Czech University of Life Sciences Prague

Faculty of Environmental Sciences

Department of Zoology and Fisheries (FAFNR)

Czech University of Life Sciences Prague

Ecology and Conservation of the Mediterranean Sea Corals

Bachelor Thesis

Author: Bc. Nicole Doležalová

Supervisor: Ing. Miloslav Petrtýl, PhD.

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Environmental Sciences

BACHELOR THESIS ASSIGNMENT

Bc. Nicole Doležalová

Applied Ecology

Thesis title

Ecology and conservation of the Mediterranean Sea corals

Objectives of thesis

This thesis aims to summarise the current knowledge about the corals in the Mediterranean Sea with a deeper focus on the newly formed term described as MCEs – Mesophotic Coral Ecosystems and their role, ecology, and conservation efforts which have been conducted recently. As the role of the Mediterranean Sea is constantly evolving and growing in importance for local communities from the perspective of economic and cultural value, the habitats are under more significant threats every day. The importance is to bring to light in the upcoming challenges in the conservation of the corals in the Mediterranean Sea and provide an update on the understanding of these habitats and their value for both mankind and the ecosystem through its services.

Methodology

The review is conducted through a literature review by synthesis and reflection on the existing recent studies and papers with the main focus on the Mediterranean region and other general knowledge the scientific world has discovered about MCEs. Supported by critical discussion on the findings and highlighting the possible existing knowledge gaps as well as providing important questions, which need to be focused on by respected scientific groups, guiding to possible objectives of further research all over the Mediterranean region

The proposed extent of the thesis

40-60

Keywords

Anthozoa, Cnidarians, Mesophotic Coral Ecosystem, Biodiversity

Recommended information sources

Corriero, G. et al., 2019: A Mediterranean mesophotic coral reef built by non-symbiotic scleractinians. Scientific Reports, p. 9. DOI: 10.1038/s41598-019-40284-4.

Kahng, S. E. et al., 2010: Community ecology of mesophotic coral reef ecosystems. Coral Reefs, p. 29, 255-275. DOI: 10.1007/s00338-010-0593-6.

Orejas, C. et Jimenez, C., 2019: Mediterranean Cold-Water Corals : Past, Present and Future. Coral Reefs of the World, Springer, ISBN: 978-3-319-91607-1.

Rocha, L. A. et al., 2018: Mesophotic coral ecosystems are threatened and ecologically distinct from shallow water reefs. Science. 361. p. 281-284. DOI: 10.1126/science.aaq1614.

Thurman H. V. et Trujillo A. P., 2017: Essentials of oceanography. Pearson. ISBN: 978-0-134-07354-5.

Expected date of thesis defence

2022/23 SS – FES

The Bachelor Thesis Supervisor

Ing. Miloslav Petrtýl, Ph.D.

Supervising department

Department of Zoology and Fisheries

Electronic approval: 4. 4. 2022

prof. Ing. Iva Langrová, CSc.

Head of department

Electronic approval: 31. 10. 2022

prof. RNDr. Vladimír Bejček, CSc.

Dean

Prague on 30. 03. 2023

Declaration

I hereby declare that I have independently elaborated the diploma/final thesis with the topic of: Ecology and Conservation of the Mediterranean Sea Corals and that I have cited all the information sources that I used in the thesis and that are also listed at the end of the thesis in the list of used information sources.

I am aware that my diploma/final thesis is subject to Act No. 121/2000 Coll., on copyright, on rights related to copyright and on amendment of some acts, as amended by later regulations, particularly the provisions of Section 35(3) of the act on the use of the thesis.

I am aware that by submitting the final thesis I agree with its publication under Act No. 111/1998 Coll., on universities and on the change and amendments of some acts, as amended, regardless of the result of its defence.

With my own signature, I also declare that the electronic version is identical to the printed version and the data stated in the thesis has been processed in relation to the GDPR.

In Prague ……………………………

…………………………………………..

