AB). Both parameters follow a similar pattern, a large decline up to 2018 followed by a milder one the rest of the years, causing a cumulative reduction of the density and biomass of around 40% for the entire period. The mean height showed a small decline to smaller sizes (Fig. 1C). The percentage of affected colonies by partial mortality doubled from 2016 to 2018 and maintained stable for the rest of the study (Fig. 1D). In a similar pattern, the extend of injury per colony tripled in these two years (Fig. 1E). Distinguishing between types of injury, a clear peak of recent injuries was recorded in 2018, observed both in the affected colonies and the extend of injury.

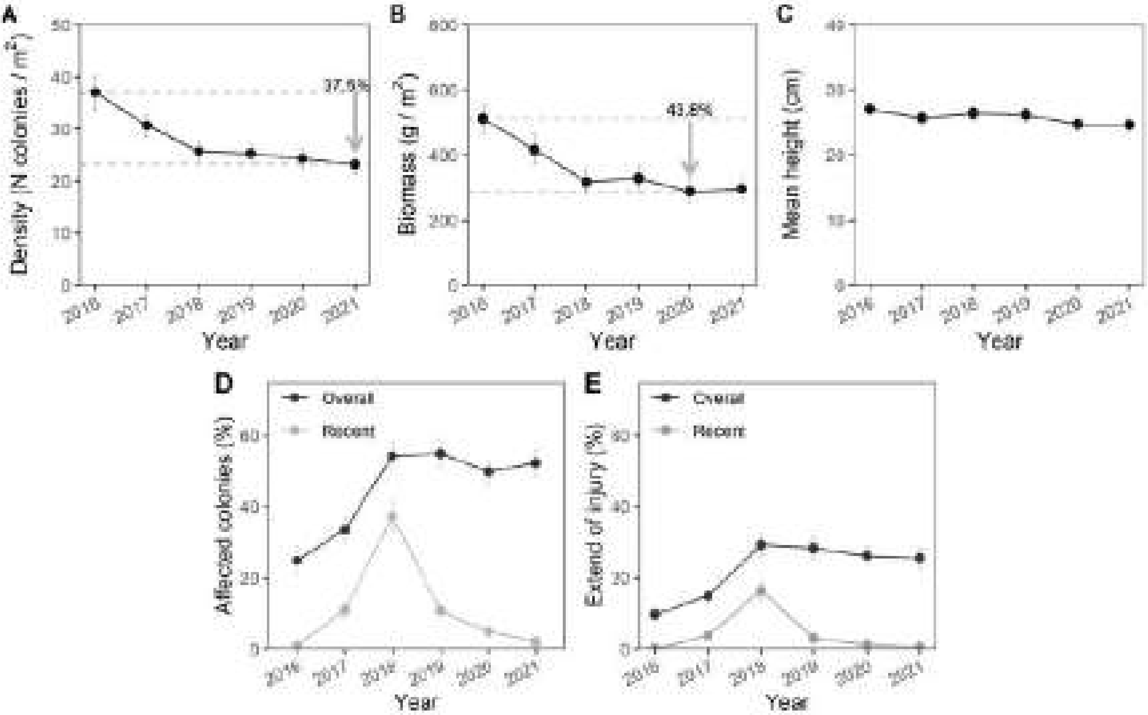


Fig. 1: Demographic parameters for the studied *Paramuricea clavata* colonies

Total mortality rate of adult colonies (> 10 cm height) was also high during this period, 9.75 ± 1.73% per year, mean ± s.e.). When determining the cause of mortality, mortality caused by colony detachment was 7.60 ± 1.85% per year, while mortality by fully injured surface (overgrowth) was 2.15 ± 0.68 % per year. Examining how the detachment rate varies, depending on the level of injuries presented the year prior to their disappearance, shows a clear increase the higher their surface was injured (Tab. 1).

Tab. 1: Annual total mortality rate (t1) estimated for colonies categorized by the injured surface they presented the previous year (t0)

Partial mortality t0 (Colonies in each category)	Detachment rate t1 (%/y, mean ± s.e.)	Overgrowth rate t1 (%/y, mean ± s.e.)
Healthy (57.24%)	6.89 ± 1.66	1.39 ± 0.40
Mildly Injured (26.37%)	7.09 ± 1.52	1.72 ± 0.86
Highly Injured (16.40%)	9.34 ± 3.97	5.74 ± 1.60

The annual populations growth rates indicate a negative population growth rate for all transitions (ranging from 0.840 to 0.983). Stochastic simulations predict a quasi-extinction occurring in the next 12 to 20 years for 95% of the scenarios. Plotting the estimated stochastic lambda for a multitude of combinations between the local and global stressors shows a synergistic interaction (Fig. 2). The synergistic effect is observable in the curved pattern formed by the lambda isoclines, as an additive relation would create parallel isoclines. The combination of an increase on both impacts causes a bigger reduction on the stochastic lambda, than the one obtained by adding the reduction that each impact causes individually.

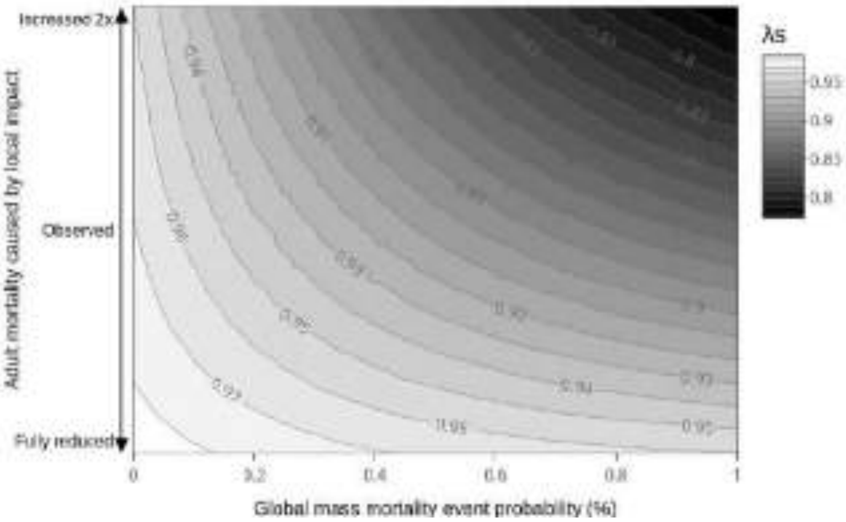


Fig. 2: Stochastic lambda (λ_s) for multiple combinations between the local and global stressors

Discussion and conclusion

There is an increasing concern that existing MPAs may not be enough to protect marine ecosystems from the recurrent warming impacts (Bruno *et al.*, 2018). In this context, our study highlights: i) the interaction of local and global stressors cause an important decline in a relevant habitat-forming species within MPAs; and ii) adaptative conservation strategies such can delay the impacts caused by climate change, enhancing the long-term viability of a key Mediterranean octocoral.

For the past 6 years a significant decline of *Paramuricea clavata* has been recorded in the Medes Islands Marine Reserve. The cumulative reduction observed in colony density and biomass is comparable to the one described in previous MME of this species (Gómez-Gras *et al.*, 2021; Linares *et al.*, 2005). On the other hand, only 2018 presents values of partial mortality that are within the moderate range of other MHW-induced mortalities (Garrabou *et al.*, 2009). This miss-match between density/biomass loss and partial mortality data might have been enlarged by the mucilage event and the extreme storm. Nevertheless, 2017 and 2019 recent injury values are still higher than the ones recorded in this MPA during the 2003 large-scale MHW. This indicates that temperature conditions have worsen to the point where the red gorgonian is now showing signs of temperature stress.

The estimation of total mortality rate further clarifies why such a steep decline has occurred, since the main reason of colony death is the detachment of a colony from its substratum. This mortality has been previously associated to the high diving activity occurring within the Medes Islands MPA (Coma *et al.*, 2004) and is supported by multiple

studies describing the impact that over-frequentation of divers cause on branching organisms (reviewed in Giglio *et al.*, 2020). As a result, the combined effect of the local diving impact with the increase of temperature-driven mortality has caused a bigger decline than the expected taking in account the mentioned events. This effect gets magnified by the synergistic behavior between these two impacts (Linares & Doak, 2010), which is clearly observable in the detachment rates, as an increase occurs the more injured the colonies were the year prior to their disappearance.
The growth rates detected during this period reflect the observed decline and the overall resulting stochastic growth rate and their long-term viability projection truly show the detrimental effect that occurs as a combination of the present impacts. Even though this outcome could seem over pessimistic, as it implies that such a decline will occur repeatedly every five years, a scenario of increasing frequency of MHWs is expected in the future (Smale *et al.*, 2019). Moreover, a recent study on red gorgonian populations that were affected by recurrent heatwaves showed a collapsed trajectory in only 15 years (Gómez-Gras *et al.*, 2021), a time similar to the one projected with our data.
In view of the future viability of *P. clavata* and the clear presence of a local impact worsening the effects of climate change, it is crucial to properly manage the high diving activity occurring in this MPA, especially considering that the global stressors are difficult to manage at local scales. This is clearly exemplified when simulating the viability of these colonies under different scenarios of global and local impacts, as the synergistic nature of these impacts make it more beneficial to achieve a reduction of adult mortality the more temperature conditions worsen. These modelling efforts give useful insights to managers to assess different adaptive conservation strategies, as the control on the local impact can be tweaked around a climate-responsive design which is based on biological criteria.

Bibliography

AMORES A., MARCOS M., CARRIÓ D.S., GÓMEZ-PUJOL L. (2020) - Coastal impacts of Storm Gloria (January 2020) over the north-western Mediterranean. *Natural Hazards and Earth System Sciences*, 20(7): 1955–1968.

BRUNO J.F., BATES A.E., CACCIAPAGLIA C., PIKE E.P., AMSTRUP S.C., VAN HOOIDONK R., HENSON S.A., ARONSON R.B. (2018) - Climate change threatens the world’s marine protected areas. *Nature Climate Change*, 8(6): 499–503. https://doi.org/10.1038/s41558-018-0149-2

CASWELL H. (2000) - *Matrix population models* (Vol. 1). Sinauer Sunderland, MA, USA.

COMA R., POLA E., RIBES M., ZABALA M. (2004) - Long-term assessment of temperate octocoral mortality patterns, protected vs. Unprotected areas. *Ecological Applications*, 14(5): 1466–1478.

GARRABOU J., COMA R., BENSOUSSAN N., BALLY M., CHEVALDONNÉ P., CIGLIANO M., DÍAZ D., HARMELIN J.G., GAMBI M.C., KERSTING, D. K. (2009) - Mass mortality in Northwestern Mediterranean rocky benthic communities: Effects of the 2003 heat wave. *Global Change Biology*, 15(5): 1090–1103.

GIAKOUMI S., SCIANNA C., PLASS-JOHNSON J., MICHELI F., GRORUD-COLVERT K., THIRIET P., CLAUDET J., DI CARLO G., DI FRANCO A., GAINE, S. D., GARCÍA-CHARTON J.A., LUBCHENCO J., REIMER J., SALA E., GUIDETTI, P. (2017) - Ecological effects of full and partial protection in the crowded Mediterranean Sea: A regional meta-analysis. *Scientific Reports*, 7(1): 8940. https://doi.org/10.1038/s41598-017-08850-w

GIGLIO V.J., LUIZ O.J., FERREIRA C.E.L. (2020) - Ecological impacts and management strategies for recreational diving: A review. *Journal of Environmental Management*, 256, 109949. https://doi.org/10.1016/j.jenvman.2019.109949

GÓMEZ-GRAS D., LINARES C., LÓPEZ-SANZ A., AMATE R., LEDOUX J.B., BENSOUSSAN N., DRAP P., BIANCHIMANI O., MARSCHAL C., TORRENTS O., ZUBERER F., CEBRIAN E., TEIXIDÓ N., ZABALA M., KIPSON S., KERSTING D. K., MONTERO-SERRA I., PAGÈS-ESCOLÀ M., MEDRANO A., M. FRLETA-VALIĆ M., DIMARCHOPOULOU D., LÓPEZ-SENDINO P., GARRABOU J. (2021) - Population collapse of habitat-forming species in the Mediterranean: A long-term study of gorgonian populations affected by recurrent marine heatwaves. *Proceedings of the Royal Society B: Biological Sciences*, 288(1965), 20212384. https://doi.org/10.1098/rspb.2021.2384

HUGHES T.P., BAIRD A.H., BELLWOOD D.R., CARD M., CONNOLLY S.R., FOLKE C., GROSBERG R., HOEGH-GULDBERG O., JACKSON J.B., KLEYPAS J. (2003) - Climate change, human impacts, and the resilience of coral reefs. *Science*, 301(5635): 929–933.

LEFKOVITCH L.P. (1965) - The study of population growth in organisms grouped by stages. *Biometrics*, 1–18.

LINARES C., COMA R., DIAZ D., ZABALA M., HEREU B., DANTART L. (2005) - Immediate and delayed effects of a mass mortality event on gorgonian population dynamics and benthic community structure in the NW Mediterranean Sea. *Marine Ecology Progress Series*, 305: 127–137.

LINARES C., DOAK D.F. (2010) - Forecasting the combined effects of disparate disturbances on the persistence of long-lived gorgonians: A case study of Paramuricea clavata. *Marine Ecology Progress Series*, 402: 59–68.

LUBCHENCO J., GRORUD-COLVERT K. (2015) - Making waves: The science and politics of ocean protection. *Science*, 350(6259): 382–383. https://doi.org/10.1126/science.aad5443

MORRIS W.F., DOAK D.F. (2002) - *Quantitative conservation biology*. Sinauer, Sunderland, Massachusetts, USA: 507 pp.

ROBERTS C.M., O'LEARY B.C., MCCAULEY D.J., CURY P.M., DUARTE C.M., LUBCHENCO J., PAULY D., SÁENZ-ARROYO A., SUMAILA U.R., WILSON R.W., WORM B., CASTILLA J. C. (2017). Marine reserves can mitigate and promote adaptation to climate change. *Proceedings of the National Academy of Sciences*, 114(24): 6167–6175. https://doi.org/10.1073/pnas.1701262114

SMALE D.A., WERNBERG T., OLIVER E.C.J., THOMSEN M., HARVEY B.P., STRAUB S.C., BURROWS M.T., ALEXANDER L.V., BENTHUYSEN J.A., DONAT M.G., FENG M., HOBDAY A.J., HOLBROOK, N.J., PERKINS-KIRKPATRICK, S.E., SCANNELL, H.A., SEN GUPTA A., PAYNE B.L., MOORE P.J. (2019) - Marine heatwaves threaten global biodiversity and the provision of ecosystem services. *Nature Climate Change*, 9(4): 306–312. https://doi.org/10.1038/s41558-019-0412-1

****

POSTERS

****

Onur Umut AKYUZ, BARRAUD T., TOPALOGLU B., OKUDAN E.S., SARACOGLU C., DALYAN C., GONULAL O., TOPCU N. E.
Istanbul University, Faculty of Aquatic Sciences, Department of Marine Biology, Balabanağa Mah. Ordu cad. No8 Laleli 34134 Istanbul-Turkey.
E-mail: topalbl@istanbul.edu.tr

STRUCTURE OF CORALLIGENOUS COMMUNITIES OF AYVALIK ISLANDS NATURE PARK

Abstract
Coralligenous formations are defined as calcareous bioconcretions produced by sciaphilic coralline algae. Coralligenous communities (CCs) are an important component of Mediterranean hard-bottom environments with great structural and functional complexity. These communities are particularly impacted by disturbances such as overfishing, excessive recreational diving, anchoring, anthropogenic sedimentation, invasive species, mucilage and particularly in last decades, thermal anomalies. Hence there is a dire need for studies on coralligenous to better preserve them. Most studies are concentrated in the NW Mediterranean and only few studies are present in the easternmost Mediterranean. The aim of this study was to assess the CCs of a MPA in Ayvalık, NE Aegean Sea, which harbours dense Eunicella cavolini gorgonian populations. In the present study, the structure of coralligenous in the Ayvalık Islands Marine Park (AIMP) was investigated by comparing 2 stations dominated by gorgonians and 2 stations without gorgonians by SCUBA diving and photoquadrats. Ecological status of coralligenous was assessed through a standardized procedure, differences in the structure of coralligenous with and without gorgonians were analysed through PERMANOVA. Overall, a total of 61 benthic taxa were identified, with 47 taxa in gorgonian dominated coralligenous and 50 taxa in non-gorgonian assemblages. The CCs were mainly characterized by high number/percent cover of sponges and low number/percent cover of erect bryozoans/tunicates in accordance with other reports from the Aegean. Despite being a 28 years MPA, the AIMP has no actual protection since there are no on-site management. Impacts by fishing activities and traces of the invasive algae Caulerpa racemosa (Chlorophyta) are clear on the CCs of the MPA.

Key-words: Gorgonians, marine protected area, Aegean Sea, biodiversity, *Caulerpa racemosa*

Introduction
Coralligenous environments are an important component of hard-bottom habitats. Long-lived endemic species in coralligenous communities, for instance gorgonians such as *Eunicella cavolini* (Koch, 1887), greatly enhance marine diversity. This gorgonian commonly found in the Mediterranean coralligenous assemblages was reported in dense populations at Ayvalık. The Ayvalık Islands Marine Park (AIMP) was established in 1995 but despite the existence of a management plan, there is no on-site management. The aim of this study was therefore to assess the ecological status of coralligenous communities in the AIMP and compare yellow gorgonian dominated assemblages to those without gorgonians.

Materials and methods
The field study was performed by SCUBA diving in September 2020 within the AIMP located in the northeast Aegean Sea at 4 stations: Ayvalık Taşları and Hayalet Taşları (coralligenous communities dominated by the yellow gorgonian *E. cavolini, "G" stations*) vs Güneş Adası and Kraliçe Taşları (coralligenous communities without gorgonians "nG" stations). Samples were collected at a depth of 30 – 35 m. Two replicates of 4m^2 transects per

station were performed, with 10 photoquadrats of 0.2 m^2/transect. Ecological status of coralligenous was assessed through the standardized procedure of STAR (STAndaRdized coralligenous evaluation) procedure (Piazzi *et al.,* 2019).

Fig.1. Location of Ayvalık Islands Nature Park

Results

Among "G" stations, benthic coverage for sponges was 42.03%, 23.93% for chlorophytes and 16.73% for rhodophytes. 45.56% of "nG" stations were covered by rhodophytes, 35.73% by chlorophytes and 16.30% by sponges. Statistical analyses underlined that "G" stations were defined by high coverages of sponges/tunicates, while "nG" were characterized by increased coverages of sediment /rhodophytes/chlorophytes. PERMANOVA analysis did not yield any significant differences between "nG" and "G" groups, however significant differences were observed between Ayvalık Taşları (G) and Güneş Adası (nG) (N=80, p-value = 0.048).

Discussion and conclusions

Results underline the prevalence of sponges when coralligenous assemblages harbour *E. cavolini,* which enable a higher heterogeneity for the spatial distribution of the benthos. Gorgonian dominated habitats provide a complex three-dimensional micro-habitat which in turn enhance the local diversity. The present study is in concordance with other studies undertaken in the Aegean Sea (Cinar *et al.,* 2020, Sini *et al.,* 2019). Non-gorgonian stations were defined by increased algal turf coverage. The presence of *Caulerpa racemosa* and fishing nets at Güneş Adası and Kraliçe Taşları were also reported. In conclusion, AIMP hosts valuable coralligenous communities but they are under high pressure from fisheries, sedimentation and the invasive species *C. racemosa.* The management plan in 2004 needs to be urgently updated and effectively applied.

Acknowledgments

This study was financially supported by the Scientific Research Unit of Istanbul University (I.U. BAP project n° 34363).

Bibliography

CINAR M.E., FERAL J.P., ARVANITIDIS C., DAVID R., TASKIN E., SINI M., DAILIANIS T., DOGAN A., GEROVASILEIOU V., EVCEN A., CHENUIL A. (2020) - Coralligenous assemblages along their geographical distribution: Testing of concepts and implications for management. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 30 (8): 1578-1594.

PIAZZI L., CECCHI E., CINTI M.F., STIPCICH P., CECCHERELLI G. (2019) - Impact assessment of fish cages on coralligenous reefs through the use of the STAR sampling procedure. *Mediterranean Marine Science,* 20 (3): 627-635.

SINI M., GARRABOU J., TRYGONIS V., KOUTSOUBAS D. (2019) - Coralligenous formations dominated by *Eunicella cavolini* (Koch, 1887) in the NE Mediterranean: biodiversity and structure. *Mediterranean Marine Science,* 20 (1): 174-188.