Ecology and Conservation of the Mediterranean Sea Corals

Abstract:

This study offers a contemporary review of the ecology and conservation challenges faced by the Mediterranean Sea anthozoans, commonly known as corals. The primary objective is to provide a comprehensive understanding of the current state of these benthic organisms, including their ecology and the latest findings on anthropogenic pressures they face, as well as the conservation efforts made in the Mediterranean Sea region. The review is carried out by synthesizing and analyzing the existing scientific and grey literature over the last decade. Given the revealed significance of all coral habitats in the Mediterranean Sea and their fragility and current deteriorating condition, a comprehensive understanding is crucial for sustainable and realistic conservation efforts, which should encompass both ecosystem and socio-economic services. The unclarity in terminology for these environments is one of the noticed phenomena. Furthermore, the revealed challenges are the imbalanced conservation efforts correlated positively towards the GDP of the conducting country, highlighting mainly European waters. Both conservation and research efforts are lacking in the south-eastern Mediterranean Sea with prevailing indirect research methods. In particular, the situation of protection of the Temperate Mesophotic Ecosystems (TMEs) is currently insufficient. Only a minimal part is effectively protected due to historical reasons regarding the creation of Marine Protected Areas (MPAs). The state of the latter and other effective area-based conservation measures (OECM) is strongly dependent on sufficient financing, which has been particularly problematic in recent years due to the global pandemic. This study reveals the potential knowledge gaps as well as the disconnection of research and its application in further research or management.

Keywords: Anthozoa, Cnidarians, Mesophotic Coral Ecosystem, Biodiversity

Ekologie a ochrana korálů Středozemního moře

Abstrakt:

Bakalářská práce se zabývá ekologickými a ochranářskými problémy, kterým čelí koráli (Anthozoa) ve Středozemním moři. Cílem práce je analýza současného stavu těchto bentických organismů, včetně nejnovějších poznatků o jejich ekologii. Dále je pozornost zaměřena na antropogenní tlak a lidské ochranářské aktivity v oblasti Středozemního moře. Porozumění ekosystému korálových stanovišť je, vzhledem k jejich ekologické významnosti, křehkosti a současně zhoršujícímu se stavu, zásadní.

Za účelem dosažení cíle práce byla provedena analýza a syntéza existující vědecké i další literatury, zejména za poslední desetiletí. Bylo zjištěno, že problémy v úsilí o ochranu korálů pozitivně korelují s výší HDP dané země, přičemž ochrana prostřednictvím mořských chráněných rezervací převažuje především v evropských vodách. Dalším pozorovaným jevem byla rozporuplnost používané terminologie, která může mít vliv na účinnou standardizaci ochranářských metod ve světovém měřítku. V jihovýchodním Středozemním moři byla sledována snížená míra aktivity v oblasti ochrany a výzkumu. Důležitým zjištěním byla neuspokojivá situace v ochraně temperátních mezofotických ekosystémů (TME), kde je jen minimální část účinně chráněna. A to jednak z historických důvodů vzniku chráněných mořských oblastí (MPA) a také proto, že jejich stav a stav dalších oblastí s režimem ochrany je silně závislý na dostatečném financování, které bylo v posledních letech obzvláště problematické kvůli celosvětové pandemii.

Bakalářská práce odhaluje potenciální mezery ve stavu znalostí o korálech, což může být zapříčiněno dalším ze zjištěných faktorů, a to odpojením výzkumu od navazujících aplikací v ochraně přírody.

Klíčová slova: Anthozoa, Cnidaria, mezofotické korálové ekosystémy, biodiverzita

Acknowledgement

I would like to thank the Czech University of Life Sciences for allowing me to participate Erasmus+ Internship on the Apulian coast in Italy. Special thanks belong to the Diving Puglia D.C. for letting me belong to the local diving community and become a well-prepared diver for my further career path. Precisely I would like to mention Pio Vincenzo De Mitri Morano, Roberto D'Alessandro, Davide Miniscalco, Alessia Tomassone, Piero Lacitignolo, Lucrezia Lamanna and many others.

Apart from that I would like to mention the research team from the University of Bari Aldo Moro, with prof. Giuseppe Corriero, Dr Carlotta Nonnis Marzano and others who have welcomed me during their ongoing research of one of the newly found MCEs near Monopoli in 2019 and I have had the chance to observe sampling extraction and preparation in the year 2022.

Last but not least I would like to thank my supervisor Ing. Miloslav Petrtýl, PhD. for guiding me throughout the whole process of the thesis together with Dr Carlotta Nonnis Marzano.