Patrick ASTRUCH, ORTS A., SCHOHN T., BELLONI B., BALLESTEROS E., BIANCHI C.N., BOUDOURESQUE C.F., HARMELIN J.G., MORRI C., THIBAUT T., VERLAQUE M.
GIS Posidonie, Aix-Marseille University, France
E-mail: patrick.astruch@univ-amu.fr

TOWARDS AN ECOSYSTEM-BASED INDEX TO ASSESS THE ECOLOGICAL STATUS OF MEDITERRANEAN COASTAL DETRITAL BOTTOMS

Abstract
In the Mediterranean Sea, Coastal Detrital Bottoms (CDB) are one of the most extensive habitats of the continental shelf. The EU Marine Strategy Framework Directive has embraced the concept of a socio-ecosystem-based approach to consider the functioning of marine habitats and their related services. We propose an ecosystem-based quality index (EBQI) for CDB based on a conceptual model of this ecosystem (functional compartments, their relative weight, assessment methods and potential descriptors). Twenty-nine sites were sampled along the French Mediterranean coast. Study sites encompassed a wide range of hydrological conditions and human pressures. A contrasting range of ecological status was recorded, driven by local natural features and human activities, attesting to the interest of applying the EBQI to CDB.

Key words: Coastal Detrital Bottoms, EBQI, EU MSFD, NW Mediterranean

Introduction

Coastal Detrital Bottoms (CDB) are a Mediterranean circalittoral biocenosis constituted by recent organogenic and bioclastic sediments, both autogenous and allochtonous (Pérès & Picard, 1964). CDB provide important ecosystem services but also CDB are facing intensive issues related to human activities and global change. Current knowledge about CDB is mainly related to assemblage description of endofauna or macrophytes (Joher *et al.*, 2015 and references therein). The aim of our work is to apply an ecosystem-based approach (Boudouresque *et al*., 2020) to CDB, proposing an Ecosystem-based Quality Index (EBQI) for CDB in accordance with the Marine Strategy Framework Directive.

Material and Methods

A conceptual model of CDB, functional compartments, compartment weights and descriptors per compartment have been designed. Descriptors were chosen to assess the 11 boxes (B) of CDB (Astruch *et al*., 2021): Rhodolith cover at upper and intermediate zone (B1), perennial macroalgae cover (B2), Seasonal macroalgae cover at upper and intermediate zone (B3-4), diversity of herbivores (B5), % of fine sediment <63 µm (B6), % of organic matter of the sediment (B7), cover by detritic litter (B8), density of detritivores (B9a-9b), filter and suspensive feeders density (B10), planktivorous teleosts specific richness (B11) and taxonomic richness of carnivorous invertebrates (B12a) and vertebrates (B12b). The EBQI is calculated using the formula: $EBQI = [\sum_{i=1}^{11}(W_i \times S_i) / \sum_{i=1}^{11}(W_i \times S_{max})\ ] \times 10$. W_i is the weight of the box, S_i the status of the box and S_{max} maximum status (4/4). Twenty-nine sampling sites were investigated along the littoral of Provence and French Riviera (France). Two depth ranges were sampled at each site: (i) upper zone (between 28 to 43 m according to sites) and the intermediate deep zone (between 48 to 78 m depth). *In situ* observations, sediment sampling, photoquadrats and seascape videos were carried out. Full details of the method are given in Astruch *et al.* (2021).

Results and Discussion

EBQI notation ranges from 2.05/10 to 8.06/10; 8 sites present a Good or Very Good status while 10 present a Poor or Bad status. The CI was reduced for box 7 (Endofauna) for all sites because of the method used (organic matter assessment instead of macrofauna analysis). The CI remains Very Good for all sites, ranging from 88 to 93 %. EBQI notation is explained by local specificities and the proximity or not of Human activities. Principal Component Analysis shows a gradient following Axis 2 (16.8 %) from Poor to Very Good sites. Good and Very Good EBQI notations are explained by high status for boxes 1, 2 and 3-4 (Primary producers). Boxes 7 (Endofauna), 8 (Detritic litter) and 12 (Carnivores) are less discriminating. The aim of this work is to provide a useful tool for managers and to advocate for a better assessment of this key habitat. Our analysis provides evidence that sites far from urbanization and without trawling show the best notation. According to our results, EBQI applied to CDB seems to provide accurate results. However, it would have been more useful to assess properly the macrofauna of the sediment instead of measurement of the organic matter, which would have improved the quality of the assessment. The next step will be to apply and test EBQI on CDB in areas with other biogeographic specificities and other pressures (e.g. oligotrophic, warmer, impacted by NIS).

Acknowledgment

We warmly thank the French Office of Biodiversity for financial support, the experts involved and M. Paul for proof-reading of the text. This work is dedicated to the memory of Boris Daniel.

Bibliography

ASTRUCH P., ORTS A., BELLONI B., SCHOHN T., BOURSAULT M., NEGGAOUI-CRAIPEAU S., CABRAL M., BOUDOURESQUE C.F. (2021) - *ACDSea : Assessment of Coastal Detrital conservation Status: an ecosystem-based approach, Evaluation de l'état de conservation du Détritique Côtier selon une approche écosystémique, Rapport final.* Contrat GIS Posidonie – Office Français de la Biodiversité, *GIS Posidonie publ*. 206 p + annexes.

BOUDOURESQUE C.F., ASTRUCH P., BĂNARU D., BLANFUNE A., CARLOTTI F., FAGET D., GOUJARD A., HARMELIN-VIVIEN M., LE DIREACH L., PAGANO M., PASQUALINI V., PERRET-BOUDOURESQUE M., ROUANET E., RUITTON S., SEMPERE R., THIBAULT D., THIBAUT T. (2020) - Global change and the management of Mediterranean coastal habitats: a plea for a socio-ecosystem-based approach. In: Evolution of Marine Coastal Ecosystems under the Pressure of Global Changes, Springer, 297-320.

JOHER S., BALLESTEROS E., RODRÍGUEZ-PRIETO C. (2015) - Contribution to the study of deep coastal detritic bottoms: the algal communities of the continental shelf off the Balearic Islands, Western Mediterranean. *Mediterranean Marine Science*, 16(3): 573-590.

PÉRÈS J.M., PICARD J. (1964) - Nouveau manuel de bionomie benthique de la mer Méditerranée. *Recueil des Travaux de la Station marine d Endoume*, Fr., 31 (47): 5-137.

Ignacio BAENA VEGA, PALOMINO, D., ARRIETA, J.M., CALVO-MANAZZA, M., DE LA BALLINA, N.R., DÍEZ, I.P., DÍEZ, S., FRAILE-NUEZ, E., GONZÁLEZ-IRUSTA, J.M., GONZÁLEZ-VEGA, A., GOÑI, R., MALLOL, S., MARESCA, F., MORATÓ, M., MUÑOZ, A., NARANJO, S., QUILES-PONS, C., REAL, E., RODRÍGUEZ, J.M., SÁNCHEZ, F., VÁZQUEZ, J.T., & DÍAZ, D.
Instituto Español de Oceanografía (CN-IEO-CSIC), Muelle de Poniente s/n, 07015, Mallorca, Islas Baleares, Spain.
E-mail: ignacio.baena@ieo.csic.es

MAPPING COMMUNITY INTEREST HABITATS IN THE COLUMBRETES ARCHIPELAGO, AN EXTRAORDINATY HOT STOP OF BIODIVERSITY

Abstract
The Columbretes Archipelago and their submerged surroundings are part of an unusual, Pleistocene volcanic field located in the Western Mediterranean designated as a Site of Community Importance (SCI) of the Natura 2000 Network. In the present study, 4 benthic habitats of community interest (1110, 1170, 1180 and 8330) have been identified by analyzing several sources of information. Generalized additive models (GAMs) have been used to model the potential distribution of reefs (1170) and maërl beds (1110). Our results highlight the diversity and extent of these habitats and allow comparisons to other marine SCIs of Spain. This can be attributed to the variability of the environment of this site. The Columbretes Islands combine a relatively shallow environment with volcanic structures, hydrothermalism with active degassing, current-driven sedimentary lobes and the influence of inland flows. Understanding high biodiversity spots is crucial as they offer natural laboratories to describe how ecosystems respond to the effects of global change. The knowledge obtained will be of paramount importance for the conservation of species and habitats. Furthermore, it will establish a baseline for future monitoring and assist in the development of effective management plans.

Key-words: Benthic communities, Marine Protected Area, Distribution Modeling, Generalized Additive Models, Habitat Biodiversity

Introduction
The Columbretes Archipelago has been protected since 1987 and included as an SCI in 2006. However, poor information about its habitats has been available until now. Previous studies have described some specific spots (Linares et al. 2012). This study develops the first cartography of the habitats distribution covering the whole protected site by means of distribution modeling (DM) following the steps developed by Serrano *et al*. (2017).

Materials and methods
Data were collected in multidisciplinary surveys carried out in two periods (2009-2013, 2018-2021). The habitat data consisted of a total of 5427 points separated every 5 meters within transects, in accordance with the spatial resolution of the environmental data (fig. 1). Habitats presence was linked to the environmental variables using of binomial GAMs in R software. ArcGIS was used to create the map combining the distribution of the different habitats (fig. 1b).

Results

We have found a total surface of 3.96 km^2 of the occupied by these two communities, meaning 2.96% out of the total surface of the SCI (tab. 1). Compared to other marine SCIs of Spain where these analyses have been conducted, we have found a higher quantity of directive habitat presence.

Table 1: A) Comparison of Habitats Directive communities between Spanish SCIs

Site of Community interest	1110 (%)	1120 (%)	1170 (%)	1180 (%)	8330 (nº)
Columbretes (K)	2.3	-	0.65	Not measured	8
Seco de los Olivos (K)	1.77*	Not measured	9.24 (15.01*)	-	-
Banco de la Concepción (TSS)	-	-	16.52	-	-
Banco de Galicia (K)	-	-	26.72	-	-

* Percentage including habitats suggested to be included within the category. K = Kappa. TSS = True Skill Statistic

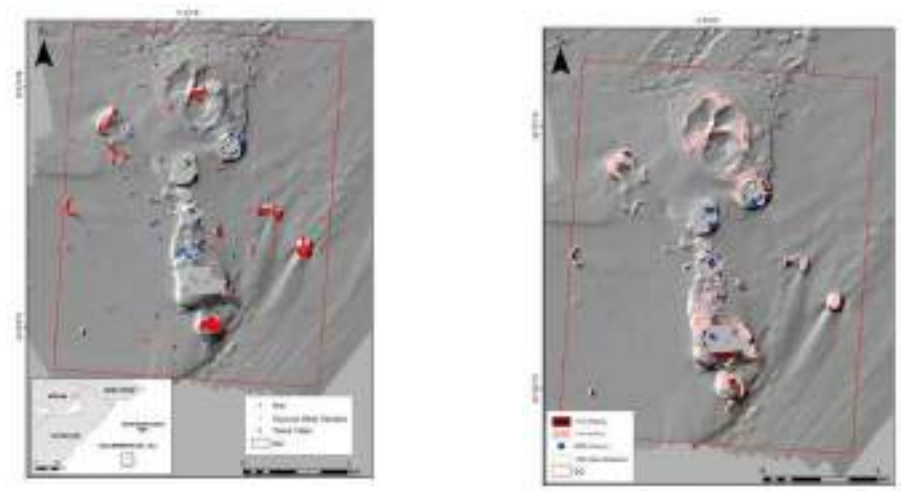


Fig. 1: A) Sampling transects. B) Cartography of the Habitats Directive communities.

Discussion and conclusions

Our results have produced the first continuous map of the benthic habitats by means of SdM in this protected site. This study will provide a baseline to track changes in habitat distribution and support management measures.

Acknowledgments

LIFE IP INTEMARES project (LIFE15 IPE/ES/000012).

Bibliography

LINARES, C., VIDAL, M., CANALS, M., KERSTING, D.K., AMBLÁS, D., ASPILLAGA, E., CEBRIÁN, E., DELGADO-HUERTAS, A., DÍAZ, D., GARRABOU, J., HEREU, B., NAVARRO, L., TEIXIDÓ, N. y BALLESTEROS, E. (2015) - Persistens natural acidification drives major distribution changes in marine benthic ecosystems. *Proceedings Real Society B*, 282 (20150587).

SERRANO, A., GONZÁLEZ-IRUSTA, J.M., PUNZÓN, A., GARCÍA-ALEGRE, A., LOURIDO, A., RÍOS P., BLANCO, M., GÓMEZ-BALLESTEROS, M., DRUET, M., CRISTOBO, J., & CARTES, J.E. (2015) - Deep-sea benthic hábitats modeling and mapping in a NE Atlantic seamount (Galicia Bank). *Deep Sea Research Part I: Oceanographic Research Papers*, 126, 115-127.

Hocein BAZAIRI, RAMZI SGHAIER Y., MECHMECH A., BENHOUSSA A., BENHISSOUNE S., BOUTAHAR L., SELFATI M., SEMPERE-VALVERDE J., OSTALÉ-VALRIBERAS E., GONZÁLEZ ARANDA A.R., ESPINOSA F.
Biodiversity, Ecology and Genome Laboratory, Faculty of Sciences, Mohammed V University in Rabat, Rabat, Morocco.
E-mail: hoceinbazairi@yahoo.fr

CURRENT STATE OF THE MARINE BIODIVERSITY IN THE NATIONAL PARK OF AL HOCEIMA (ALBORAN SEA, MOROCCO)

Abstract
The National Park of Al Hoceima (NPAH) is the unique protected area officially declared in 2004 on the Mediterranean coast of Morocco. Moreover, it has been recognized as Specially Protected Areas of Mediterranean Importance (SPAMI) since 2009. Within the framework of the MedKeyHabitats II project, implemented by SPA/RAC with the financial support of MAVA Foundation, the marine area of the NPAH (0 – 50 m depth) was prospected and ecologically characterized in 2019 using multiple approaches (bathymetry, habitat mapping, benthic profiles, underwater visual fish census, census of the giant limpet Patella ferruginea and socio-economic characterization). The NPAH fully deserves its status as a protected area and SPAMI at a regional scale. Overall, 49 protected species were observed in the marine area of the NPAH in 2019 versus 25 species observed in 2002. In addition, the mapping of benthic habitats in the marine area between 10 and 50 m depth, carried out for the first time in the NPAH, allowed the identification of 27 habitats among which 16 habitats of particular conservation interest in the Mediterranean such as coralligenous and seagrass meadows. The main threats on benthic habitats observed in the marine area of the NAPH were related to illegal fishing, in particular bottom-trawling, by-catch of protected species (e.g. Dendrophyllia ramea and Charonia lampas) and invasive non-indigenous species, especially the brown algae Rugulopteryx okamurae.

Key-words: National Park of Al Hoceima, marine Biodiversity, habitats mapping, vulnerability, ecological state.

Introduction
The National Park of Al Hoceima (NPAH) is the unique protected area officially declared in 2004 on the Mediterranean coast of Morocco. Moreover, it has been recognized as Specially Protected Areas of Mediterranean Importance (SPAMI) since 2009. Here we present the most updated scientific data on the marine biodiversity of the NPAH.

Materials and methods
The marine area of the NPAH (0 – 50 m depth) was prospected and ecologically characterized in 2019 using multiple approaches (bathymetry, habitat mapping, benthic profiles, underwater visual fish census, census of the giant limpet *Patella ferruginea* and socio-economic characterization).

Results

Overall, 49 protected species were observed in the marine area of the NPAH in 2019 (Fig. 1) (SPA/RAC–ONU ENVIRONNEMENT/PAM, 2020). In addition, the mapping of benthic habitats in the marine area between 10 and 50 m depth, carried out for the first time in the NPAH, allowed the identification of 27 habitats among which 16 habitats are of particular conservation interest in the Mediterranean (SPA/RAC–UN ENVIRONMENT/MAP, 2019). The main threats on benthic habitats observed in the marine area of the NAPH were related to illegal fishing, in particular bottom-trawling, by-catch of protected species (e.g. *Dendrophyllia ramea* and *Charonia lampas*) and invasive non-indigenous species, especially the brown algae *Rugulopteryx okamurae*.

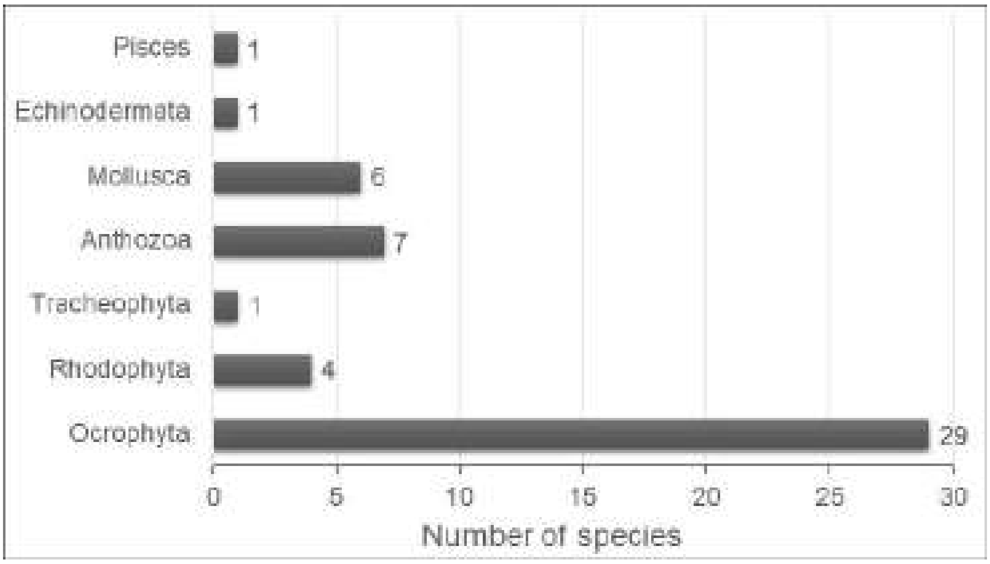


Fig. 1: Number of protected species recorded in the marine area of the National park of Al Hoceima

Discussion and conclusions

The NPAH fully deserves its status as a protected area and SPAMI at a regional scale. The update scientific data provided in 2019 will help in the development of an integrated management plan for the National Park of Al Hoceima.

Acknowledgements

This work was conducted within the framework of the MedKeyHabitats II Project implemented by UNEP/MAP-RAC/SPA in close collaboration with the Département des Eaux et Forêts (DEF) and financially supported by SPA/RAC, Tunisia, and the MAVA Foundation, Switzerland.

Bibliography

SPA/RAC–UN ENVIRONMENT/MAP (2019) - Updated Classification of Benthic Marine Habitat Types for the Mediterranean Region, 15pp.

SPA/RAC–ONU ENVIRONNEMENT/PAM (2020) - Parc National d'Al Hoceima. Rapport Final. Par Bazairi H., Ramazi-Sgaier Y., Mechmech A., Benhoussa A., Malouli Idrissi M., Benhissoune S., Boutahar L., Selfati M., Khalili A., Inglese O., Marquez J.L., Martinez A., Perez E., Mauri G., Gonzalez A.R., Ostalé-Valriberas E., Sempre-Valverde J. & Espinosa F., Ed SPA/RAC – Projet MedKeyHabitats II (cartographie des habitats marins clés et évaluation de leur vulnérabilité aux activités de pêche en Méditerranée), Tunis : 265 pages +Annexes.

Said BELBACHA, DAHEL A. T., LEBDJIRI K., DJEBAR B.
Department of Marine Sciences. Badji Mokhtar University Annaba ALGERIA
E-mail: saidbelbacha1@gmail.com

COMPOSITION, DISTRIBUTION AND STATE OF THE CORALLIGENOUS FROM FUTURE EDOUGH MARINE PROTECTED AREA (SW MEDITERRANEAN, EAST ALGERIA)

Abstract

This work completes the preliminary studies for the creation of the Edough marine protected area, west of Annaba, within the framework of the GENBI program "environmental governance and biodiversity" of the GIZ Algeria . Pre-coralligenous and coralligenous concretions are well represented in the Edough MPA, but their distribution is heterogeneous. The coralligenous bottoms spread out and cover important surfaces mainly on the vertical walls and the external part of the sea caves developing coralligenous cords between 11 and 50 m deep. Communities of great species diversity were observed and 193 species were recorded. There are many signs of a healthy coralligenous community due to the absence of direct anthropic action on the environment, such as urban or industrial discharges, and only artisanal fishing is recorded in the area studied. This situation is not likely to last given the planned tourist extension projects.

Key-words: coralligenous assemblage, conservation, Algeria, SW Mediterranean

Introduction

Within the framework of the program GENBI "environmental governance and biodiversity" of the GIZ Algeria in the aim of the integrated management of the coastal zone and within the framework of the Action Plan for the Conservation of Coralligenous and other Calcareous Bioconcretions in the Mediterranean, a study was carried out on the coralligenous communities within the framework of an integrated management of the future MPA of the Edough. The objectives are to (i) identify the types and species of coralligenous facies; (ii) determine the distribution and mapping of coralligenous communities; and (iii) identify the remarkable species of the coralligenous; Set up an action plan for the monitoring of coralligenous communities

Materials and methods

The future MPA Edough located west of the city of Annaba extends over a coastal stretch, between Cap de Garde and Cap Axine, of about 40 km. To cover its entire surface, we explored 25 stations between -11 and -50 m depth. The dives was carried out between September 2021 and February 2022. Depending on the scale and precision needed, data was collected in 4 different ways: Diving towed by hydroplane for the localization of the coralligenous and the bathymetric extension with an accuracy of 10 m; Punctual dive for the characterization of assemblages along transects for an accuracy of 1 m; Underwater photography as recommended by Kollman & Stachowitsch (2001) and macrobenthic sampling with accuracy < 1 m; Direct determination of the species in the laboratory.

Results and Discussion

Coralligenous is well represented in the study area. These assemblages are spread over large deep rocky bottoms, mainly on vertical walls and on the outer part of marine caves forming coralligenous strips between 11 and 50 m depth. Less important but nevertheless present, the coralligenous "plateau" is observed below 40 m.

A total of 193 taxa were recorded, showing the great biological diversity of these assemblages. The most characteristic and dominant species are: Calcareous rhodophyta (*Lithophyllum, Mesophyllum, Neogoniolithon,…*), Sponges (*Agellas oroides, Spongia virgultosa, Axinella damicornis*), Gorgonians (*Paramuricea clavata, Eunicella cavolini, Leptogogia sarmentosa*), Other cnidarians (*Parazoanthus axinellae, Astroides calycularis,* Corallium rubrum), Bryozoans (*Pentapora fascialis, Reteporella grimaldii, Smittina cervicornis*), Ascidians (*Halocynthia papillosa, Aplidium*), Echinoderms (*Centrostephanus longispinus*) and Fish (*Sciaena umbra, Epinephelus marginatus*).

Compared to the other Mediterranean regions, the coral in the study area corresponds more closely to that in the South-West African zone: Ceuta (Ocaña *et al.*, 2009) and Chafarinas (Sanchez-Tocino *et al.*, 2009), where gorgonians (*Eunicella, Paramuricea, Ellisella spp.*) are predominant, as well as *Astroides calycularis.* Paradoxically, towards the East, we note differences with the Tunisian North (Ben Mustapha *et al*., 2004) and the region of El Kala, as the total absence of the epiphytic alcyonacea *Parerythropodium coralloides* and the *Paramuricea clavata* (Belbacha *et al*., 2009). The coralligenous of the area can be considered healthy based on (1) abundance of the presence of calcareous algal slats (*Lithophyllum* spp., *Mesophyllum*) growing three-dimensionally, (2) the presence of *Cystoseira* spp., (2) the presence of large gorgonians of all size classes without necrosis, (3) the abundance of large bryozoans, (4) the clean coralligenous bottoms with very little silt and (5) the presence of remarkable species (grouper, large cicada, red coral).

Conclusion

The coralligenous of the future MPA of Edough is well developed with a great biological diversity marked by the presence of various protected Mediterranean species and characterized by the absence of major threats (trawling, wastewater discharge). However, to avoid overfishing of targeted species, to protect threatened habitats and to conserve the remarkable marine biodiversity, it is necessary to accelerate the classification of this area to face the tourism expansion projects planned in the area.

Bibliography

BELBACHA S., SEMROUD R., DUPUY DE LA GRANDRIVE R. & FOULQUIE M. (2009) - Données préliminaires sur la répartition et la composition de la biocenose du coralligene du littoral d'El Kala (Algerie). *Proc. 1st. Medit. Symp. Conservation of the coralligenous and other calcareous bio-concretions,* Tabarka (Tunisia), 15-16 January 2009: 157-159.

BEN MUSTAPHA K., BOUAJINA A., GUELLOUZ S., RAMOS-ESPLA A.A., SÁNCHEZ-JÉREZ P. (2004) - Rapport global des travaux de prospection marine: Bionomie benthique. *Elaboration du plan de gestion de la partie marine du Parc National de Zembra et Zembretta,* Projet MedMPA (activité mp3), CE/RAC-SPA/Université d'Alicante: 11-24.

KOLLMANN H., STACHOWITSCH M. (2001) - Long-term changes in the benthos of the Northern Adriatic Sea: A phototransect approach. P.S.Z.N. *Marine Ecology,* 22(1-2): 135-154.

OCAÑA O., RAMOS-ESPLÁ A.A., TEMPLADO J. (2009). *Los paisajes sumergidos de la Región de Ceuta y su Biodiversidad.* Fundación Museo del Mar de Ceuta, 254pp.

SÁNCHEZ-TOCINO L., MALDONADO M., NAVARRO C., GONZÁLEZ-VELASCO C. (2009) - *Informe de la campaña realizada en el Refugio Nacional de Caza de las Islas Chafarinas*. Universidad de Granada-CEAB Blanes, 18pp.

Isabella BITETTO, CAU A., CARBONARA P., PESCI P., FOLLESA M.C.
University of Cagliari, Via Università, 40 09124 Cagliari (Italy)
E-mail: i.bitetto@studenti.unica.it; bitetto@coispa.it

A FIRST CONTRIBUTION ON *CORALLIUM RUBRUM* ASSESSMENT IN SARDNINIAN WATERS

Abstract
Coralligenous is among the main benthic communities in the Mediterranean Sea and represents one of the most important biodiversity hotspot. This work is focused, in particular, on Corallium rubrum (Linnaeus, 1758), being also a key resource of Sardinians waters fishery and currently showing a decrease in landings in the whole Mediterranean Sea. General Fishery Commission for Mediterranean Sea (GFCM) put in place several safeguard actions for monitoring and protect this important resource. The objective of this study is to provide a first evaluation of the status of the Corallium rubrum populations status in North-Western Sardinian waters. The assessment was carried out using a length-based method for data-limited fisheries based on spawning potential (LBSPR) applied on samples collected in Alghero, Bosa and Fertilia in 2012, 2013, 2014 and 2015. Growth parameters were also estimated fitting a von Bertalanffy. The results show that the fishery selects the colonies characterised by a diameter above the size at first maturity. The results show that the stock spawning potential could be deteriorated and highlight a moderate overexploitation situation.

Key-words: *Corallium rubrum*, Sardinia, stock assessment, LBSPR, Mediterranean Sea

Introduction
Coralligenous is among the main benthic communities in Mediterranean Sea and represents one of the most important biodiversity hotspot. This work is focused on the red coral, being also a key resource of Sardinians waters fishery and currently showing a decrease in landings in the whole Mediterranean Sea. General Fishery Commission for Mediterranean Sea (GFCM) put in place several safeguard actions for monitoring and protect this important resource, towards an Adaptive Management Plan for red coral in all Mediterranean (Recommendation GFCM/36/2012/1; Recommendation GFCM/35/2011/2; Recommendation GFCM/41/2017/5). The objective of this study is to provide a first evaluation of the status of the *Corallium rubrum* populations in North-Western Sardinian waters (GSA 11, sensu GFCM).

Materials and methods
Samples of *C. rubrum* colonies harvested by SCUBA divers were collected for 2012, 2013, 2014 and 2015 from three ports of North-Western Sardinian waters (Alghero, Bosa and Fertilia); the basal diameter in mm was measured by observers on board for each colony. Growth parameters were estimated fitting a von Bertalanffy growth function on the age data collected according to the thin section— organic matrix staining method (Marschal et al. 2004). On the basis of the estimated parameters, the natural mortality was derived by a combination of different methods (http://barefootecologist.com.au/shiny_m). The assessment was carried out using the LBSPR method (Length Based Spawning Potential Ratio, Hordyk 2015 and 2016), developed for data-limited fisheries.

Results

The results show that the fishery selects the colonies with a diameter above the size at first maturity (Figure 1, left). Under the assumption of steady state the stock spawning potential seems deteriorated, according to the SPR indicator. Indeed the SPR=0.27 is below the reference value of 0.4 (Figure 1, right; Clark, 2002), highlighting a moderate overexploitation situation.

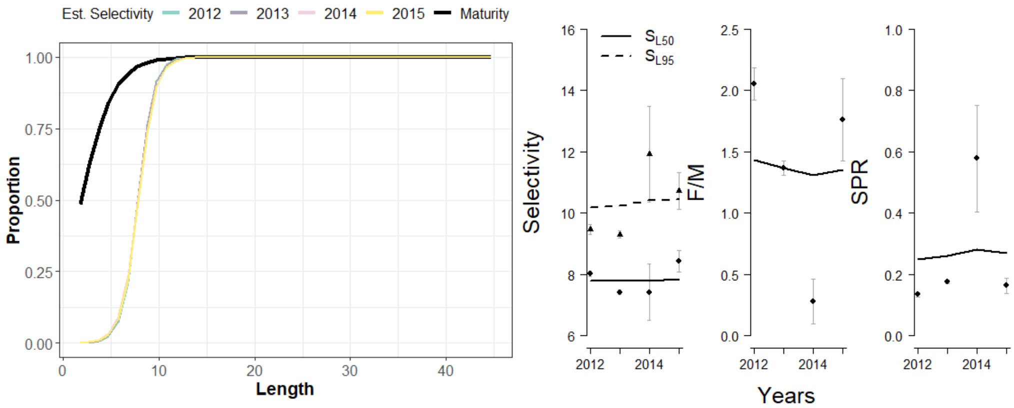


Fig.1: Left: Comparison maturity at length and selectivity of the fishery. Right: Selectivity parameters, F/M and SPR estimated by LBSPR

Discussion and conclusions

Red coral is a key species of the coralligenous habitats an important biodiversity hotspot and a key resource of Sardinians waters fishery. GFCM put in place several safeguard actions for monitoring and protect this important resource due to its warning decrease in landing in the whole Mediterranean Sea. The decrease in red coral catches could be due prohibition of remotely operated vehicles (ROV) and decrease of the number of licenses (about 30%). The data collected under the monitoring program (Sardinia Regional Government) allowed making a first evaluation of the stock status through LBSPR, highlighting a possible moderate overexploitation of the resource.

Bibliography

CLARK W.G. (2002) - F 35% revisited ten years later. North American Journal of Fisheries Management, 22(1): 251-257.

HORDYK A. R., ONO K., PRINCE J. D., WALTERS C. J. (2016) - A simple length-structured model based on life history ratios and incorporating size-dependent selectivity: application to spawning potential ratios for data-poor stocks. *Canadian Journal of Fisheries and Aquatic Sciences*, 73(12): 1787-1799.

HORDYK A. R., LONERAGAN N. R., PRINCE J. D. (2015) - An evaluation of an iterative harvest strategy for data-poor fisheries using the length-based spawning potential ratio assessment methodology. *Fisheries Research*, 171: 20-32.

MARSCHAL C., GARRABOU J., HARMELIN J. G. PICHON M. (2004) - A new method for measuring growth and age in the precious red coral *Corallium rubrum* (L.). Coral reefs, 23(3): 423-432.

Martina CANESSA, BAVESTRELLO G., TRAINITO E.
DiSTAV (Department of Earth, Environment and Life Sciences), University of Genoa, Corso Europa 26, 16132 Genova, Italy
E-mail: marti.canessa@gmail.it

THE INFLUENCE OF SUBSTRATE LITHOLOGY ON BENTHIC ASSEMBLAGES IN DIM LIGHT-CONDITIONS

Abstract
Among abiotic factors, substrate lithology demonstrated to play an important role in shaping the structure and diversity of sessile zoobenthic assemblages in several ecological contexts.
The present study was dedicated to the description of the communities settled on two substrates (limestone vs granite) in shadow habitats. In this conditions it was possible to isolate the effect of the lithology from other environmental factors like solar light intensity and sedimentation rate.
In this aim the occurrence of several sessile species, living inside communities characterized by the solitary scleractinian Leptopsammia pruvoti, settled on limestone and granites, in the same depth range were compared in the Tavolara MPA (Mediterranean Sea. The analysis of photographic samples revealed significant differences in the composition of the whole assemblages according to lithology. The crustose coralline algae and Peyssonnelia spp. were almost exclusive of limestones where L. pruvoti was significantly more abundant. Moreover, branched calcified bryozoans resulted dominant on limestone. Conversely, granites were mainly characterized by encrusting sponges, encrusting bryozoans and the chitinous branched bryozoan Chartella papyrea.

Key-words: semi-dark habitats, biomineralogy, calcified organisms, Tavolara Is.

Introduction
The influence of lithological properties of substrates on the ability of marine sessile organisms to colonize hard surfaces has recently been recognized in different ecological contexts. In particular, a pool of studies was conducted at the Tavolara Punta Coda Cavallo MPA where the carbonatic Tavolara is. faces a group of granitic shoals located in the Tavolara Channel (Canessa *et al*., 2020a).
The obtained results strongly indicated that limestone enhanced the growth of coralline algae until the production of the typical coralligenous outgrowths that were completely absent on granitic substrata. The coralline algal sheet drove, in its turn, the following colonization and development of benthic assemblages (Canessa *et al*., 2020b).
Nevertheless, these results were in part not definitive, for the difficulty to separate the effect of lithology from other environmental factors. For example, the granitic shoals of the channel were prone to a high rate of sedimentation that may reduce algal growth (Canessa *et al*., 2021). To obtain more definitive results about the effect of substrate composition we have decided to study the communities settling and development on shadow vertical cliffs and overhangings, where the sedimentation rate is negligible.

Materials and methods
The shady side of vertical cliffs and overhangings, all characterised by a community dominated by the scleractinian *Leptopsammia pruvoti,* were investigated in twelve sites

(six characterised by a limestone substrate and six granite) in the Tavolara MPA. In each site, ten photographs on a standard surface 50 × 70 cm (3500 cm^2) were randomly taken for a total of 120 images. Photographs were analysed using ImageJ Software to identify taxa at the maximum possible taxonomic resolution. Values of recurrence were calculated for each species as a percent of sites hosting it. When specific or generic identifications were not achieved, operational taxonomic units (OTUs) were adopted.

Results

Significative differences according to the substrate type emerged for the investigated dim-light benthic assemblages. The element characterising both the communities was the solitary scleractinian *Leptopsammia pruvoti* that, on limestone was about three times more abundant than on granites (13.4 ± 0.6 vs. 4.8 ± 0.4 specimens per 100 cm^2). Limestones were characterized mainly by the exclusive presence of the crustose coralline algae and *Peyssonnelia* spp., which often enveloped the base of the corallites of *L. pruvoti*. On the contrary, on granites, the coverage was mainly due to encrusting and massive sponges. Bryozoans were one of the most represented groups, showing a clear preference for limestones. On this last substratum,11 species were recorded (9 of these exclusive). Among these species, *Adeonella calveti* and *Myriapora truncata* were observed in all the explored sites and *Reteporella grimaldi* and *Schizomavella mamillata* occurred in 5 of the 6 ones. On granites, only 4 species were recorded. The most diffused bryozoan was the chitinous *Chartella papyrea* present in 4 on 6 sites; together with *Flustra foliacea*, they were exclusively found on granites. Moreover, *A. calveti* was present in half of the considered sites.

Discussion

The investigation of shaded habitats has allowed deepening the role of lithology in the conditioning of the structure of the benthic communities, excluding other environmental factors like solar light intensity and sedimentation rate. In these habitats, our results confirm that the lithological properties of the substrates can drive the benthic assemblages at different levels: modifying the growth of coralline algae, selecting species and creating peculiar phisic/chemical conditions for consequent settling and communities' development. On this subject, it is intriguing that a calcified group like bryozoans is more diffused on limestone and the only species present in all the investigated granitic sites is *C. papyrea* characterized by a chitinous skeleton.

Bibliography

CANESSA M., BAVESTRELLO G., BO M., TRAINITO E., PANZALIS P., NAVONE A., CARAGNANO A., BETTI F., CATTANEO-VIETTI R. (2020a) - Coralligenous assemblages differ between limestone and granite: a case study at the Tavolara-Punta Coda Cavallo Marine Protected Area (NE Sardinia, Mediterranean Sea). *Regional Studies in Marine Science*, 35: 101159.

CANESSA M., BAVESTRELLO G., TRANITO E., NAVONE A., CATTANEO-VIETTI R. (2020b) - Lithology could affect benthic communities living below boulders. *Journal of the Marine Biological Association of the United Kingdom*, 100(6): 879-888.

CANESSA M., BAVESTRELLO G., TRAINITO E., BIANCHI C.N., MORRI C., NAVONE A., CATTANEO-VIETTI R. (2021) - A large and erected sponge assemblage on granite outcrops in a Mediterranean Marine Protected Area (NE Sardinia). *Regional Studies in Marine Science*, 44: 101734.

Martina CANESSA, BO M., BETTI F., BAVESTRELLO G.
Dipartimento di Scienze della Terra, dell'Ambiente e della Vita (DISTAV), Università degli Studi di Genova, Corso Europa 26, 16132 Genova, Italy
Email: marti.canessa@gmail.com

THE BENTHIC PALEOASSEMBLAGE OF THE SCIACCA CORAL

Abstract
The subfossil red coral deposits of Sciacca (Sicily Channel) have attracted scientific attention for nearly 150 years. Their origin and formation have been long questioned and investigated, given the fact that they represent one of the most intriguing geobiological events ever occurred in the Mediterranean basin. Less attention was given to the paleo-community associated with the subfossil coral. The taxonomic study of micritic coral conglomerates coming from Sciacca deposits revealed that Corallium rubrum was contemporary to most of its epibionts for several millennia, while it co-existed with the CWC Madrepora oculata only for about 600 years, suggesting the existence of a co-dominated facies (red coral-white coral) in the nearby living assemblages, nowadays virtually disappeared from the Mediterranean Sea.

Key-words: red coral, deep cold-water corals, paleo-assemblages, Sicily Channel

Introduction

In the Mediterranean Sea, the Sicily Channel has long been one of the most famous fishing grounds for precious coral (*Corallium rubrum*). This site hosts the largest sub-fossil red coral deposits ever found in the Mediterranean basin, discovered between 1875 and 1878, at depths ranging from 150 m to 200 m off Sciacca (SW Sicily) (Lodolo et al., 2017). Despite numerous studies focused on the deposit origin, very few data are available regarding the paleo community associated with the red coral (Di Geronimo *et al*., 1993; 2001).
Here we present data obtained by the taxonomic study of conglomerates of calcareous organisms intermixed with red coral branches coming from Sciacca Banks, accompanied by a radiocarbon age determination of the main species recorded.

Material and methods

In the area of the Sciacca deposits, red coral was collected as fragments free in the sediments or as conglomerates of different size, these latter being the target of this study. The examined material included photographs taken from three conglomerates, courtesy of the coral farms of the Consorzio Corallo Sciacca (Sicily), and two conglomerates present in the authors' collection. All the specimens came from the Sciacca deposits; depth and date of collection are unknown. All the recognizable carbonatic organisms were analysed. Radiocarbon age determination was conducted on the most diffused elements. The analysis was performed using an Accelerator Mass Spectrometry (AMS) at the Centre of Dating and Diagnostic (CEDAD) of the University of Salento.

Results

The study of the conglomerates from Sciacca indicated that they were mainly composed of broken branches of *Corallium rubrum* and fragments of the colonial cold-water scleractinian *Madrepora oculata* associated with the tube of the polychaete *Eunice norvegica*. All these fragments were cemented together by a micritic matrix. On this scaffold, corallites of the scleractinians *Caryophillia* sp. and *Polycyathus muellerae* were settled hosting, in their turn, the barnacle *Megatrema anglicum*. In some cases, colonies of red coral were recorded settled on branches of *M. oculata*, indicating that the scaffold was the result of multiple settling events. Shells of the bivalve *Spondylus gussonii* and fragments of an unidentified pectinid, brachiopods *Megerlia truncata* and *Terebratulina retusa*, serpulids tubes (*Serpula* spp.) and an unidentified bryozoan were frequently present.

The carbon age of the main components of the Sciacca conglomerates was estimated. Red coral showed a wider age range from 3564 to 274 YBP. The age range of *M. oculata* was more limited, from 3000 to 2400 YBP, while those of the accompanying species ranged from 3900 to 1280 YBP.

Discussion

The study of the red coral conglomerates from Sciacca indicates that the frameworks are the result of the settling of different biological components over some millennia. On the contrary, *M. oculata* became part of the conglomerates in a more restricted time range. Given the co-occurrence of the two dominant species in the same framework it is plausible that, at that time, the nearby hardgrounds hosted a peculiar biocoenosis, co-dominated by *C. rubrum* and *M. oculata*. Today, similar living associations, including also arborescent habitat-forming species, are virtually absent in the Mediterranean Sea and recorded only in the Cassidaigne Canyon along the French coast, at about 180-200 m depth (Fabri *et al*., 2017), which could have been also the approximate bathymetric range of the source populations of the Sciacca deposits in the Sicily Channel.

Bibliography

DI GERONIMO I., ROSSO A., SANFILIPPO R. (1993) - *I banchi fossiliferi di* Corallium rubrum *al largo di Sciacca (Canale di Sicilia).* In: Il corallo rosso in Mediterraneo: arte, storia e scienza (Cicogna F., Cattaneo-Vietti R., eds). Ministero Risorse Agricole, Alimentari e Forestali, Roma, pp. 75-107.

DI GERONIMO I., ROSSO A., LA PERNA R., SANFILIPPO R. (2001) - *Deep-sea (250–1.550 m) benthic thanatocoenoses from the southern Tyrrhenian Sea*. In: Structure and processes in Mediterranean ecosystems (Faranda F.M., Guglielmo L., Spezie G., eds). Springer, Milan, pp. 277-287.