Figure 1*: Cladocora caespitosa* - a zooxanthellae stony coral in the Apulian coast, Italy near Monopoli, around 8m depth. Author: Nicole Dolezalova

Table of Contents

List of Abbreviations

BP - Before Present time

BPC - Benthic-Pelagic Coupling

DFGs - Derelict Fishing Gears

DRRH - Deep Reef Refugia Hypothesis

EBSAs - Ecologically or Biologically Significant Areas

EFH - Essential Fish Habitats

EMODnet - European Marine Observation and Data Network

IUCN - International Union for Conservation of Nature

MAP - Mediterranean Action Plan

MBES - Multibeam Echo Sounder

MCEs - Mesophotic Coral (Reef) Ecosystems

MHW - Marine Heat Wave

MME - Mass Mortality Event

MPAs - Marine Protected Areas

MS - Mediterranean Sea

OA - Ocean Acidification

OECMs – Other Effective area-based Conservation Measures

POM - Particulate Organic Matter

SCRs - Shallow Coral Reefs

SCUBA - Self-Contained Underwater Breathing Apparatus

SSFs - Small-Scale Fisheries

TMEs - Temperate Mesophotic Ecosystems

UNEP - United Nations Environment Programme

VMEs - Vulnerable Marine Ecosystems

1. Introduction

Coral species became one of the main foundation species for communicating the global climate change crisis (Pennett R., 2022) and the public is likely more aware of alarming situations in the tropical Oceans represented by the world's largest coral reef of the world - the Great Barrier Reef (Queensland Government, 2022) and near locations of the Indo-Pacific region known as the Coral Triangle. On the other hand, the public recognizes corals as most likely to be the shallow water scleractinian species typical for locations of exotic vacations. Yet less is known about the situation in the Mediterranean Sea where corals represent a minor group of its biodiversity (Coll M. et al., 2010). With the lacking studies on the overall situation of the Mesophotic Coral Ecosystems (further abb. MCEs) their complex importance and functions in biocenosis are still generally unknown (Willmer G., 2020).

In this study, current findings from the field of studies of MCEs are presented, especially concerning the Mediterranean Sea, which is a unique environment characterised newly as Temperate Mesophotic Ecosystems (Laverick J., Rogers A., 2019) and has played an important role in human history. Corals are the main and the most important habitat-building organisms that create a rich environment for a whole range of species (Anonymous, 2016) and thus the focus is dedicated to their ecology and recent conservation efforts in this region.

Global climate change represents challenges for mankind and only sophisticated research efforts can help to understand the undergoing changes in these environments. Noteworthy the phenomenon of decreasing knowledge which is represented by the relation of the effect of depth on the number of released studies about these environments proves how huge a challenge studying MCEs is (Bongaerts P., 2019). On the side with the emerging blue-growth sector (Da Ros Z. et al., 2019) and deep-sea mining already impacting unknown ecosystems, the scientific community must go hand in hand with the need for understanding and timely intervention in the field of protection and reduction of the impacts of these activities.

2. Objectives of the thesis

This thesis aims to summarise the current knowledge about the corals in the Mediterranean Sea with a deeper focus on the newly formed term described as MCEs – the Mesophotic Coral Ecosystems and the Temperate Mesophotic Ecosystems (TMEs) and their role, ecology and conservation efforts which are conducted recently. As the role of the Mediterranean Sea is constantly evolving and growing in importance for local communities from the perspective of economic and cultural value, the habitats are under bigger threats every day. The importance is to bring light to the upcoming challenges in the conservation of the corals in the Mediterranean Sea and provide an update on the understanding of these habitats and their value for both mankind and the ecosystem through its services.

3. Methodology

This narrative study is conducted through literature review by synthesis, reflection and discussion on the existing recent studies and scientific papers as well as grey literature with the main focus on the Mediterranean region as well as other general knowledge the scientific world has discovered about the MCEs. Supported by analysis of keywords (scopus.com, Google Scholar, mesophotic.org), critical discussion on the findings and highlighting the possible existing knowledge gaps as well as providing crucial questions, which need to be focused on by respected scientific groups, guiding to further objectives of research all over the Mediterranean region.