FABRI M.C., PEDEL L., BEUCK L., GALGANI F., HEBBELN D., FREIWALD A. (2014) - Megafauna of vulnerable marine ecosystems in French Mediterranean submarine canyons: Spatial distribution and anthropogenic impacts. *Deep Sea Research Part II*: *Topical Studies in Oceanography*, 104: 184-207.

LODOLO E., SANFILIPPO R., RAJOLA G., CANESE S., ANDALORO F., MONTAGNA P., ROSSO A., MACALUSO D., DI GERONIMO I., CAFFAU M. (2017) - The red coral deposits of the Graham Bank area: Constraints on the Holocene volcanic activity of the Sicilian Channel. *Geo. Res. J.*, 13: 126-133.

Celeste DOMÍNGUEZ MONGE, PAVÓN PANEQUE A., OSTALÉ-VALRIBERAS E., CARBALLO CENIZO JL.
Laboratorio de Biología Marina de la Universidad de Sevilla (LBMUS)/ Estación de Biología Marina del Estrecho (Ceuta), Departamento de Zoología, Facultad de Biología de la Universidad de Sevilla, Av. de la Reina Mercedes, 41012 Sevilla, Spain. E-mail: cdominguez@us.es

BIOLOGICAL INDICATORS OF CLIMATE CHANGE IN ANDALUSIAN COASTS: STUDY OF THE CALCIFICATION RATES BY CALCIFYING ORGANISMS AND THEIR RELATIONSHIP WITH CO_2 SYSTEM VARIABLES.

Abstract
The present work aims, on the one hand, to establish a baseline study of calcium carbonate production of secondary calcifiers, and on the other hand, to determine their response of biological variables to sea temperature, as well as to CO_2 system variables. A 30% of the total CO_2 released is assimilated by the sea causing an increase of 100ppm in the partial pressure of atmospheric CO_2, which continues to increase linearly. This process affects the oceanic carbonate system, leading to a decrease in carbonate ion concentration and, in turn, in pH. In addition, biological carbonate production, or biocalcification, is an important component of the carbon cycle and represents an important CO_2 storage process in the form of carbonates.
That is why a monitoring network has been established. Two of the stations have already been in operation for two years and data have been collected with significant results. This is the case of the City of Ceuta and La Línea in Algeciras, sites with monitoring stations inside and outside the harbor. A better water quality has been observed in Ceuta, with a higher calcification compared to Algeciras.

Key-words: Accretion Units, Andalusian Coasts, Climate Change, Secondary Calcifiers.

Introduction
Studies have been carried out to determine carbonate production by secondary calcifiers in tropical environments of the Pacific, Caribbean and Indian Oceans, but never in temperate latitudes. It is intended to establish the basis for a long-term monitoring program in the Andalusian coasts, as well as in the city of Ceuta, making a total of four monitoring stations. This is also in order to assess any differences in calcification as a function of anthropogenic impact and the location of stations along the Strait.

Materials and methods
The methodology applied is that proposed by the National Oceanic and Atmospheric Administration of the United States (NOAA) in the Pacific Ocean reef monitoring program called Pacific RAMP ("Pacific Reef Assessment and Monitoring Program") (DesRochers *et al.*, 2015). For the quantification of $CaCO_3$ produced by secondary calcifiers, experimental accretion units (hereinafter UEA's) were constructed (see Fig. 1, A-D). Data have been collected in City of Ceuta and in La Línea in Algeciras, with monitoring stations inside and outside the harbor.

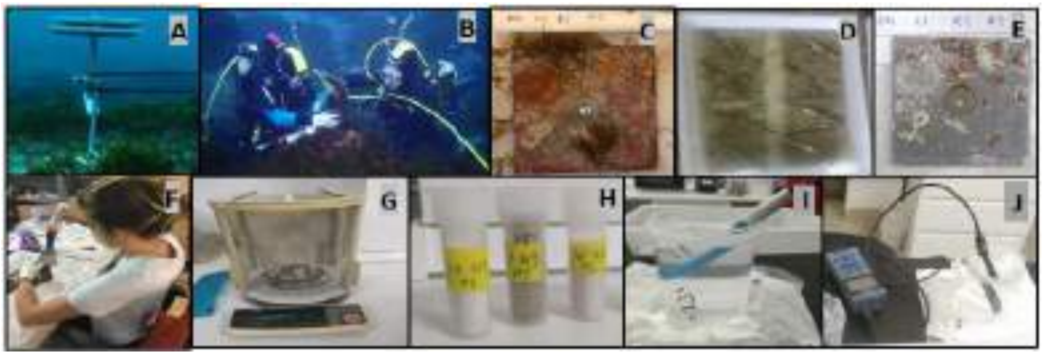


Fig. 1: A, B, C, D, E, F, G, H, I, J: Installation of UEA's and monitoring methodology.

Results

The average calcification rate of all UEA's was 5.14 g $CaCO_3 \cdot m^{-2} \cdot year^{-1}$. In Algeciras, from February 2020 to March 2021, the average was 3.54 g $CaCO_3 \cdot m^{-2} \cdot year^{-1}$ with a significant difference between the two sampling stations. The average calcification rate of Outer Harbor (PE) was 5.27 g $CaCO_3 \cdot m^{-2} \cdot year^{-1}$ versus Inner Harbor (PI) with 1.85 g $CaCO_3 \cdot m^{-2} \cdot year^{-1}$. In Ceuta from November 2019 to November 2020, the average was 6.74 g $CaCO_3 \cdot m^{-2} \cdot year^{-1}$. The overall average pH was this was 8.24. In PE the pH varied between 8.12 and 8.39 and between 8.13 and 8.20 in the PI. In Ceuta it varied between 7.96 and 8.44. The overall mean temperature was 16.53ºC. In PE it ranged between 14.99ºC and 16.24ºC, and in PI between 15.473ºC and 16.99ºC. In Ceuta it ranged between 15.19ºC and 21.24ºC.

Discussion and conclusions

We observed that Ceuta presented a greater range of pH variation than Algeciras. In PI, less variation was obtained than PE, where the water resilience time is longer. The temperature difference confirms the theory that water turnover in the interior of the port is lower (Gupta *et al*., 2005). The difference in calcification between zones was attributed to the disturbance of the environment, where such a factor decreases the coverage of secondary calcifiers, with these barely accounting for 20% of the total under these conditions (Mallela, 2013). This means that the outer seawall of Alcaidesa Marina, in Algeciras, delimits two different environments, i.e., the inner area bounded by the seawall and the outer area exposed to the open sea. The port structures would have a negative effect on the environmental characteristics of the inner zones as they prevent the exchange of water with the strait.

Aknowledgements

To my thesis directors José Carlos García Gómez and José Luís Carballo Cenizo. Financially supported by University of Seville.

Bibliography

DesRochers, A., Oliver, T., Kanemura, T. (2015) - *Calcification Rates of Crustose Coralline Algae derived from Calcification Accretion Units (CAUs) deployed across U.S. Pacific Reefs since 2010 (NCEI Accession 0137093)*. NOAA National Centers for Environmental Information.

Gupta, A.K., Gupta, S.K., Rashmi, S. (2005) - Patil Environmental management plan for port and harbour projects. *Clean Techn. Environ. Policy*, 7: 133–141.

Mallela, J (2013) - Calcification by Reef-Building Sclerobionts. *PLOS ONE*, 8(3): e60010.

Gemma DONATO, ROSSO A., SANFILIPPO R., SCIUTO F., D'ALPA F., BRACCHI V.A., BAZZICALUPO P., SERIO D.,LEONARDI R., VIOLA A., GUIDO A., NEGRI M.P., BERTOLINO M., COSTA G., BASSO D.
Department of Biological, Geological and Environmental Sciences, University of Catania, Catania, Italy
E-mail: gemma.donato@unict.it

BIODIVERSITY ASSOCIATED WITH THE CORALLIGENOUS: THE CASE OF A COLUMNAR BUILD-UP AT 36m DEPTH OFF MARZAMEMI (SE SICILY, IONIAN SEA)

Abstract
This work, within the CRESCIBLUREEF project, focuses on the biodiversity of the coralligenous bioconstructions off Marzamemi (SE Sicily, Ionian Sea), aiming at better understanding which taxa inhabit the build-up and their possible contribution to the framework's formation. Soft and calcareous algae together with the erect bryozoan Margaretta cereoides form a canopy at the surface of the structure. Bryozoans are the species-richest taxon, mostly with Celleporina caminata and encrusting species. Serpulids are less diversified but some species, such as Josephella marenzelleri are very abundant. Sponges, foraminifers, molluscs, crustaceans, brachiopods and hydrozoans are subordinate.

Key-words: Macroalgae, bioconstruction, benthic assemblages, threatened ecosystem, Mediterranean Sea

Introduction
Coralligenous is a priority habitat of the Mediterranean Sea, whose bioconstructions' framework primarily consists of calcareous algae (Di Geronimo *et al.*, 2002; Bracchi *et al.*, 2022), but invertebrates contribute to the growth of the build-ups, each playing a specific role in the coralligenous construction. Within the FISR project CRESCIBLUREEF – "Grown in the blue: new technologies for knowledge and conservation of Mediterranean reefs", we focused on coralligenous biodiversity associated with a build-up, aiming at understanding which taxonomic groups form/inhabit it, and their species richness, specifically for bryozoans and serpulids.

Materials and Methods
The build-up studied (CBR2_4_21, nicknamed Di Geronimo, Fig. 1) was collected in August 2021 off Marzamemi (SE Sicily, Ionian Sea) at 36 m depth. The site is characterized by scattered decimetre-sized build-ups that rise from a coarse biogenic bottom. All the erect canopy-forming organisms on the build-up surface were picked, identified and counted.

Results
Several taxonomic groups were found, still many under study. Bryozoans include 72 species (some abundant, e.g. *Celleporina caminata*) and serpulids 20 species (*Josephella marenzelleri* above all). Algae (>100 species, mostly *Flabellia petiolata* and peyssonneliaceans) and foraminifers (ca. 30 species) are species-rich. Molluscs

(bivalves including *Gregariella semigranata* and encrusting gastropods with *Vermetus granulatus* are common); brachiopods (*Joania cordata*) and cirripeds (*Verruca spengleri*) are subordinate.

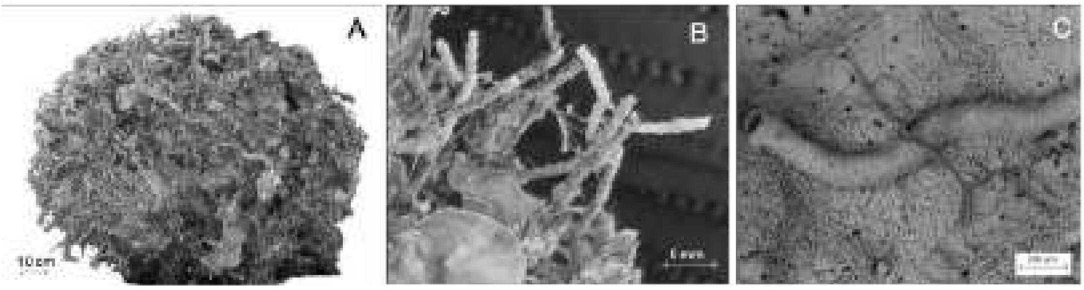


Fig. 1: (A) The build-up studied ; (B) The bryozoan *Margaretta cereoides*; (C) The serpulid *Josephella marenzelleri*

Discussion and conclusions

Although data only refer to few taxonomic groups, the ongoing research points to a high species richness for bryozoans and serpulids, largely above the 9 and 7 species found on a previously studied columnar build-up from the same area (Di Geronimo *et al.*, 2002). Though comparisons are difficult, bryozoans and foraminifers from this single build-up account for more than 1/3 and 1/2 of the total species richness known for the Mediterranean coralligenous (Ballesteros, 2006, and references therein). We expect to increase these figures with the ongoing analyses.

Acknowledgement

This work was funded by the Italian Ministry of Research and University – Fondo Integrativo Speciale per la Ricerca (FISR), project FISR2019_04543 "CRESCIBLUREEF - Grown in the blue: new technologies for knowledge and conservation of Mediterranean reefs". We thank R. Leonardi (Univ. Catania), N. Pietralito and the SUTTAKKUA Diving Centre (Pachino, Italy) for their technical support. Catania Paleontological Group contribution n. 491.

Bibliography

BALLESTEROS E. (2006) - Mediterranean coralligenous assemblages: a synthesis of present knowledge. Oceanography and Marine Biology: an Annual Review 44, 123–195.

BRACCHI V.A., BAZZICALUPO P., FALLATI L., VARZI A.G., SAVINI A., NEGRI M.P., ROSSO A., SANFILIPPO R., GUIDO A., BERTOLINO M., COSTA G., DE PONTI E., LEONARDI R., MUZZUPAPPA M., BASSO D.(2022) - The main builders of Mediterranean coralligenous: 2D and 3D quantitative approaches for its identification. *Frontiers in Earth Science*, *Paleontology* 10:910522.

DI GERONIMO I., DI GERONIMO R., ROSSO A., SANFILIPPO R. (2002) - Structural and taphonomic analysis of a columnar coralline algal build-up from SE Sicily. *Geobios* 35, 86-95.

Laura FIGUEROLA-FERRANDO, GARRABOU J., AMBLAS D., LINARES C.
Departament de Biologia Evolutiva, Ecologia i Ciències Ambientals, Institut de Recerca de la Biodiversitat (IRBIO) Universitat de Barcelona, Avda. Diagonal 643, 08028 Barcelona, Spain.
Email: lfiguerola@ub.edu

MULTISPECIES DISTRIBUTION MODELS OF GORGONIANS IN CORALLIGENOUS ASSEMBLAGES

Abstract
Species Distribution Models (SDMs) have been recognized as optimal tools to predict the potential species distributions and identify their environmental drivers. Our aim is to assess the potential distribution of 4 gorgonian species considered key habitat-formers in coralligenous assemblages. Occurrence records were extracted from the CorMedNet database, OBIS, and citizen-science initiatives. Predictors were specifically chosen according to the biology of the model species, and encompass both topographic and environmental variables. Ensembled SDMs revealed similar potential distributions for C. rubrum, P. clavata, and E. singularis, showing higher suitability in North-Western Mediterranean, Adriatic, and Aegean Sea. In contrast, E. cavolini potential distribution is further northeast. Moreover, potential habitat suitability for the four species was shown in the southern Mediterranean, where there is a lack of published records. Our study represents a step forward in analyzing the present and future distribution of coralligenous dominated by gorgonians with important applications in conservation and management.

Key-words: Coralligenous assemblages, Benthic invertebrates, Species Distribution Models (SDMs), Ensemble modelling, Mediterranean Sea.

Introduction
Global warming is affecting the dynamics and conservation status of Mediterranean coralligenous assemblages, particularly impacted by mass mortality events driven by recurrent marine heatwaves (Garrabou *et al.*, 2009). Bearing in mind that the North-Western Mediterranean concentrates most research efforts on the coralligenous, we face an important gap of knowledge that hinders exploring the consequences of the ongoing environmental changes in this key habitat. Species Distribution Models (SDMs) have been recognized as optimal tools to predict the potential species distribution and identify their environmental drivers (Thuiller *et al*., 2005). In this context, the aim of this study is to assess the potential distribution of 4 gorgonian species considered key habitat-forming species in coralligenous assemblages (*Corallium rubrum*, *Paramuricea clavata*, *Eunicella singularis*, and *E. cavolini*) by estimating its habitat suitability.

Materials and methods
To maximize the representation of the occurrence records, we take advantage of the CorMedNet database, that gathers information of marine invertebrate habitat forming species, OBIS, and citizen-science initiatives such as *Observadores del Mar* and ReefCheck, which use expert validations. Occurrence spatial auto-correlation was checked using a Nearest Neighbor Index. Predictors were specifically chosen according to the biology of the model species, and encompass topographic (e.g. slope, bathymetry, type of substrate) and environmental variables (e.g. temperature, current velocity,

nutrients, water transparency) from EMODNet and Copernicus Marine Environment Monitoring Service (CMEMS); the most effective resolution at this spatial scale. Predictors were resampled with the same resolution and geographic extent (Mediterranean Sea with a maximum depth of 150 m). The covariance of predictors was checked by both, correlation analysis and a Variance Inflator Factor ratio. We estimated habitat suitability using an ensemble approach resulted from the combination of different algorithms (e.g. Generalised Additive Model, Random Forest, Classification Tree Analyses, Maximum Entropy), which performed best in the final model. Pseudo-absences and background required by selected algorithms were generated according to Barbet-Massin *et al*. (2012). The "*Biomod2"* R package (Thuiller *et al*., 2009) was used to perform the models.

Results

Ensembled Multispecies Distribution Models revealed similar habitat suitability distributions for *C. rubrum, P. clavata*, and *E. singularis*, showing higher suitability in North-Western Mediterranean, Adriatic, and Aegean Sea. In contrast, *E. cavolini* potential distribution is further northeast. Moreover, potential habitat suitability for the four species was shown in the southern Mediterranean, where there is a lack of published records. Topographic variables (e.g. bathymetry) were the most important predictors.

Discussion and conclusions

Our study represents a step forward in analyzing the present and future distribution of coralligenous dominated by gorgonians, with important insights for its conservation and management, especially considering the recent policy initiatives in biodiversity and ecosystem function (e.g. European Habitats and Marine Strategy Framework Directives).

Acknowledgments

This research has been funded by the Spanish Ministry of Economy and Innovation through the Smart project (CGL2012-32194), the HEATMED project (RTI2018-095346-B-I00, MCIU/AEI/FEDER, UE). JG acknowledges the funding of the Spanish government through the 'Severo Ochoa Centre of Excellence' accreditation (CEX2019-000928-S). CL acknowledges the financial support by ICREA under the ICREA Academia program. LF was supported by FI SDUR grant (2020 FISDU 00482) from "Generalitat de Catalunya".

Bibliography

BARBET-MASSIN, M., JIGUET, F., ALBERT, C. H., & THUILLER, W. (2012). Selecting pseudo-absences for species distribution models: how, where and how many? *Methods in Ecology and Evolution* 3 (2), 327-338.

GARRABOU, J., COMA, R., BENSOUSSAN, N., BALLY, M., CHEVALDONNÉ, P., CIGLIANO, M., DIAZ D., HARMELIN J. G., GAMBI M. C., KERSTING D. K., J. B. LEDOUX, LEJEUSNE C., LINARES C., MARSCHAL C., PÉREZ T., RIBES M., ROMANO J. C., SERRANO E., TEIXIDO N., TORRENTS O., ZABALA M., ZUBERER F., CERRANO C. (2009) -. Mass mortality in Northwestern Mediterranean rocky benthic communities: Effects of the 2003 heat wave. *Global Change Biology* 15, 1090–1103.

THUILLER, W., LAVOREL, S., & ARAÚJO, M.B. (2005). Niche properties and geographical extent as predictors of species sensitivity to climate change. *Global Ecology and Biogeography* 14 (4), 347-357.

THUILLER, W., LAFOURCADE, B., ENGLER, R., & ARAÚJO, M. B. (2009). BIOMOD–a platform for ensemble forecasting of species distributions. *Ecography* 32 (3), 369-373.

Ivan GUALA, PIAZZI L., DE FALCO G., BORRAS-PALOMAR A.I., BRAMBILLA W., BUDILLON F., CINTI M.F., CONFORTI A., DE LUCA M., DI MARTINO G., FERRIGNO F., GRECH D., INNANGI S., LA MANNA G., PANSINI A., PASCUCCI V., PINNA F., PIREDDU L., PUCCINI A., RUSSO G.F., SANDULLI R., SANTONASTASO A., SIMEONE S., STELLETTI M., STIPCICH P., TONIELLI R., CECCHERELLI G.
IMC - International Marine Centre, Oristano, Italy.
E-mail: i.guala@fondazioneimc.it

DISTRIBUTION AND STATUS OF CORALLIGENOUS ASSEMBLAGES IN SARDINIA (WESTERN MEDITERRANEAN)

Abstract
This work summarizes the main results obtained through collaborative investigations conducted in Sardinia on both coralligenous banks and cliffs. The findings provide crucial background knowledge to support effective monitoring plans, proper conservation and maritime spatial planning strategies, thus meeting the requirements of both the European directives and the Action Plan for the conservation of coralligenous bioconstructions in the Mediterranean Sea.

Key-words: biogeographic patterns, coralligenous banks, coralligenous cliffs, ecological quality, mapping

Introduction
In Sardinia (Italy, Western Mediterranean), a huge effort has been recently made to increase knowledge about distribution, spatial variability and ecological status of coralligenous reefs, according to European directives. This work summarizes the main results obtained on both coralligenous banks and cliffs.

Material and methods
Coralligenous banks were mapped along the northern and western continental shelf of Sardinia through multibeam echosounder surveys and Remote Operating Vehicles (ROV). ROV images were also used for assessing the spatial variability of assemblages at multiple spatial scales and their ecological quality (CBQI Index, Ferrigno *et al.*, 2017). Coralligenous cliffs were photo-sampled by SCUBA diving on vertical rocky substrate at 35 m of depth and the ecological quality was evaluated through the ESCA index (Piazzi *et al.*, 2021a). The community structure, the spatial variability and the ecological quality of bank and cliff assemblages were evaluated.