4. Literature review

4.1. Foreword

Around six million years ago, during the Early to Middle Miocene period, the Mediterranean Sea was home to thriving coral reefs, with over 80 genera and hundreds of species of scleractinians (Vertino A. et al., 2014). However, the Messinian salinity crisis, which occurred around 5.96 million years ago (Coll M. et al., 2010), changed everything. The crisis caused the sea to become isolated from the ocean and nearly dried out (Thurman H. V. et Trujillo A. P., 2017), leading to extreme climate changes and alterations in the physical properties of the water. As a result, many species went extinct, including most coral reefs, leaving behind only endemic species unique to the Mediterranean Sea (Aguilar R. et Pastor, X., 2010).

After the straits of Gibraltar reopened, the Mediterranean Sea regained its extent, and new organisms began to spread into the newly formed environment. However, the sea acquired the characteristics of the Atlantic fauna mixed with its endemism, and the last living proof of the Indo-Pacific fauna disappeared for the following geological ages. Currently, there are only 25 genera and 33 species of Scleractinia in the Mediterranean Sea, while Anthozoa corals represent a minor group (around 200 species) of its biodiversity (Vertino A. et al., 2014).

The corals referred to in this study encompass subphylum Anthozoa belonging to Cnidaria phylum, and the most dedication is to that habitat-forming, creating vast animal forests in the region of the Mediterranean Sea. Corals in the MS occupy all different habitats, from shallow infralittoral rock substrata with algae, solitary corals, stony coral boulders (the cushion coral - *Cladocora caespitosa)* or anemones (*Actinia striata*), to circalittoral mesophotic zones covering reefs and banks with vibrant colours (the gorgonian, violescent sea-whip *Paramuricea clavata,* the red coral *Corallium rubrum* or the star coral *Astroides calycularis*) together with sponges, algae, bryozoans, crinoids, brachiopods and ascidians (Castellan G., 2022). Until reaching bathyal muds of continental shelf and slopes in deep cold waters covered with pale trees-like structures (*Lophelia pertusa* or the zigzag coral *Madrepora oculata)* (Aguilar, R. et Pastor, X., 2010).

4.2. The Mediterranean Sea

4.2.1. Oceanographic review of the Mediterranean Sea

The *Mare medi terraneum* from Latin can be translated as the sea in the middle of the land and it truly is the largest and deepest enclosed sea with basin dimensions of 2,969,000 km^2 and an average depth of 1,460 m, reaching a maximum at 5,267 m (Coll M. et al., 2010).

The climate of the region is in general hot and dry in summer and cold and humid during winter which makes it a popular destination for many tourists. Just in 2014, over 314 million visited the region and the UNEP predicts this number to grow up to 500 million by 2030 (Mediterranean Action Plan, 2017).

The sea divides Europe from the African continent with the narrowest point in the west, the Strait of Gibraltar, where it connects to the Atlantic Ocean, and the Dardanelles disconnecting Europe from the Asian continent in the east, joining with the Sea of Marmara and the Black Sea. Apart from that it has been connected to the Red Sea, part of the Indian Ocean with the man-made Suez Canal in the southeast for more than 150 years (see Figure 3 (A)). In the middle part of the basin is found the Strait of Sicily, which with its 400 m shallow ridge, divides the Mediterranean Sea into two subregions, the North-western MS and the Eastern MS (see Figure 3 (D)) and forms a natural border between the coast of Tunisia and the island of Sicily. The western MS has an area of around 0.85 mils. km^2 and the eastern MS 1.65 mil. km^2 (Coll M. et al., 2010).

The MS is a concentration basin, where the evaporation is higher in the eastern half. Because of that the water level tends to be lower in the east causing the higher salinity MS' water to sink, in the west the Atlantic Ocean's low-salinity water flows into the basin towards the eastern part creating the current (see Figure 2). On the eastern coast it becomes warmer and saltier and sinks into the Levantine Sea. After that, the water flows back in a deeper profile back to the west and exits to the Atlantic Ocean again (Coll M. et al., 2010).

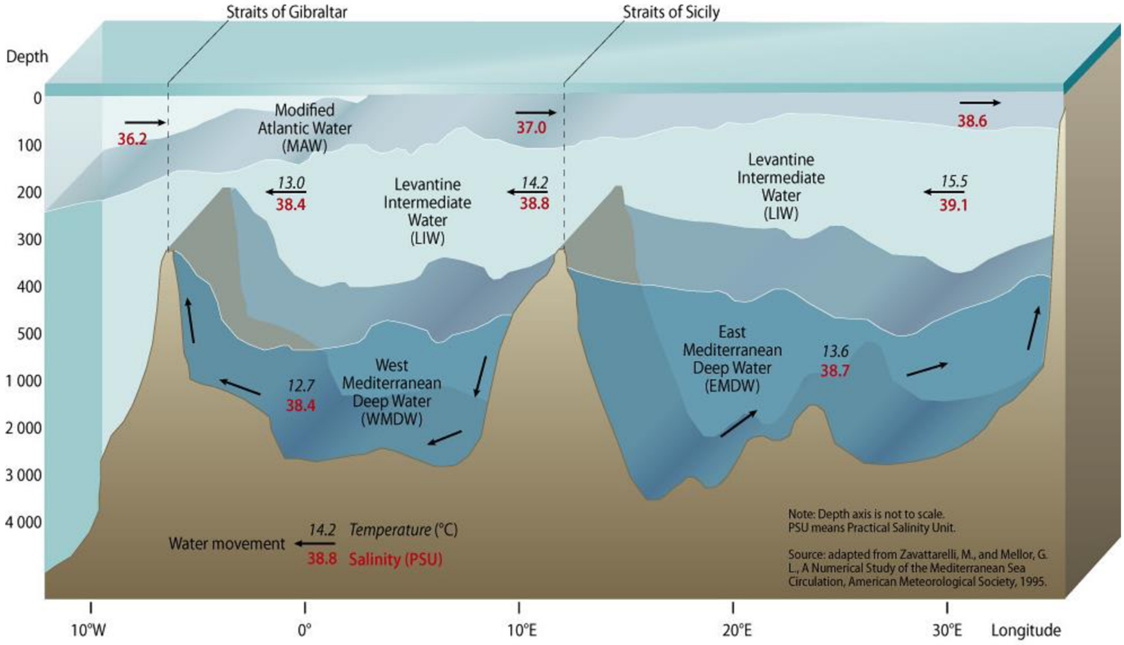


Figure 2: Water mass circulation in the Mediterranean Sea

Lighter, less salty water from the Atlantic Ocean enters the Mediterranean basin as Modified Atlantic Water (MAW), where it mixes in the Levantine Sea. Once it is warmed up and mixed with saltier water, it becomes Levantine Intermediate Water (LIW) and floats back to the west through the Straits of Sicily and Straits of Gibraltar back to the Atlantic Ocean. Deep waters generally do not leave the basins, but upwelling occurs. The diagram adapted from Zavattarelli M., Mellor G.L., A Numerical Study of the Mediterranean Sea Circulation, American Meteorological Society, 1995. 8. (from: GRID-Arendal, 2013)

Despite the oligotrophic gradient from east to west of the MS basin, the sea faces regional eutrophication. In general, the areas which suffer are mainly the coastal locations where estuaries, sewage, industrial or agricultural development are located. Apart from the direct placement of the source of pollution, the meteo-physical properties of the region such as wind, currents, thermocline, and precipitation have a further effect on how the nutrients spread (Bosc E. et al., 2004; Gasol J. et al., 2016; Zavatarelli M. et al., 1998). The gradient of primary production is strongly oriented towards the north-west (see Figure 3, (C)), which is contrary to the temperature gradient (see Figure 3 (B)) and salinity, both higher in the eastern part over the western (Coll M. et al., 2010) which as stated before is more oligotrophic.