Results
A total surface of 436 km^2 of coralligenous banks was mapped in the depth range between 40 and 160 m, where the habitat occupies 8.8% of the surface of the continental shelf (De Falco *et al.*, 2022). The assemblages appeared well structured and diversified with a relevant abundance of erect habitat-forming anthozoans dominated by *Eunicella cavolini* and *Callogorgia verticillata*. Some local context-dependent taxa (e.g. *Ellisella flagellum*, *Parantipathes larix* and *Antipathella subpinnata* in the South, *Corallium rubrum* and *Paramuricea clavata* northwards) define the spatial variability of assemblages (Piazzi *et al.*, 2022a). Coralligenous cliffs are characterized by diverse

assemblages with a high variability at large (among areas 10s of km apart) spatial scales which seems more related to biogeographic patterns (e.g. different hydrodynamic conditions, temperature and nutrient supply) rather than spatial distance (Piazzi *et al.*, 2021b). The eastern areas were characterized by bryozoans and gorgonians, the northern areas by *Corallium rubrum* and the western ones by encrusting sponges and erect algae. Patterns of spatial variability differed between banks and cliffs. CBQI classified all areas in good quality while the ESCA index highlighted three areas with high ecological quality and two areas with good ecological quality (Piazzi *et al.*, 2022b).

Discussion and conclusions

Results contribute to the knowledge of the habitat distribution requested by the main European directives and provide information to support effective monitoring plans and conservation strategies, meeting the requirements of the Action Plan for the conservation of coralligenous bioconstructions in the Mediterranean Sea. In particular, results highlight that (i) the total area covered by coralligenous bioconstructions was deeply redefined by increasing mapping efforts; (ii) the maximum depth (160 m) where the banks were detected is among the greatest depths recorded for this habitat; (ii) biogeographic patterns should be considered when selecting specific reference conditions to assess the ecological quality of this habitat; (iii) given the specificity of coralligenous banks and cliffs, concurrent assessment of both systems should be considered in designing monitoring programs.

Bibliography

DE FALCO G., CONFORTI A., BRAMBILLA W., BUDILLON F., CECCHERELLI G., DE LUCA M., DI MARTINO G., GUALA I., INNANGI S., PASCUCCI V., PIAZZI L., PIREDDU L., SANTONASTASO A., TONIELLI R., SIMEONE S. (2022). Mapping of coralligenous banks along the western and northern continental shelf of Sardinia Island (Mediterranean Sea), *J. Maps*, DOI 10.1080/17445647.2021.2020179.

FERRIGNO F., RUSSO G.F., SANDULLI R. (2017). Coralligenous Bioconstructions Quality Index (CBQI): a synthetic indicator to assess the status of different types of coralligenous habitats. *Ecol. Indic.*, 82: 271-279.

PIAZZI L., GENNARO P., CECCHI E., BIANCHI C.N., CINTI M.F., GATTI G., GUALA I., MORRI C., SARTORETTO F., SERENA F., MONTEFALCONE M. (2021a). Ecological status of coralligenous assemblages: Ten years of application of the ESCA index from local to wide scale validation, *Ecol. Indic.*, 121: 107077.

PIAZZI L., CINTI M.F., GUALA I., GRECH D., LA MANNA G., PANSINI A., PINNA F., STIPCICH P., CECCHERELLI G. (2021b). Variations in coralligenous assemblages from local to biogeographic spatial scale, *Mar. Environ. Res.*, 169: 105375.

PIAZZI L., DE FALCO G., DE LUCA M., GUALA I., BORRAS PALOMAR A., CONFORTI A., PASCUCCI V., SIMEONE S., CECCHERELLI G. (2022a). Coralligenous assemblages of continental shelf: multiple spatial scale variability in the western Sardinia. *Cont. Shelf Res.*, 245: 104790.

PIAZZI L., FERRIGNO F., GUALA I., CINTI M.F., CONFORTI A. , DE FALCO G., DE LUCA M., GRECH D., LA MANNA G., PASCUCCI V., PANSINI A., PINNA F., PIREDDU L., PUCCINI A., RUSSO G.F., SANDULLI R., SANTONASTASO A., SIMEONE S., STELLETTI M., STIPCICH P., CECCHERELLI G. (2022b). Inconsistency in community structure and ecological quality between platform and cliff coralligenous assemblages. *Ecol. Ind.*, 136: 108657.

Giusto LO BUE, MARCHINI A., MANCIN N.
Dipartimento di Scienze della Terra e dell'Ambiente, Università di Pavia, via Ferrata 1, 27100 Pavia, Italy.
E-mail: giustolobue@gmail.com

CONTRIBUTION OF CALCAREOUS PROTISTA (FORAMINIFERA) TO BIOCONSTRUCTIONS OF THE HONEYCOMB WORM *SABELLARIA ALVEOLATA*

Abstract
The honeycomb worm Sabellaria alveolata (Linnaeus, 1767) is a sedentary polychaete which lives in littoral environments playing a key role for coastal protection and habitat provision. Its wave-resistant arenaceous reefs are made of aggregated tubes of sand-sized grains, including several bioclasts, such as foraminiferal tests. Samples of bioconstruction were collected in southern Sicily (Central Mediterranean), along with samples from the nearby sediment. Foraminiferal tests contained in both types of samples were quantified, classified into morphogroups, and quantitatively compared through multivariate analyses and diversity indices. Results show statistical differences in terms of abundance and foraminiferal community structure between bioconstruction and neighbouring sediment, hence supporting the hypothesis of active selection of grains operated by the polychaete.

Key-words: *Sabellaria alveolata*, foraminiferal tests, grain selection, arenaceous reef, Central Mediterranean Sea.

Introduction
Bioconstructions are three-dimensional structures that rise from the sea bottom creating new habitats and preventing coastal erosion. In the Mediterranean Sea, particularly important are the bioconstructions of a sedentary polychaete, *Sabellaria alveolata* (Linnaeus, 1767). This species builds, in the intertidal zone, areanceous tubes by agglutinating sand-sized grains picked from the water column. Literature data (e.g. Sanfilippo *et al*., 2019 with ref.) and direct observations show that agglutinated grains are selected by the organism: in particular, there exists a preference for carbonatic bioclasts, including tests of foraminifera (Protista). The aim of this study is to investigate whether foraminiferal tests are preferentially selected by *S. alveolata* and whether these tests are chosen as a function of their morphology (morphogroups) or simply of their abundance in the sediment kept in suspension by wave motion.

Materials and methods
In September 2019, samples of bioconstruction were collected in two localities of southern Sicily (respectively, Marina di Ragusa - MR and Punta Braccetto - PB), along with samples from the nearby sediment. Small portions of aggregate tubes (~ 12 tubes) were picked from two distinct portions of the bioconstruction: bottom and top; similarly, sediment samples (~ 15 ml of sediment) were collected near the bioconstruction (< 5 m from the bioconstruction bottom) and farther (> 5m). All samples were dried, weighed, prepared with the standard washed technique using a 63µm mesh sieve and analysed under a stereomicroscope. Foraminifera were identified at the genus level, counted (number of specimens per g of dry sediment) and subdivided into morphogroups according to Mancin & Pirini (2002). Three

small portions of bioconstruction were also prepared as polished sections to be analysed by Scanning Electron Microscope (SEM).

Results

In bioconstruction samples from both sites, foraminiferal tests were more abundant than in sediment samples. The biconvex genera *Ammonia*, *Cibicides* and *Cibicidoides* and the spherical, planktonic genera *Globigerina* and *Globigerinoides* were the most abundant within the bioconstruction (Fig. 1A). Foraminiferal tests increased in abundance and were more diversified in the upper portions of the bioconstruction and in the sediment collected near it, while they were less abundant and diversified in the samples from the bioconstruction bottom and in the sediment collected at a greater distance (> 5 m). Results deriving from polished sections confirmed these observations (Fig. 1B).

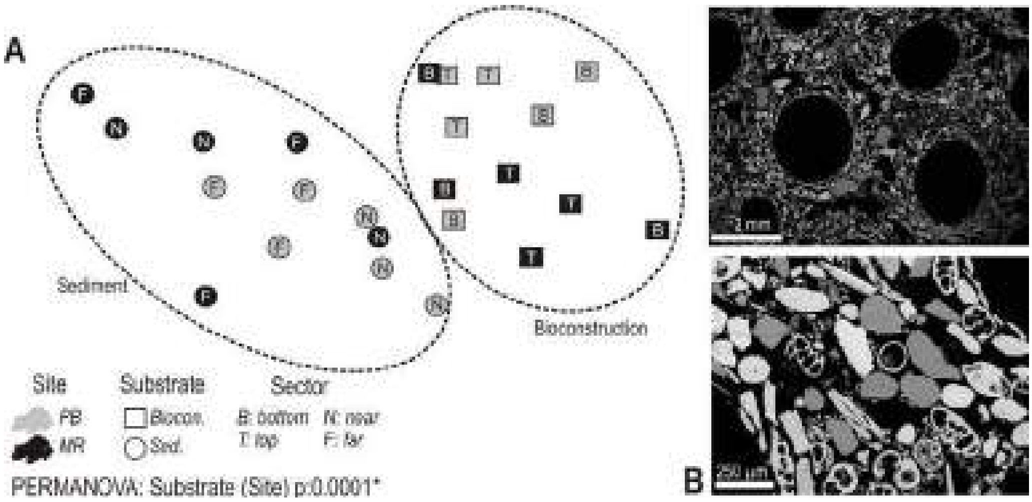


Fig. 1: A) nMDS graphs produced on Bray-Curtis similarity index calculated on morphogroups dataset (stress level = 0.09); B) SEM images of aggregated tubes horizontally sectioned showing biconvex and spherical foraminifera agglutinated within the tube wall.

Discussion and conclusions

The high abundance of biconvex and spherical foraminiferal tests in the bioconstructions of *S. alveolata* could be explained by the different hydrodynamics of the grains kept in suspension by waves. The lower weight and the spherical and/or biconvex morphology probably have favoured foraminiferal tests to buoyancy, making them more available for the capture by the polychaete, in a continuous recycling mechanism (Reuter *et al.*, 2010).

Bibliography

MANCIN N., PIRINI C. (2002) – Benthic and planktonic Foraminifera of the Paleogene Epiligurian succession (Northern Appenines, Italy): a tool for paleobathymetric reconstruction. *Boll. Soc. Paleont. It.*, 41: 187-213.

SANFILIPPO A., ROSSO A., MASTANDREA A., VIOLA M., DEIAS C., GUIDO A. (2019) – *Sabellaria alveolata* sandcastle worm from the Mediterranean Sea: new insights on tube architecture and biocement. *J. Morphol.*, 280: 1839–1849.

REUTER M., PILLER W., KROH A., HARZHAUSER M. (2010) – Foraminifera recycling in worm reefs. *Coral reef*, 29: 57.

Vesna MAČIĆ, PETOVIĆ S., ĐORĐEVIĆ N.
Institute of marine biology, University of Montenegro, Put I Bokeljske brigade 68, 85330 Kotor, Montenegro
E-mail: macic.v@ucg.ac.me

AXINELLA CANNABINA FACIES IN THE MPA STARI ULCINJ (MONTENEGRO, ADRIATIC SEA)

Abstract
Porifera species Axinella cannabina (Esper, 1794) is playing the dominant role at 20-22 m depth, along 600 m of the coast in the MPA Stari Ulcinj. Average A. cannabina density along four 25 m long and 1 m wide transects was 2.88 specimens/m^2 and the average height was 39.23 cm. In this area were registered, also many other, mostly invertebrate species, from which some are protected. Unfortunately, mechanical damage was registered on some specimens, caused by fishing gears, marine litter, and anchoring. This important area is now officially protected from anchoring and some types of fishing. Further research is needed in order to better understand the complexity and importance of A. cannabina facies as well as to assess the conservation status of this protected species. In parallel, cleaning campaigns and raising of public awareness should be organized.

Key-words: *Axinella cannabina*, density, MPA, Adriatic Sea

Introduction

One of the large and long-lived sponge species is *Axinella cannabina* (Esper, 1794). Because of its erect and bushy structure it plays a significant role as a three-dimensional habitat provider and that is why it is of special importance for biodiversity conservation. *A. cannabina* is included on the list of endangered and threatened species under the Barcelona Convention (Annex II) and it is listed on the national list of protected species in Montenegro. The presence of important populations of *A. cannabina* in two different areas on the coast of Montenegro (Boka Kotorska Bay and cape Marjan) was known from previous surveys (RAC/SPA – UNEP/MAP, 2011; Mačić *et al.*, 2015), but data on population density are missing and not only for the South Adriatic. The aim of this paper is to contribute to the knowledge of this vulnerable species and to provide a baseline for the appropriate measures of conservation planning.

Material and methods

Having in mind governmental intention for the creation of the MPA Stari Ulcinj in the surrounding of the Valdanos inlet, Montenegro (Adriatic Sea), more detailed surveys were performed in the area of 929 ha by SCUBA diving and ROV during 2020 (Fig. 1). Density of *A. cannabina* population and height of the specimens were measured along four transects 25m long and 1m wide. Transects were placed parallel to the coast at the depth range of 20-22m depth.

Results

The huge majority of the MPA Stari Ulcinj is characterized by sandy-muddy bottom, while seagrass meadows of *Posidonia oceanica* and coralligenous covers only 55ha. Along the southwest coast of the hill Marjan habitat type developed in the dim light conditions on the rocky bottom does not represent a typical coralligenous habitat.

However, in this area protected sponge *A. cannabina* has been registered in a very dense population (Fig. 1). Average *A. cannabina* density was 2.88 specimens/m^2 and the average height was 39.23 cm. Furthermore, in this area have been registered also many other Porifera species from which some are vulnerable and protected (*Spongia (Spongia) officinalis* Linnaeus, 1759, *S. lamella* (Schulze, 1879), *Aplysina* spp. Nardo, 1834, *Sarcotragus foetidus* Schmidt, 1862, *Axinella damicornis* (Esper, 1794), *A. verrucosa* (Esper, 1794) Unfortunately, on some specimens impacts of fishing gears, anchoring and marine litter were evident.

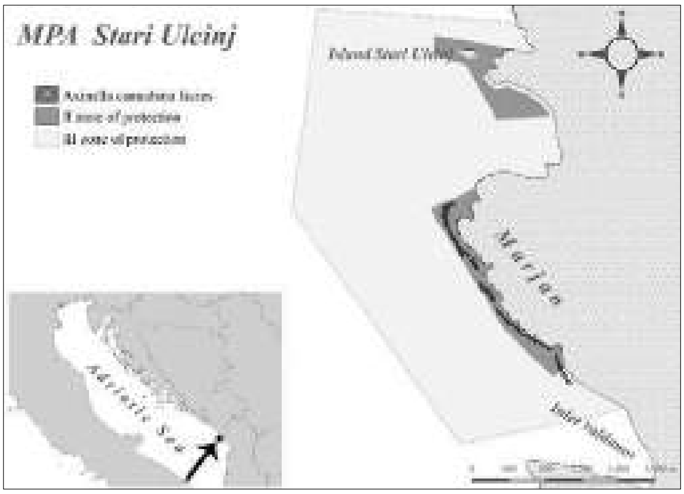


Fig. 1: Map of the MPA Stari Ulcinj and location of *A. cannabina* facies

Discussion

This important *A. cannabina* facies in MPA Stari Ulcinj is now officially protected from anchoring and some types of fishing, so the enforcement will be one of the future challenges. Further research is needed in order to better understand the complexity and importance of *A. cannabina* facies as well as to assess the conservation status of this protected species. In parallel, cleaning campaigns and raising of public awareness should be organized showing that although along not urbanized coast, because of the not appropriate treatment of the waste on land and marine currents, marine litter is impacting all parts of the sea.

Acknowledgements

The authors gratefully thank Vaso Bušković and Milena Bataković for coordinating the project "Promoting Protected Areas Management through Integrated Marine and Coastal Ecosystems", No: UNOPS-UNEP2-2019-GRANT-005 funded by the United Nations Office of Project Services (UNOPS).

Bibliography

MAČIĆ, V., PETOVIĆ, S., BACKOVIĆ, S. (2015) – Contribution to the knowledge of protected *Axinella* (Porifera, Demospongiae) species along the Montenegrin coast. Studia Marina 28(1): 9-20. ISSN 0585-5349

RAC/SPA - UNEP/MAP (2011) – Rapid assessment survey of coastal habitats to help prioritize the suitable new areas needing a status of protection for the development of a network of Marine and Coastal Protected Areas in Montenegro. By Badalamenti F., Garcia Charton J.A., Treviño-Otón J., Mačić V., and Cebrian D. Ed. RAC/SPA - MedMPAnet Project, Tunis: 52 p + Annexes

Simone MODUGNO, DE GRISSAC A. J., DEL GRANDE C., PREVIATI M., PANTALEO U., MYFTIU G., DEDEJ Z., ZARROUK A.
IRSSAT, Via del Fornaio, 7, 95033, Biancavilla (CT), Italy
E-mail: info@ilbludelma re.it

RESULTS OF THE FIRST IMAP MARINE SURVEY IN PATOK RODONI BAY (ALBANIA)

Abstract
Cape Rodoni (Albania) splits Lalzit bay in two parts. Patok-Rodoni bay is impacted by continuous flow-outs of Ishmi and Mati rivers, despite of its relevant biodiversity and the presence of fragile wetlands, complaints a sedimentation effect on the residual Posidonia meadows and a geophysical disturbance due to various inland activities, contaminants and marine-litter. During 2020 a first IMAP marine survey was conducted by an Albanian-Italian team within the GEF Adriatic Project. During field phase, IMAP Ecological Objectives (EO) were investigated and environmental data were collected to comply all relevant Common Indicators (CI) requested. 8 sampling stations, distributed along 3 transects, have been monitored, in order to assess the GES of the area and identify the main threats. Modern oceanographic equipment were used. Scientific Divers and video-reporters were involved to realize both bionomic underwater LIT transects, both photo-video documentation and innovative 360 VR tour, as a new tool for scientific dissemination. Data has been entered into IMAP InfoSystem and presented in GIS-based maps. This IMAP survey provided relevant scientific informations about CI: EO1, EO2, EO5, EO7, EO9, EO10 and provided preliminary data for Fisheries in Albania.

Key-words: IMAP marine survey, Ecological Objective (EO), Common Indicator (CI), SSS-SBES, Scientific Divers

Introduction

GEF Adriatic project aims to support MSP throughout the Adriatic region as a tool for sustainable development. It's among the first initiative of its kind, embedding national IMAPs developed within the Barcelona Convention (BC) into MSP to achieve GES of the Mediterranean Sea (Bianchi & Morri, 2000). This project has implemented in Albania by UNEP/MAP, PAP/RAC, SPA/RAC with NAPA and Albanian Ministry of Tourism and Environment. The surveyed area of Patok-Rodoni Bay is known for its relevant biodiversity and protected areas, but it's impacted by human activities and appears strongly influenced by water exchanges with Patok Lagoon, Ishmi and Mati rivers. This study focused in particular on CIs of IMAP EOs related to: biodiversity, hydrology, eutrophication, contaminants and marine litter.

Materials and methods

All sampling activities performed were aligned with IMAP (UNEP/MAP, 2016) methodology as agreed by the Contracting Parties to the BC. During field phase, IMAP EOs (EO1, EO2, EO5, EO7, EO9, EO10) were investigated and environmental data were collected to comply with all relevant CIs requested. 8 sampling stations, distributed along 3 transects (off-shore, Patok bay, Lalzit bay) have been monitored, in order to assess the GES of the area and identify the main threats (Deudero & Alomar, 2015). Modern oceanographic equipment were used. Scientific divers and video-reporters realized both bionomic underwater LIT transects, both photo-video documentation and innovative 360 Interactive Virtual Tour, as new media tool for scientific dissemination process.

Results

Final results have been presented into many products: 1 Final Report, 20 Annex Files, 1 Executive Summary, 1 On the Job Training, 1 complete GIS based maps, 1 Monitoring Database on IMAP Info System, 1 UHD photo reportage, 5 4k videos from ROV and dives, 5 mins short promo clip, 25 mins video-documentary and 1 Interactive Virtual Tour. A complete echo-mosaic from SSS-SBES, ROV and Scientific Dives surveys of the whole Patok-Rodoni Bay has been produced. Thanks to these new bionomic maps some interesting coralligenous assemblages have been identified both in the center of the bay, both along the deepest bathymetrics over the cape towards off-shore Sea.

Discussion

Results and recommendations will be useful to assess the levels of pressure on the environment and identify the most fragile areas of Patok-Rodoni Bay, to finally affine the Albanian Integrated Monitoring Programme within the area and propose measures allowing the preservation of marine areas and the development of sustainable economic activities. Results complaint a sedimentation effect on the rare Posidonia meadows (Buia *et al.*, 2003) and a geophysical impact due to various inland anthropogenic activities, contaminants and marine-litter. Final recommendations represent ideas both for planning, both for future management and interventions that, in long term, could guarantee an improvement of the present habitats and marine life: this must be the "first food for thought" aiming at the development or control of socio-economic activities (tourism, fishing, water sports) and environmental protection (marine and coastal protected areas) in Patok Rodoni Bay area, as currently considered by National Authorities.

Acknowledgments

Special thanks goes to: SPA/RAC; NAPA; Albanian Shengjin Port authorities and community of Patok-Rodoni bay who supported project activities.

Bibliography

BIANCHI C.N., MORRI C. (2000) - Marine Biodiversity of the Mediterranean Sea: Situation, Problems and Prospects for Future Research. Marine Pollution Bulle tin 40: 365-376.

BUIA M.C., GAMBI M.C., DAPPIANO M. (2003) - I sistemi a fanerogame marine. In: Gambi M.C., Dappiano M. (Editors). In: Manuale di Metodologie di campionamento e studio del benthos marino mediterraneo. *Biol. Mar. Med*, 19 (Suppl.): 145-198.

DEUDERO S., ALOMAR C. (2015) - Mediterranean marine biodiversity under threat: Reviewing influence of marine litter on species. *Mar. Poll. Bull.*, 98, 1–2: 58-68

UNEP/MAP (2016) Decision IG.22/7 - Integrated Monitoring and Assessment Pro gramme (IMAP) of the Mediterranean Sea and Coast and Related Assessment Criteria. COP19, Athens, Greece. UNEP, Mediterranean Action Plan, Athens.

Simone MODUGNO, PUSTINA I., ZUNA V., DODBIBA E., FICARA S.
IRSSAT, Via del Fornaio, 7, 95033, Biancavilla (CT), Italy
E-mail: info@ilbludelmare.it

RESULTS OF THE LAST 5 YEARS OF WORK FOR THE SCIENTIFIC EVALUATION AND MANAGEMENT OF KARABURUN-SAZAN: THE FIRST MARINE PROTECTED AREA (VLORA BAY, ALBANIA)

Abstract
The "Parku Detar" Karaburun-Sazan was the first Marine Coastal Protected Area (MCPA) in Albania (established in April 28, 2010). Thanks to United Nations Development Programme (UNDP) and Italian Agency for Development Cooperation (AICS Tirana), recent researches have been carried out since 2018 till 2022, performing scientific monitoring plans by International Con- sultant, in order to follow and understand the progress in MCPA's management and the real en- vironmental status. In these last 5 years, many works have been done on Posidonia oceanica mapping, Cystoseira spp. evaluations, water quality analyses, fish stocks study, revealing of monk seal and increasing the protection of sea turtles and marine mammals. The most recent data obtained with these studies have been published in the UNDP Reports, which have under- lined not only the great environmental value of the AMP, but have also demonstrated the effecti- ve good management developing since 2009 by National Agency of Protected Areas (NAPA) and RAPA of Vlora, with UNDP support. The data were used for the total production of a BIO-GIS Master Plan and an Atlas of updated thematic maps.

Key-words: Albania, MCPA, UNDP, AICS, Bio-GIS-Master-Plan, 3D model.

Introduction
The "Parku Detar" Karaburun-Sazan, the first and up today the only one Marine Coastal Protected Area (MCPA) in Albania, occupies a surface of about 12,428 ha and a length of about 16 km (Rajkovic & Kromidha, 2015). The MCPA presents a high biodiversity level and can be described as a living wonder of Albanian's nature. Karaburun-Sazan MPCA was established on April 28, 2010 in Vlora County, in southwestern Albania. As regards the natural values, the MCPA became the main attraction for elite tourism in Al- banian country since 2010 (Beqiraj *et al.*, 2010). In order to study and better manage the AMP, scientific surveys have been carried out since 2018 thanks to UNDP and NAPA, supported initially by GEF and then by AICS.

Materials and methods
The environmental monitoring activities were carried out according to the indications borrowed from the EU Marine Strategy Framework Directive 2008/56/EC, (MSFD) and the International Protocols of Underwater Scientific Researcher (ESDP, European Scientific Diving Panel). In the last 5 years of work on MCPA, International Consultants and Marine Biologists realized researches and surveys on: seagrass assessment and state of meadows; evaluation of benthic assemblages on sandy and rocky shores; chemical-physical analysis along sea water column on fixed sampling stations; updating of CAR-LIT index; fish stocks evaluation; Mediterranean Monk Seals and Marine Turtles sightings and rescues. Monitoring protocols have been implemented, in order to follow

and understand the progress in MCPA's management and the real environmental status, also demonstrating the effective good management by NAPA and RAPA of Vlore.

Results

All data have been published in 10 UNDP Reports and a serie of Annex Reports and Follow Up. An overall publication of the whole UNDP scientific research effort, presenting all the data obtained till now since 5 years is in progress, as a monograph and activity manual that will be provided to Vlore University. A Bio-GIS-Master-Plan system was recently created, both on paper and digital, for the visualization of all results reached and mapped: - chemical-physical seawater monitoring campaigns; - visual census and bionomic benthic mapping of the various seabed assemblages; - preliminary evaluation of Posidonia oceanica status; - the implementation of the CARLIT Index (2007); - a continuous monitoring of sea temperature (data from 0 to -30 m) with waterproof autonomous data-loggers (10 stations); - a production of some 3D models of underwater wrecks and some video-documentaries of the underwater world and an Interactive Virtual Tour of the entire Vlora bay, in order to promote and enhance the naturalistic and underwater heritage.

Discussion and/or conclusions

The MAP of Karaburun-Sazan has become a natural laboratory that is making it possi- ble to set up international environmental research activities in Albania: it represents a marine park where UNDP and Universities are increasingly deepening, thanks to the support of Consultants, the knowledge on the ecology of the Albanian sea.

Acknowledgments

Thanks to AICS Tirana for the economic support and the great UNDP logistic work with NAPA and the Albanian Ministry of Tourism and Environment.

Bibliography

BEQIRAJ S., ZUNA V., DODBIBA E. (2010) - Plani Prioritar i Veprimit për ZMD “Sa- zan-Karaburun”. GEF/UNDP. Tiranë, 74 faqe.

RAJKOVIC Z., KROMIDHA G. (2015) - Management plan for National Marine Park Karaburun-Sazan. UNDP, 100 PP. + ANNEXES.

Carlos NAVARRO-BARRANCO, MOREIRA J., ESPINOSA F., ROS M., RALLIS I., GUERRA-GARCÍA J.M.
Laboratorio de Biología Marina, Departamento de Zoología, Universidad de Sevilla, Sevilla, Spain.
Email: carlosnavarro@us.es

MOBILE EPIFAUNA ON CORALLIGENOUS: BIODIVERSITY ASSESSMENT AND RESPONSE TO MACROALGAL INVASIONS

Abstract
The high abundance and heterogeneity of calcareous builders on coralligenous outcrops determine the development of highly diversified and structured benthic communities. The present study provides a complete assessment of the mobile macroinvertebrate epifauna associated to four dominant sessile hosts inhabiting coralligenous outcrops at the Strait of Gibraltar: Paramuricea clavata, Spongia lamella, Sphaerococcus coronopifolius and Rugulopteryx okamurae, the latter being a recent invasive macroalga. Four replicates of each sessile host were collected at three different study areas in order to evaluate the influence of host identity as well as the spatial heterogeneity of epifaunal assemblages. Overall, 135 different taxa were found along the whole study. Amphipoda was the dominant group in terms of abundance on all sessile substrates, except for the gorgonian (dominated by the polychaete Haplosyllis chamaeleon). Generalist species with a widespread distribution were dominant on macroalgal hosts (specially on the invasive substrate), while invertebrate hosts showed a high percentage of exclusive taxa and higher spatial heterogeneity on their associated communities. Thus, the spreading of R. okamurae would likely result in a significant loss of epifaunal biodiversity, as well as a taxonomical and functional homogenization of the epifaunal community.

Keywords: Marine invertebrates, Arthropoda, Biological invasions, Strait of Gibraltar.

Introduction
Despite being one of the most important Mediterranean marine habitat in terms of biodiversity and productivity (Ballesteros, 2006), little is known about the small vagile fauna inhabiting the coralligenous (Casellato & Stefanon, 2008). However, mobile epifauna often play a key ecological role in the functioning of benthic habitats (Taylor, 1998). Thus, complete quantitative studies addressing the biodiversity and ecological patterns (e.g. spatial distribution, response to disturbances) of coralligenous epifauna are required to obtain a comprehensive understanding of such ecosystems.

Material and methods
Four dominant sessile hosts inhabiting coralligenous outcrops at the Strait of Gibraltar were considered: the gorgonian *Paramuricea clavata*, the sponge *Spongia lamella*, the native macroalga *Sphaerococcus coronopifolius* and the invasive one *Rugulopteryx okamurae*. Four replicates of each sessile host were collected at three different study areas along the coast of Ceuta (Spain). Samples were washed over a 0.5mm mesh sieve, sorted into major groups and identified to species level (when possible).

Results
Overall, 135 different taxa were found inhabiting the four sessile species considered. Arthropoda was the dominant phylum in terms of abundance on all sessile substrates,

except for the gorgonian (dominated by the polychaete *Haplosyllis chamaeleon*). Amphipoda was the most abundant and diverse arthropod taxon, followed by copepods, isopods, and pycnogonids. Mollusca, represented by 11 and 30 species of bivalves and gastropods respectively, were especially abundant on the two sampled macroalgae. Macroalgal species were dominated by generalist detritivorous species that can inhabit different hosts, while specialized interactions between mobile epifauna and sessile hosts were observed almost exclusively on sessile invertebrates. Higher spatial heterogeneity was also observed on epifaunal assemblages associated to sessile invertebrates in comparison to macroalgal hosts.

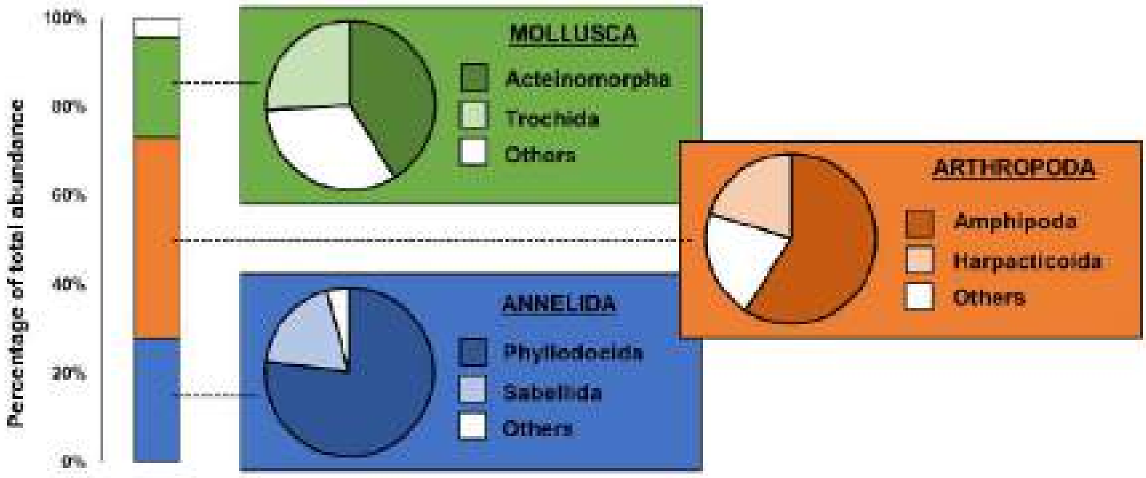


Fig.1: Percentage of abundance of major taxa along the whole study.

Discussion and conclusions

The present study provides evidence about the major contribution of mobile epifauna to the overall biodiversity on coralligenous outcrops, as well as the relevance of such habitats as biodiversity hotspots. Considering the aforementioned differences among sessile hosts in their epifaunal composition, it is expected that the spreading of *R. okamurae* would likely result in a significant loss of epifaunal biodiversity, as well as a taxonomical and functional homogenization of the epifaunal community. Further studies should address the magnitude and direction of the cascading effects of those changes on higher trophic levels.

Acknowledgments

The present study was funded by *“Instituto de Estudios Ceutíes: Ayudas a la Investigación 2018”.* Authors are really grateful to Enrique Ostalé and Juan Sempere and other colleagues at the “*Estación de Biología Marina del Estrecho”* (University of Seville) for their collaboration along the fieldwork.

Bibliography

BALLESTEROS E. (2006) - Mediterranean coralligenous assemblages: A synthesis of present knowledge. *Oceanogr. Mar. Biol. Ann. Rev.,* 44: 123-195.

CASELLATO S., STEFANON A. (2008) - Coralligenous habitat in the northern Adriatic Sea: an overview. *Mar. ecol.*, 29(3): 321-341.

TAYLOR R. B. (1998) - Density, biomass and productivity of animals in four subtidal rocky reef habitats: the importance of small mobile invertebrates. *Mar. Ecol. Progr. Ser.*, 172: 37-51.

Víctor ORENES-SALAZAR, NAVARRO-MARTÍNEZ P. C., RUÍZ JM., GARCÍA-CHARTON J.A
Department of Ecology and Hydrology, University of Murcia, Campus Espinardo, 30100, Murcia, Spain
E-mail: victor.orenes@um.es

CUMULATIVE EFFECTS OF MARINE HEAT WAVES ON *EUNICELLA SINGULARIS* IN A MEDITERRANEAN MARINE PROTECTED AREA

Abstract
As part of a long-term monitoring program, the populations of the white gorgonian (Eunicella singularis, Esper, 1791) (Cnidaria, Octocorallia, Gorgoniidae) are being surveyed yearly in the Cabo de Palos – Islas Hormigas marine reserve (SE Spain, SW Mediterranean) since 2005. The sampling protocol includes recording colonies density, sizes, and affection by necrosis in four sites within the marine reserve. In addition, water temperature was continuously recorded from April 2007 at two depths (25 and 35 m). Our results show that two mass mortality events occurred in 2007 and 2018, coinciding with temperature anomalies, with the second mortality event being more intense than the first. These documented mortalities add to the evidence which points to abnormal water warming as the main cause of gorgonian mortality outbreaks in the Mediterranean in recent decades.

Key-words: Mass Mortality Event, *Eunicella singularis*, Marine Heat Wave, Marine Protected Area, Climate Change

Introduction
In the last decades, several episodes of mass-mortality (MME) of sessile epibenthic invertebrates have been recorded in the Western Mediterranean Sea, especially for gorgonians populations. The increase in frequency, intensity, and depth of thermal anomalies in these habitats is alarming. The acquisition of time series on the health status of these animals is crucial to better characterize and understand current shifts in their environmental conditions at larger spatial scales. Since 2005, Cabo de Palos – Islas Hormigas MPA (Murcia, Spain) is subject of a multidisciplinary scientific monitoring program where the white gorgonian (*Eunicella singularis*) is annually surveyed to assess its conservation status and to determine the thermal conditions prevailing in those years, so that observed MMEs and thermal anomalies can be linked.

Materials and methods
Between October and November of each year since 2005 (with exceptions due to financial cuts), at each of four randomly chosen sites, 8 1-m^2 quadrats were randomly set on gorgonian beds between 20 to 35 m depth. In each quadrat, all colonies were measured and the percentage of necrotic tissue (i.e., denuded axis and/or overgrowth by other organisms) was quantified in the range of 0-100% at 5% intervals. Two variables were calculated: (1) the damage extent, i.e., percentage of denuded axis or epibiosis per colony, and (2) the incidence level, or the percentage of affected colonies, i.e., showing tissue necrosis over >5% of its surface. Temperature records were taken by *in situ* HOBO Water Temp Pro autonomous sensors set up within the MPA at intermediate-

and infra- thermoclinal levels (25 and 35 m depth, respectively). To determine the thermal conditions prevailing in those years associated with MMEs, we applied a hierarchical methodology for the detection and characterization of marine heatwaves and cold spells (MHW-MCS) following Hobday *et al*. (2016).

Results

Population incidence varied significantly with time, peaking in 2007 (57.8 ± 3.9%; mean ± se) and 2018 (69.4 ± 2.0%), these values contrasting with respect to the 5.6% incidence level measured during the 2005-2006 reference period. Damage extension per colony showed sound differences associated with different years along the study period (Fig. 1). Exceptionally high values were detected in 2018 (38.3 ± 1.7%) and 2007 (12.5 ± 1.6%). This caused the populations to show an increasing degree of necrosis and a cumulative impact over time.

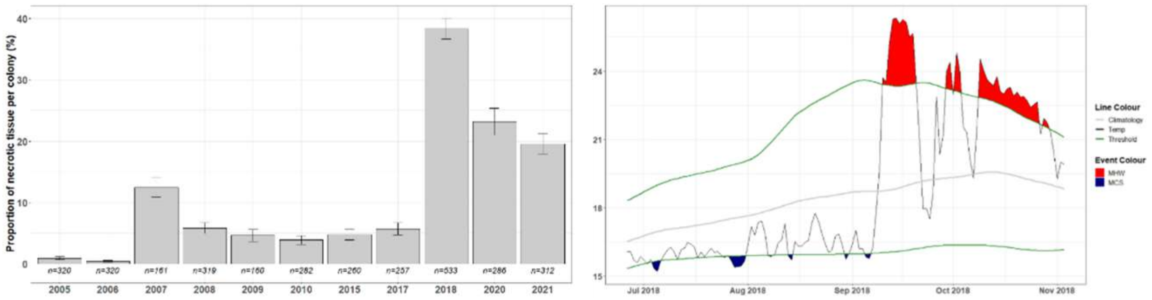


Fig. 1: Population damage extent (left) and detected MHW and MCS in 2018 at 35 m depth (right) of Cabo de Palos – Islas Hormigas MPA white gorgonian population since 2005 to the present

Different thermocline dynamics led to distinctive temperature profiles in 2007 and 2018. MHWs were detected for both years at 35 m depth. In 2007, the event lasted 11 days and temperature reached above 25.5 °C the 24th of August. In 2018, a 5-day MCS followed by multiple proto-events were detected during summer months, which caused a pronounced thermal shock when temperature exceeded 26 °C for 5 consecutive days in early September. Also, temperature remained above 22 °C until late October.

Conclusions

The results presented above suggest that the 2007 and 2018 MMEs were between the largest, in terms of intensity, ever recorded in the Mediterranean Sea. Furthermore, the sudden onset and concomitance with sea water extreme temperature anomalies further a meteorological cause whose origin remains uncertain but probably related to an anomalous thermocline derived from unusual wind patterns.

Bibliography

HOBDAY A.J., ALEXANDER L.V., PERKINS S.E., SMALE D., STRAUB S., OLIVER E. C. J., BENTHUYSEN J. A., BURROWS M. T., DONAT M. G., FENG M., HOLBROOK N. J., MOORE P. J., SCANNELL H. A., SEN GUPTA A., & WERNBERG T (2016) - A hierarchical approach to defining marine heatwaves. *Progress in Oceanography*, 141: 227-238.

Camilla ROVETA, BIERWIRTH J., CALCINAI B., COPPARI M., DI CAMILLO C.G., PULIDO MANTAS T., VILLECHANOUX J., CERRANO C.
Department of Life and Environmental Sciences, Polytechnic University of Marche, Italy
E-mail: c.roveta@staff.univpm.it

MITIGATION STRATEGIES OF THE RED CORAL *CORALLIUM RUBRUM* (LINNAEUS, 1758) TO FACE CLIMATE WARMING

Abstract
Modular colonial organisms can respond to environmental factors through phenotypic plasticity, but, when environmental changes occur abruptly, the adaptive capabilities can be limited, leading to mass mortality events. Moreover, following the temperature-size rule, a decrease in body size was proposed as a common response to climate warming. With this study, we present changes in colony density and size of different population of Corallium rubrum (Cnidaria:Anthozoa) from various Italian locations. Pictures were taken few years apart, showing a significant reduction in colony size (-13% ÷ -73%), number of ramifications (-12% ÷ -92%), and population density (-7% ÷ -21%), in all the surveyed sites. These observations show that the colony size can get strongly affected after thermal anomalies, suggesting autotomy as a possible mitigation strategy against the climate warming.

Key-words: precious coral, animal forest, Mediterranean Sea, climate change, mesophotic

Introduction
Modular colonial organisms can present a high phenotypic plasticity, considered the major response to abiotic and biotic factors variability (Verberk *et al.*, 2021). When environmental parameters suddenly change, the adaptive capabilities can be limited, especially in the aquatic system, leading to frequent mass mortalities (Garrabou *et al.*, 2019). Following the temperature-size rule, a decrease in body size has been proposed as one of the most recurrent responses of organisms to climate warming (Verberk *et al.*, 2021). In this context, we present herein changes in colony density and size of different population of the precious red coral *Corallium rubrum* from various Italian locations, suggesting resizing as a possible mitigation strategy against rising temperatures.

Materials and methods
Photographic surveys were conducted at the Gallinara Island (Ligurian Sea), Portofino Marine Protected Area (MPA, Ligurian Sea) and Porto Ercole (Tyrrhenian Sea), at 25, 30 and 18 m depth, respectively. Pictures were taken few years apart, and changes in population density, colony size and number of ramifications were evaluated.