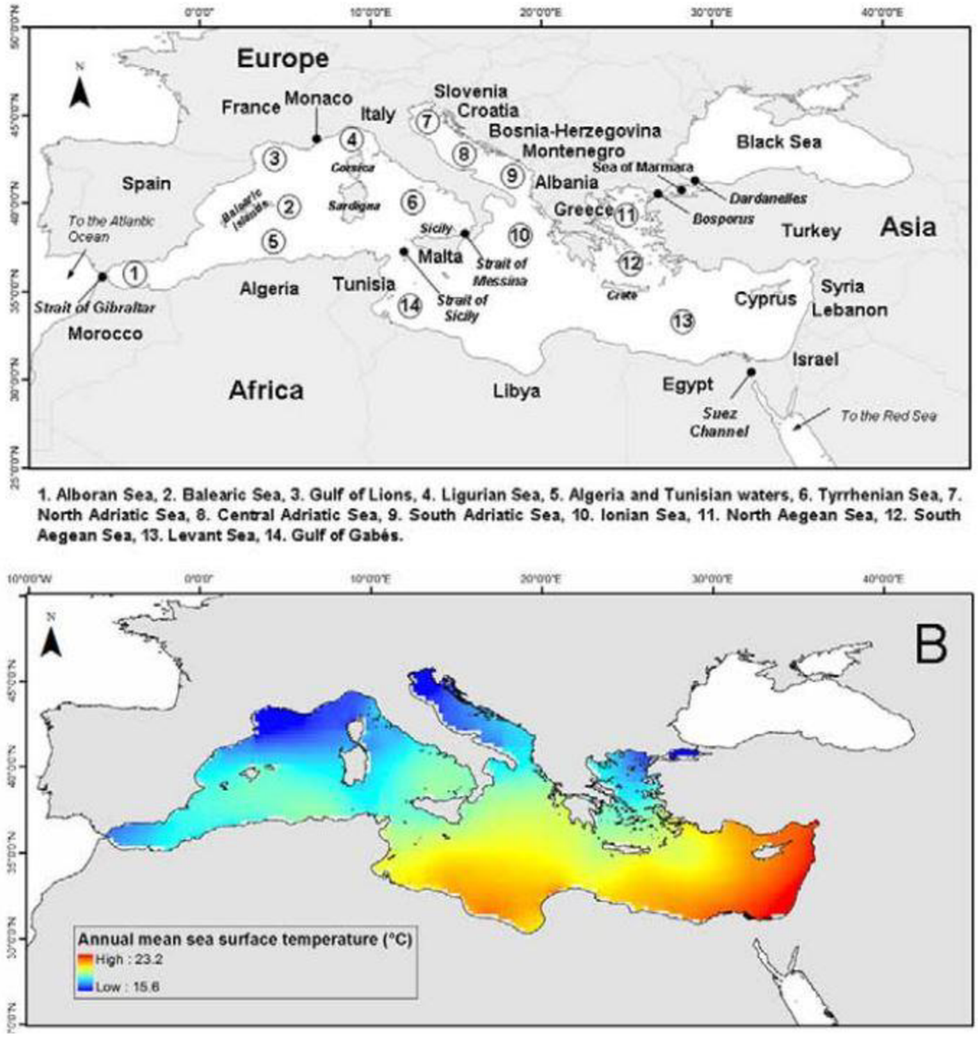


Figure 3A-B: Properties of the Mediterranean Sea

"Biogeographic regions and oceanographic features of the Mediterranean Sea. (A) Main biogeographic regions, basins, and administrative divisions of the Mediterranean Sea, (B) Annual mean sea surface temperature (°C) (2003, NOAA)" (from: Coll M. et al., 2010)