Results
The red coral populations from both Portofino MPA and Porto Ercole showed an evident reduction in colony size (from -13% to -73%) and number of ramifications (from -12% to -92%), and a decrease in population density (from -7% to -21%) (Fig. 1). At the Gallinara Island, we focussed on single transplanted colonies. During years, colonies were healthy and vital, but as observed in the other locations, they displayed a marked reduction in size and suffered the loss of many ramifications (Fig. 2).

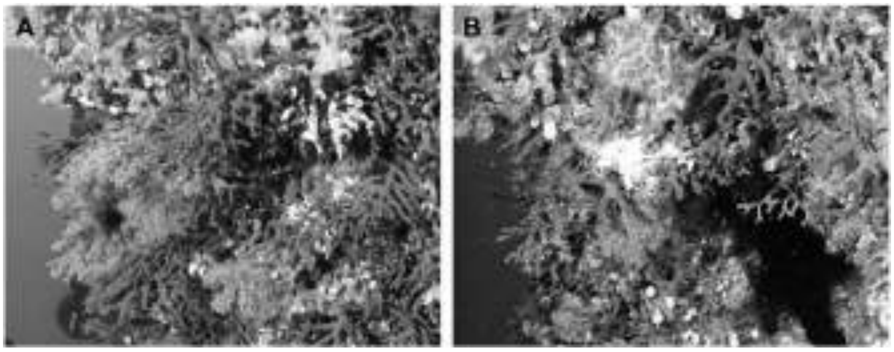


Fig. 1: Red coral population from the Portofino MPA in 2011 (A) and 2021 (B).

Fig. 2: A transplanted red coral colony at the Gallinara Island in July 2017 (A), August 2018 (B) and September 2021 (C). The white arrows indicate the loss of ramifications.

Discussion and conclusions

The results of this study highlight that, even though coral densities do not suffer a high reduction in term of number of total colonies, the colony size can get strongly affected after thermal anomalies. Under laboratory conditions, changes in temperature and salinity were found to induce fragmentation of the red coral branches through autotomy, a phenomenon considered as an asexual reproductive strategy, ensuring population survival (Russo, 1995). Our observations have never documented the settlement of the dropping portions, suggesting that *C. rubrum* can use autotomy as a possible mitigation strategy against the rising temperatures and the climate warming, showing an unexpected resilience through phenotypic plasticity.

Acknowledgments

Part of this research was supported by the Polytechnic University of Marche (Ricerca Scientifica di Ateneo – MESOMED project). Authors are thankful to Simone Nicolini of Argentario Divers and Bruno Borelli of Portofino Divers for the photographic surveys.

Bibliography

GARRABOU, J., GÓMEZ-GRAS, D., LEDOUX, J.-B., LINARES, C., BENSOUSSAN, N., LÓPEZ-SENDINO, P., BAZAIRI, H., ESPINOSA, F., RAMDANI, M., GRIMES, S., BENABDI, M., SOUISSI, J. B., SOUFI, E., KHAMASSI, F., GHANEM, R., OCAÑA, O., RAMOS-ESPLÀ, A., IZQUIERDO, A., PERGENT-MARTINI, C., ROUANET, E., TEIXIDÓ, N., GATTUSO, J.-P., GEROVASILEIOU, V., SINI, M., BAKRAN-PETRICIOLI, T., KIPSON, S. & HARMELIN, J. G. 2019. Collaborative Database to Track Mass Mortality Events in the Mediterranean Sea. *Front. Mar. Sci.*, 6, 707.

RUSSO G.F. (1995) - Autotomy and induced fragmentation in the red coral (*Corallium rubrum* L.). *Rapp. Comm. Int. Mer. Medit*., 34: 42.

VERBERK W.C., ATKINSON D., HOEFNAGEL K.N., HIRST AG., HORNE C.R., SIEPEL H. (2021) - Shrinking body sizes in response to warming: explanations for the temperature–size rule with special emphasis on the role of oxygen. *Biol. Rev.*, 96(1): 247-268.

Maria SALOMIDI, ISSARIS Y., DAILIANIS T., GERAKARIS V., GEROVASILEIOU V.
Institute of Oceanography, Hellenic Centre for Marine Research (HCMR), 19013 Anavyssos, Greece
Email: msal@hcmr.gr

FIRST *IN SITU* ASSESSMENT OF RED CORAL (*CORALLIUM RUBRUM*, L.) POPULATIONS IN THE AEGEAN SEA, EASTERN MEDITERRANEAN

Abstract
Despite its long-known presence and exploitation, only undetailed fisheries-dependent data and scarce, outdated scientific information exist for the precious red coral (Corallium rubrum L. 1758) in the Greek Seas and the wider Eastern Mediterranean. An ad hoc field survey was conducted in the NW Aegean Sea initially based on occurrence information provided by former coral fishers. Exploratory ROV surveys at the indicated positions extending over a depth range of 40 to 70 m, revealed sparse to dense patches of C. rubrum at depths between 47 and 64 m. Red coral typically colonized steep vertical coralligenous walls, overhangs, caverns or caves, and formed monospecific or mixed facies with larger cnidarians or sponges. Two sites presenting exposed red coral stands along continuous transects of ca. 30 m in length were further investigated at depths between 53 and 57 m by means of SCUBA diving with mixed gases. Diver operated stereo-video recording was performed along transects to acquire data on red coral demographic and morphometric traits.

Key-words: population status, red coral stocks, coralligenous, mesophotic, scientific diving

Introduction
Although an emblematic species since ancient times and still occasionally exploited to this day, populations of the precious red coral *Corallium rubrum* L. 1758 (Octocorallia, Alcyonacea) have received little scientific focus in the Greek Seas. Earlier studies provided rough information on the presence and morphometry of few colonies in the North Aegean and Cretan Seas (Chintiroglou *et al*., 1989), but *in situ* population assessments of living stocks still remain challenging due to the typically deep distribution of the species in the Eastern Mediterranean (Dounas *et al.*, 2011). In the frame of the "GFCM Research Programme on Mediterranean Red Coral" aiming to improve knowledge on *C. rubrum* distribution, population structure, ecology and genetics in harvested coral banks, an *ad hoc* deep diving survey was designed and implemented to gain insight on essential demographic, morphometric and ecological traits.

Materials and methods
A field survey was conducted in the NW Aegean Sea in March 2022, initially based on occurrence information provided by former coral fishers. Exploratory ROV surveys were performed at the indicated positions to locate extended red coral patches within suitable operational depths (~ 50 - 60 m). Deep SCUBA diving with mixed gases was performed in two sites; diver operated stereo-video recording using a custom-built stereo-camera system was performed along 30 m continuous transects at a standard depth of 55 - 57 m. Based on the stereo-video footage, red coral colonies' height, width and basal diameter

were estimated (accuracy: ± 0.5 mm) using the VidSync software, whereas red coral densities were estimated based on coral counts within virtual quadrats (0.5 x 0.5 m surface area) captioned from 30 systematically random stereo-video frames.

Results

ROV dives over a depth range of 40 to 70 m revealed three areas holding sparse to dense populations of *C. rubrum*. Red coral typically colonized steep vertical coralligenous walls, overhangs, caverns or caves at depths between 47 and 64 m, forming either monospecific or mixed facies with other cnidarians or sponges. Associated macrofauna varied per site, but *Axinella* spp., *Agelas oroides*, *Leptopsammia pruvoti*, *Parazoanthus axinellae* and *Ostrea* sp. were persistently common across surveyed locations. Ghost fishlines and nets were frequent, at places smothering reefs and biota. Mean *C. rubrum* density at site A was 13.5 ± 2.8 (mean ± SE) ind./m^2. Colonies' basal diameter ranged between 5.6 - 18.5 mm, with a mean value of 9.7 ± 0.6 (mean ± SE) mm; their colony height ranged between 29.2 - 124.0 mm, with a mean value of 68.9 ± 5.2 (mean ± SE) mm. Site B presented higher density, i.e. 114.7 ± 17.5 (mean ± SE) ind./m^2. Colonies' basal diameter ranged between 5.3 - 20.0 mm, with a mean value of 10.4 ± 0.4 (mean ± SE) mm; colony height ranged between 35.6 - 337.0 mm, with a mean value of 87.7 ± 6.8 (mean ± SE) mm.

Discussion and conclusions

Although not directly comparable due to variations in depth and applied methodologies, red coral density, height and basal diameter values detected herein fall within ranges reported from the NW basin for populations shallower than 60 m, many of which in protected areas (Mallo *et al.,* 2019). Despite the high accuracy of size estimations from stereo-video analysis, the population structure parameters measured herein (colony height and basal diameter) should be considered biased high, since smaller colonies (<30 mm in height) growing within cracks and crevices were hardly conspicuous in the video footage and therefore excluded from the analysis. Although poaching events cannot be entirely ruled out, our study areas have not been officially open to coral harvesters since at least 1997, a fact that may account for the numerous large colonies particularly characterizing one of our study sites. This effort constitutes an important first step towards the assessment of the population status of this endangered species in the Eastern Mediterranean Sea. More extensive surveys are however needed to understand wider patterns and trends in this scarcely studied basin.

Bibliography

CHINTIROGLOU C., DOUNAS C., KOUKOURAS A. (1989) - The presence of *Corallium rubrum* (Linnaeus, 1758) in the eastern Mediterranean Sea. *Mitt. Zool. Mus. Berl*., 65: 145-149.

DOUNAS C., KOUTSOUBAS D., SALOMIDI M., KOULOURI P., GEROVASSILEIOU V., SINI M. (2011) - Distribution and Fisheries of the red coral *Corallium rubrum* (Linnaeus, 1758) in the Greek Seas: an overview. *In:* Bussoletti E., Cottingham D., Bruckner A., Roberts G., Sandulli R. (Eds), NOAA Technical Memorandum CRCP-13: 106-114.

MALLO M., ZIVERI P., REYES-GARCIAV., ROSSI S. (2019) - Historical record of *Corallium rubrum* and its changing carbon sequestration capacity: A meta-analysis from the North Western Mediterranean. *PLoS ONE*, 14: e0223802.

NEUSWANGER, JASON R., WIPFLI, MARK S., ROSENBERGER, AMANDA E., HUGHES N. F., 2016. Measuring fish and their physical habitats: Versatile 2-D and 3-D video techniques with user-friendly software. *Can. J. Fish. Aquat. Sci.* 73(12): 1861-1873.

Cansu SARAÇOĞLU, BARRAUD, T., AKYÜZ, O.U., DEĞİRMEN, B., TOPÇU N.E.
İstanbul University, Faculty of Aquatic Sciences, Department of Marine and Freshwater Resources Management, Vezneciler, Fatih/İstanbul Turkey
E-mail: cnssaracoglu@gmail.com

SHARP DECREASE OF ALCYONARIAN ASSEMBLAGES FOLLOWING A SEVERE MUCILAGE EVENT IN NORTHEASTERN SEA OF MARMARA

Abstract

Alcyonarians known as soft corals and gorgonians are important organisms that play key roles as reef-forming assemblages and contribute to the complexity and biodiversity in the marine ecosystems. In northeastern Sea of Marmara, alcyonarians are among the most abundant organisms on all types of substrates. However, they were affected by severe mass mortalities that took place following excessive sedimentation due to coastal constructions and land filling activities in 2015-2016. Soft corals such as Alcyonium palmatum and A. acaule have almost disappeared and Paralcyonium spinulosum has highly diminished in the area while gorgonians, particularly Paramuricea macrospina, Spinimuricea klavereni and Eunicella cavolini have started to show some recovery signs as from 2018, after significant decreases. Unfortunately, in 2021 – 2022, winter-early spring period, a massive, basin-wide mucilage event took place in the Sea of Marmara. All types of aggregates were observed in the water column and progressively, they covered sea bottom and benthic organisms. In order to determine the impact of the mucilage on alcyonarians, nine stations previously studied for species abundance in 2013 and then in 2016, were monitored in November 2021, two months after mucilaginous aggregates have disappeared from sea bottom, by using same methods, e.g. transect and quadrats. Alcyonium spp. were almost completely absent in the area while P. spinulosum was even more diminished than in 2016. In sum, the number of soft coral colonies have diminished by 92% in 2016 compared to 2013 and by 77% after the mucilage event. Paramuricea spp. were the most impacted gorgonians while E. cavolini has better coped with mucilaginous aggregates. The number of gorgonian colonies has dropped by 66 % in 2016 and another drop by 19 % was recorded after the mucilage. The situation is clearly alarming, urgent actions are required to stop the impacts and give place to recovery.

Key-words: Benthos, Mucilaginous, Princes Islands, Sea snot, Alcyonaria

Introduction

The Sea of Marmara, due to its peculiar oceanographic conditions and high nutrient availability, enhances the occurrence of Mediterranean mesophotic-like communities, around Prince Islands, at exceptionally shallow depths, around 25-40 m. Soft corals are common on several types of substrates and *Paramuricea macrospina* (von Koch, 1882) is one of the most common alcyonarians in the region along with *Paralcyonium spinulosum* (Delle Chiaje, 1822), *Paramuricea clavata* (Risso, 1827), *Spinimuricea klavereni* (Carpine & Grasshoff, 1975) and *Eunicella cavolini* (Koch, 1887) (Topçu and Öztürk 2015). In autumn 2020, a massive, basin-wide mucilage was recorded in the Sea of Marmara and lasted until June 2021 covering a large area on the sea surface (Savun-Hekimoğlu and Gazioğlu 2021). The aim of this study was to reveal the impact of the mucilage outbreak on common soft corals and gorgonians in Prince Islands.

Materials and methods

Nine stations were surveyed within the Prince Islands region in November 2021 (in accordance with previous studies (Topçu and Öztürk, 2015; Topçu *et al*., 2019). Sampling was carried out by SCUBA diving by transect and quadrat techniques depending on substrate inclination.

Results

Two months after mucilaginous aggregates had disappeared from the bottom, *Alcyonium* spp. were almost completely absent in the area while *P. spinulosum* was even more diminished than in 2016. In sum, the number of soft coral colonies have diminished by 92% in 2016 compared to 2013 and by 77% after the mucilage event. Among gorgonians, *Paramuricea* spp. were the most impacted ones while *E. cavolini* has better coped with mucilaginous aggregates. The number of gorgonian colonies has dropped by 66 % in 2016 and another drop by 19 % was recorded after the mucilage (Figure 1).

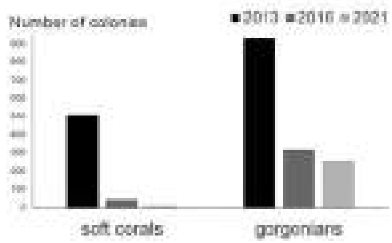


Fig. 1: Number of healthy colonies of soft corals (without axis) and gorgonians counted in 20 m^2 transects at 9 stations (Prince Islands) in 2013, 2016 and 2021.

Conclusions

Our findings underline that *P. macrospina* is critically diminished in the region and even the regional extinction of this species should be evaluated for the Sea of Marmara. Along with recent measures taken by the according ministries in response to the mucilage, a recovery period for the Sea of Marmara is expected. This could be followed by a recovery of soft corals and gorgonians, although some species with slow dynamics might require tens of years to fully recover (Montero-Serra *et al*., 2018).

Acknowledgments

This study was financially supported by TUBITAK (grant no 121G015).

Bibliography

MONTERO-SERRA, I., GARRABOU, J., DOAK, D. F., FIGUEROLA, L., HEREU, B., LEDOUX, J.-B., LİNARES, C. (2018) - Accounting for Life-History Strategies and Timescales in Marine Restoration. *Conservation Letters*, 11(1), e12341.

SAVUN-HEKİMOĞLU, B., GAZİOĞLU, C. (2021) - Mucilage problem in the semi-enclosed seas: recent outbreak in the Sea of Marmara. *International Journal of Environment and Geoinformatics*, 8(4), 402-413.

TOPÇU, E. N., ÖZTÜRK, B. (2015) - Composition and abundance of octocorals in the Sea of Marmara, where the Mediterranean meets the Black Sea. *Scientia Marina*, 79(1), 125-135.

TOPÇU, N. E., TURGAY E., YARDIMCI, R. E., TOPALOĞLU, B., YÜKSEK, A., STEINUM, T. M., KARATAŞ, S., ÖZTÜRK, B. (2019) - Impact of excessive sedimentation caused by anthropogenic activities on benthic suspension feeders in the Sea of Marmara. *Journal of the Marine Biological Association of the United Kingdom*, 99(5), 1075-1086. doi:10.1017/S0025315418001066

Juan SEMPERE-VALVERDE, BAZAIRI H., OSTALÉ-VALRIBERAS E., GONZÁLEZ ARANDA A.R., ESPINOSA, F.
Laboratorio de Biología Marina de la Universidad de Sevilla (LBMUS)/Estación de Biología Marina del Estrecho (Ceuta), Departamento de Zoología, Facultad de Biología de la Universidad de Sevilla, Av. de la Reina Mercedes, 41012 Sevilla, Spain.
E-mail: jsvalverde@us.es

INTEGRATION OF AL-HOCEIMA NATIONAL PARK (MOROCCO) INTO THE SESSILE BIOINDICATORS PERMANENT QUADRATS MONITORING NETWORK OF THE ALBORAN SEA

Abstract
The Alboran Sea is a marine biodiversity hotspot inhabited by endemic species and species from the Mediterranean and Atlantic biogeographical regions. In this sea, the coralligenous habitat occur under the dim-light conditions of vertical walls and overhangs, usually below 15 m depth. In 2019, eight locations were prospected in Al-Hoceima National Park (Al-Hoceima, Morocco) and nine Sessile Bioindicators Permanent Quadrats (SBPQ) were installed in three sites to begin monitoring the coralligenous habitat. In the west of the park, the coralligenous occur at less than 15 m depth and, although the recorded richness is a small fraction of the biodiversity of the park, 13 threatened or protected species were found during the surveys and installation of the SBPQ, with six being present inside the monitoring areas. Furthermore, several threats were identified: gorgonians and corals detached and found on sandy bottoms or discarded from fishing gear, ghost fishing lines tangled with several coralligenous species, and a sewage outfall that increased organic pollution in the eastern areas of the park. These impacts encourage the promotion of administrative initiatives and actions to protect these rich Mediterranean habitats. To conclude, the installation and follow-up of monitoring programs such as SBPQ constitute potent tools to quantify the ecosystem dynamics and assess biodiversity loss after punctual, periodic, and continuous impacts at the local and regional scales through a network of monitoring stations.

Key-words: Biodiversity, bioindicators, coralligenous, monitoring, marine protected areas

Introduction
Long-term monitoring can increase our knowledge in ecosystem dynamics and contribute to the identification and quantification of anthropogenic impacts (UNEP/MAP, 2016). These programs can provide data before and after the alteration and generate information for a better quantification of socioecological impacts (Sukhotin & Berger, 2013).

Materials and methods
In 2019, eight locations were prospected in Al-Hoceima National Park (Al-Hoceima, Morocco) and nine Sessile Bioindicators Permanent Quadrats (SBPQ) were installed in three sites to begin monitoring the coralligenous habitat in this area (see Fig. 1, A-D).

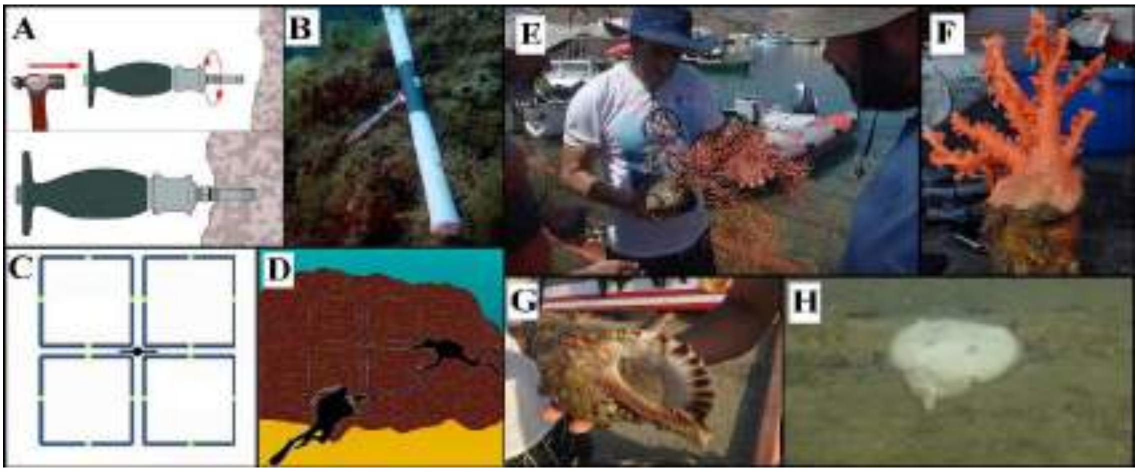


Fig. 1: A- D: Installation of SBPQ and monitoring methodology (see García-Gómez et al., 2020). E-H: fishing impacts on protected and commercially important species in Al-Hoceima National Park.

Results

Thirteen threatened or protected species were found during the surveys, with six being present inside the SBPQ monitoring areas. Several threats were identified: gorgonians, corals and other species detached or discarded from fishing gear (Fig. 1, E- H), ghost fishing lines tangled with coralligenous species, the presence of harmful NIS and a sewage outfall that increased organic pollution in the eastern areas of the park.

Discussion and conclusions

The coralligenous habitat is a biodiversity hotspot and a key contributor of coastal ecosystem services (UNEP/MAP-RAC/SPA, 2008). This habitat is in recession because of mechanical, chemical, and ecological impacts (García-Gómez et al., 2020). Long-term monitoring is key for an effective conservation of this habitat and will provide continuous information on the status of its communities, allowing rapid detection and improved response against impacts, and a more efficient allocation of management resources.

Acknowledgements

This work was conducted within the framework of the MedKeyHabitats II Project (UNEP/MAP-RAC/SPA) in close collaboration with the Département des Eaux et Forêts (DEF) and financially supported by SPA/RAC, Tunisia, and the MAVA Foundation, Switzerland. JSV was supported by a FPI Grant (PRE2018-086266, Project CGL 2017-82739-P) co-financed by ERDF European Union and Agencia Estatal de Investigación, Gobierno de España.

Bibliography

GARCÍA-GÓMEZ J.C., GONZÁLEZ A.R., MAESTRE M.J., ESPINOSA F. (2020) - Detect coastal disturbances and climate change effects in coralligenous community through sentinel stations. *PLoS ONE*, 15: e0231641.

SUKHOTIN A., BERGER V. (2013) - Long-term monitoring studies as a powerful tool in marine ecosystem research. *Hydrobiologia*, 706: 1-9.

UNEP/MAP (2016) - *Integrated Monitoring and Assessment Guidance.* United Nations Environment Programme-Mediterranean Action Pla,. Athens, Greece.

UNEP/MAP-RAC/SPA (2008) - *Action plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea*. RAC/SPA, Tunis: 21 pp.

Marko TERZIN, VILLAMOR A., MARINCICH L., PALETTA M. G., BERTUCCIO V., ABBIATI M., COSTANTINI F.
Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Università di Bologna, Campus Ravenna, Italy.
E-mail:federica.costantini@unibo.it

FINE-SCALE GENETIC STRUCTURING AMONG MEDITERRANEAN *PARAZOANTHUS AXINELLAE* (SCHMIDT, 1862) SPECIES COMPLEX POPULATIONS DISCLOSED BY 2BRAD

Abstract
Two morphotypes of the Mediterranean zoanthid Parazoanthus axinellae (Schmidt, 1862) are found in the Mediterranean Sea: 'Slender' and 'Stocky', which differ in size, color, and substrate preference. We used 2bRAD-Seq to get genome-wide genotyped single nucleotide polymorphisms to study the genetic differentiation between 'Slender' and 'Stocky' morphs, as well as their population structure. 101 specimens of P. axinellae were sampled and genotyped from locations along the Italian coastline. A marked and consistent differentiation between the morphs was observed. The widely distributed 'Slender' morph showed higher population admixture, whereas populations of the 'Stocky' morph, found only in the north-western Mediterranean, showed higher regional genetic partitioning.

Key-words: connectivity, coralligenous assemblages, Zoantharia, population genomics, SNPs

Introduction
Parazoanthus axinellae (Schmidt, 1862) is a widespread coral species in the coralligenous assemblages. In the northwestern Mediterranean, two morphotypes were observed in sympatry: Slender' - with an elongated trunk, longer and thinner tentacles and a light-yellow color; and 'Stocky' - with a shorter, thicker trunk and tentacles, and orange color. Due to marked morphological, ecological, and biochemical differences, the two morphotypes were hypothesized to be two species (Villamor *et al.,* 2020). We used genome-wide genotyping to assess the genetic divergence between the two morphotypes, as well as population connectivity patterns within the morphs.

Materials and methods
Samples from 12 populations were collected by SCUBA diving at eight localities in the Mediterranean Sea (Fig. 1). Total genomic DNA was extracted, and Genome-wide Single Nucleotide Polymorphisms (SNPs) were obtained using the 2bRAD genotyping following Terzin et al. (2021). Raw reads were quality filtered, trimmed and SNPs genotyping was performed in the Stacks v2 software. Population genetic structure analyses were performed between and within morphotypes.

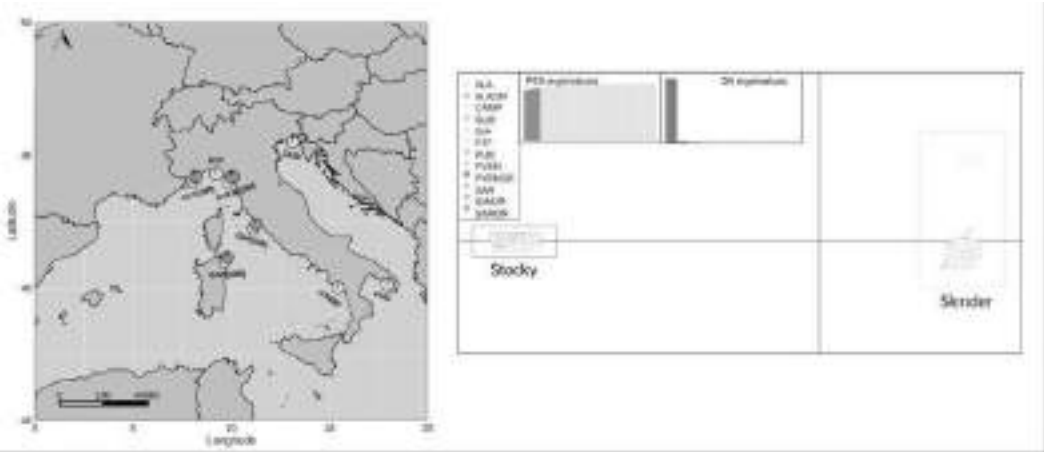


Fig. 1: Left: Map showing the sampling localities within the study. Right: Discriminant Analysis of Principal Components (DAPC) with populations as prior grouping information

Results

Discriminant Analysis of Principal Components (DAPC) showed clear genetic differentiation between 'Slender' and 'Stocky' populations (Figure 1). Moreover, DAPC revealed discrete clusters for each 'Stocky' population, with the Tyrrhenian populations (SAROR + GIAOR) clustering closely together and separate from the Ligurian populations. Stocky populations also displayed a high level of genetic differentiation between populations (pairwise F_{ST} values = 0.27 - 0.31). In contrast, the more widely distributed 'Slender' morphotype did not display an evident pattern of structuring.

Discussion and conclusions

Overall, 'Slender' and 'Stocky' morph clearly diverge in their genomic profiles, and their populations group into two clearly separated clusters. The very strong genetic differentiation provides additional evidence that these morphs are different species, although experimental validation is needed to confirm this hypothesis. Evaluation of the broadly distributed 'Slender' morphotype revealed a high degree of admixture and panmixia among populations. In contrast, the 'Stocky' morphotype displayed much stronger patterns of genetic structure. Our study highlights the importance of resolving phylogenetic and taxonomic disparities within taxonomically problematic groups, like the *P. axinellae* species complex, prior to implementing genetic connectivity data for management and conservation purposes.

Acknowledgments

This study was part of the MIUR projects PRIN 2011 project on "Coastal bio-constructions: structure, function and management" and ''Reef ReseArcH – Resistance and resilience of Adriatic mesophotic biogenic habitats to human and climate change threats''.

Bibliography

VILLAMOR, A., SIGNORINI, L. F., COSTANTINI, F., TERZIN, M., & ABBIATI, M. (2020) – Evidence of genetic isolation between two Mediterranean morphotypes of *Parazoanthus axinellae*. *Sci. Rep.*, 10: 1-11.

TERZIN, M., PALETTA, M. G., MATTERSON, K., COPPARI, M., BAVESTRELLO, G., ABBIATI, M., ... & COSTANTINI, F. (2021) - Population genomic structure of the black coral *Antipathella subpinnata* in Mediterranean Vulnerable Marine Ecosystems. *Coral Reefs 40*: 751-766.

Yanis ZENTNER, MARGARIT N., ROVIRA G., GÓMEZ-GRAS D., GARRABOU J., LINARES C.
Departament de Biologia Evolutiva, Ecologia i Ciències Ambientals, Universitat de Barcelona (UB). Av. Diagonal 643, 08028, Barcelona, Espanya
E-mail: yaniszentner@ub.edu

EXPLORING THE TIMESCALES NEEDED TO RECOVER THE FUNCTIONING OF MEDITERRANEAN CORALLIGENOUS ASSEMBLAGES THROUGH ACTIVE RESTORATION

Abstract
The long-term success of an active restoration of a key Mediterranean octocoral is explored to assess the recovery of ecological functions. A coralligenous assemblage with a restored Corallium rubrum *population was monitored over ten years in the Medes Islands Marine Reserve to quantify the temporal changes in its functional community structure through multi-taxa trait-based analysis. A nearby site with* C. rubrum *was also monitored, to assess the population and community structure of a local native assemblage. The transplanted colonies exhibited a significant growth, followed by a shift of the coralligenous functional identity, mainly caused by an increase on the traits that facilitate the 3D-habitat provisioning. When comparing these results to the natural assemblage, the restored coral population has surpassed the control values in terms of size and biomass of the colonies, while the assemblage functionality is approaching what is observed in the natural population. Our results highlight how a restoration through transplanting adult colonies of key long-lived octocorals bypassing sensitive early life stages can be an effective tool to restore the functionality of this habitat in relatively "short" timescales.*

Key-words: *Corallium rubrum*, functional recovery, active restoration, colony transplantation, coralligenous

Introduction

Active restoration initiatives are being promoted globally to halt and reverse the degradation of marine ecosystems. The main focus has been put on rebuilding coastal systems; by transplanting habitat-forming species with the goal to recover the structural complexity needed to sustain ecosystem functions and services. Traditionally, success for such strategies has been mostly assessed through the short-term survival of restored transplants, which has been criticized to be unsuitable to assess full ecological recovery (Bayraktarov *et al.*, 2016). Here, we explore the long-term success of an active restoration of a key Mediterranean octocoral by combining population and community approaches to assess the recovery of ecological functions.

Material and methods

Ten years after transplantation, we revisit a restored *C. rubrum* coralligenous community to assess the demographic state of the transplanted colonies and to explore the long-term temporal scales needed to achieve recovery of ecological functions. The later was done, by quantifying the temporal changes in its functional structure through multi-taxa trait-based analysis. Moreover, the nearby native red coral assemblage has been parallelly monitored to detect any local trends.

Results

The functional identity for the native *C. rubrum* assemblage presented a stable abundance weighted centroid, while a significant shift was recorded for the restored one (Fig. 1). This shift can be attributed mainly on the traits that facilitate the 3D-habitat provisioning.

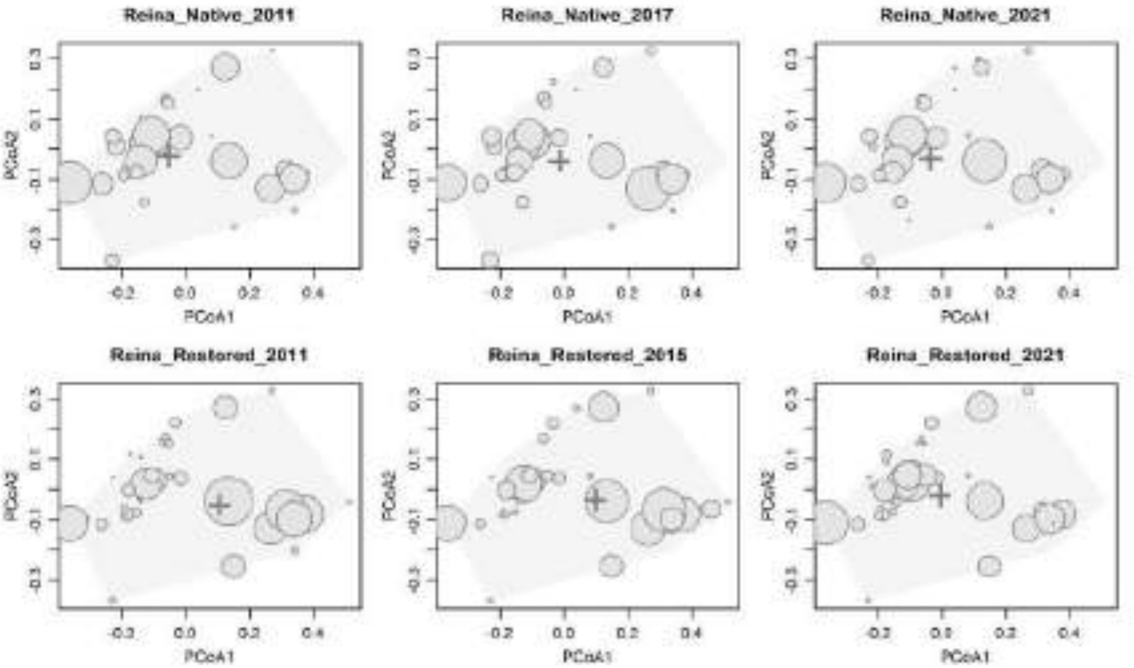


Fig.1: Functional identity (*cross*) and functional entitites abundances (*circle*) for the assemblages with restored and native *C. rubrum* populations

Discussion and conclusion

Our results show that the restored site's coralligenous assemblage functional structure has shifted, approaching the native assemblage in terms of functional identity. These findings suggest that it is feasible to achieve ecological recovery within coralligenous communities by actively restoring key habitat-building octocorallia such as the red coral.

Bibliography

BAYRAKTAROV, E., SAUNDERS, M. I., ABDULLAH, S., MILLS, M., BEHER, J., POSSINGHAM, H. P., MUMBY, P. J., & LOVELOCK, C. E. (2016). The cost and feasibility of marine coastal restoration. *Ecological Applications*, *26*(4), 1055–1074.

CONCLUSIONS AND RECOMMENDATIONS OF THE 4TH MEDITERRANEAN SYMPOSIUM ON THE CONSERVATION OF CORALLIGENOUS AND OTHER CALCAREOUS BIO-CONCRETIONS

1. Open collaborative databases have an important role in filling the knowledge gaps on coralligenous and other calcareous bio-concretions and improving the information on regional distribution and conservation status of these habitats as well as considering other parameters (such as genetics and species traits). A continuous update of the shared information should be made with the contribution from scientists, MPA managers and marine citizen science initiatives.

2. Combining research efforts with innovative techniques can support the implementation of cost-effective monitoring studies on coralligenous to strengthen the knowledge of these habitats.

3. The deep coralligenous rings studied in the north-eastern Corsica merit an implementation of joint monitoring studies towards their effective multinational protection.

4. More research efforts and monitoring studies of the vermetid reefs should be done to assess the distribution of these habitats in the Mediterranean Sea and to better understand their dynamics in the presence of human impacts, considering that they can be considered as bioindicators.

5. Maërl beds are a biodiversity hot spot habitat in the Mediterranean Sea. Scientific knowledge and mapping should be further enhanced and their legal protection in all Mediterranean countries reinforced.

6. Citizen science play a critical role in improving knowledge of coralligenous assemblages by monitoring trends in species presence, distribution and status. Simplified protocols should be elaborated, and trainings organized to improve the quality of the data collected.

7. There is the need of establishing methodological standards of data collection at the Mediterranean level, in order to foster consistent datasets.

8. The mapping effort of coralligenous assemblages should be enhanced and reporting of assessment results on habitat distributional range and condition of the habitat’s typical species and communities should be harmonised to develop a successful quantitative Quality Status Reports (MED QSR).

9. The extraordinary complexity and variety of coralligenous formations ask for an accurate characterization, establishing a shared typology, before the intercalibration of existing evaluation protocols.

10. Evaluating the GES in the framework of IMAP is still challenging at the regional scale. This was clearly pointed out by the recent review on the state-of-art regarding the use of coralligenous as proxy to evaluate the GES. There is a clear need to standardise methodologies and approaches as well as establishing thresholds. Such initiatives are critical steps forward the assessment of the GES at the Mediterranean scale as required by the Barcelona Convention. Is this context collaborative work at the basin or sub-basin level is highly recommended. Furthermore, low-time and low-money consuming protocols should be encouraged.

11. Launch communication campaigns on the value of Coralligenous and other calcareous bioconcretions.

12. Coralligenous are under a various more frequent and more intensive pressures and disturbances including climate change, fishing activities, mucilaginous etc.. There is the need to build cooperative open databases, build capacities and contribute to national, regional and international monitoring and reporting frameworks.

13. With reference to the Post-2020 MPA and OECM strategy in the Mediterranean, the MPAs, starting from SPAMIs, should be used as sentinel sites to monitor climate change impacts using standardized monitoring protocols, citizen science and collaborative approaches to support the effective management and conservation plans across the Mediterranean.

14. Environmental studies should be more connected with economical and legislative “language” to better deliver our messages to the decision makers and enforce existing laws.

SCIENTIFIC COMMITTEE MEMBERS
(In alphabetical order)

Hocein BAZAIRI
Professor
BioBioResearch Center, Faculty of Sciences, Mohammed V University in Rabat - 4 Avenue Ibn Battouta, B.P. 1014 RP, Rabat, Morocco
E-mail: hoceinbazairi@yahoo.fr

Carlo Nike BIANCHI
Professor of Ecology
DiSTAV (Dipartimento di Scienze della Terra, dell'Ambiente e della Vita), Universita' di Genova - Corso Europa 26, I-16132 Genova, Italy
E-mail: carlo.nike.bianchi@unige.it

Joaquim GARRABOU
Senior Researcher
Institut de Ciències del Mar-CSIC
Passeig Marítim de la Barceloneta 37-49
08003 Barcelona
E-mail: garrabou@icm.csic.es

Vesna MACIC
PhD
Institute of marine biology,
University of Montenegro
Put I Bokeljske brigade 68; 85330 Kotor
Montenegro
E-mail: macic.v@ucg.ac.me

Leonardo TUNESI
Reasearch Director - Head of the Area "Marine biodiversity, habitat and species Protection"
Italian National Institute for Environmental Protection and Research, ISPRA – Via Vitaliano Brancati, 60 I-00144 Roma, Italy
E-mail: leonardo.tunesi@isprambiente.it

This symposium was prepared and organized under the Overall supervision of Mr **Khalil ATTIA**, director of UNEP/MAP-SPA/RAC.

ORGANISING COMMITTEE MEMBERS
(In alphabetical order)

Naziha BEN MOUSSA
Administrative Assistant
UNEP-MAP-SPA/RAC
Boulevard du Leader Yasser Arafet, B.P. 337,
1080, Tunis Cedex, Tunisia
E-mail: naziha.benmoussa@spa-rac.org

Cyrine BOUAFIF
Consultant, PhD in Biological Sciences
23, Avenue La Gazelle, Cité La Gazelle, 2083,
Ariana, Tunisia
E-mail: bouafif.cyrine@gmail.com

Imtinen KEFI
Financial Officer
UNEP-MAP-SPA/RAC
Boulevard du Leader Yasser Arafet, B.P. 337,
1080, Tunis Cedex, Tunisia
E-mail: imtinen.kefi@spa-rac.org

Dorra MAAOUI
Communication Assistant
UNEP-MAP-SPA/RAC
Boulevard du Leader Yasser Arafet, B.P. 337,
1080, Tunis Cedex, Tunisia
E-mail: dorra.maaoui@spa-rac.org

Monica MONTEFALCONE
PhD in Marine Science
Seascape Ecology Lab
DiSTAV, University of Genoa
Corso Europa 26, 16132 Genoa, Italy
E-mail: monica.montefalcone@unige.it

Atef OUERGHI
Ecosystems Conservation Programme Officer
UNEP-MAP-SPA/RAC
Boulevard du Leader Yasser Arafet, B.P. 337,
1080, Tunis Cedex, Tunisia
E-mail: atef.ouerghi@spa-rac.org

Yassine Ramzi SGHAIER
Project Officer - NTZ/MPA
UNEP-MAP-SPA/RAC
Boulevard du Leader Yasser Arafet, B.P.
337,1080, Tunis Cedex, Tunisia
E-mail: yassineramzi.sghaier@spa-rac.org

Leonardo TUNESI
Reasearch Director - Head of the Area "Marine biodiversity, habitat and species Protection"
Italian National Institute for Environmental
Protection and Research, ISPRA – Via
Vitaliano Brancati, 60 I-00144 Roma, Italy.
E-mail: leonardo.tunesi@isprambiente.it

This symposium was prepared and organized under the Overall supervision of Mr **Khalil ATTIA**, director of UNEP/MAP-SPA/RAC.

ISBN 978-9973-9864-5-9

UN environment programme | Mediterranean Action Plan Barcelona Convention | SPA/RAC

Specially Protected Areas Regional Activity Centre (SPA/RAC)
Boulevard du Leader Yasser Arafat
B.P. 337 - 1080 - Tunis Cedex - Tunisia +216 71 206 649 / +216 71 206 485
car-asp@spa-rac.org
www.spa-rac.org