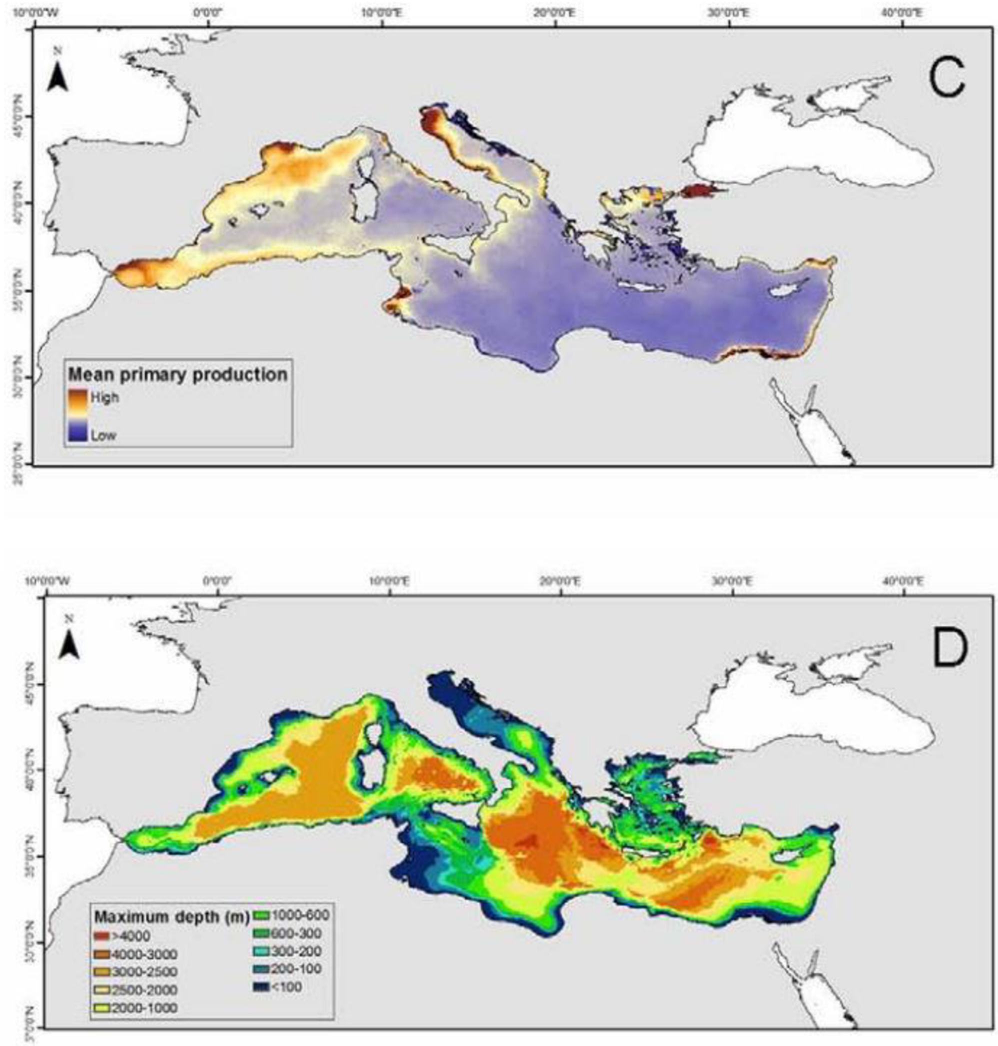


Figure 3C-D: Properties of the Mediterranean Sea

"Biogeographic regions and oceanographic features of the Mediterranean Sea. (C) Annual mean relative primary production (2002, Inland and Marine Waters Unit, Institute for Environment and Sustainability, EU Joint Research Centre, Ispra, Italy), and (D) maximum average depth (m) (NOAA)." (From: Coll M. et al., 2010)

As can be seen in Figure 3 (D), the basin is generally characterised as a deep-sea environment divided by a few continental shelves. From depths of 300 m to 500 m down to the bottom occurs high homeothermy, where temperatures oscillate around 13.5°C to 15.5°C in the western basin and 12.8 to 13.5°C in the eastern. In contrast with the Atlantic Ocean, there are no thermal boundaries in the deep sea of the MS (Coll M. et al., 2010; Emig C., 2005). The salinity varies around 37.5 to 39.5 psu (Coll M. et al., 2010) depending on the season, making it one of the saltiest seas in the world.

4.2.2. Paleoecological aspects influencing the MS corals

The basin had been under a lot of changes in the geological ages from the past until the present time. The Mediterranean itself was a part of the larger Tethyan Ocean and was shaped by tectonic events during Miocene, Pliocene and Quaternary times (Sara M., 1985). The Messinian salinity crisis more than 5.96 million years ago is one of them (Garcia-Castellanos D., 2009; Maldonado A., 1985). Nevertheless, the crisis which has had an impact on emerging endemism and the Indo-Pacific biota dying out was not the only radical change. The Last Glacial Maximum (i.e. 19.000 BP) has caused the sea level of the Mediterranean Sea to be -120 m lower than today and when approaching the Holocene (i. e. 11.700 BP) the level of the sea oscillated around -40 to -68 m lower. That supports the evolutionary different path for coral reefs in nowadays TMEs, leading to a longer time to evolve, greater stability and favouring their longer lifespans and reduced competition of autotrophs (Cerrano, C. et al., 2019). In general, there are found species of Anthozoa with mesmerising longevity exceeding more than 2700 years for *Savalia savaglia* (Cerrano C. et al., 2010) supporting this hypothesis.

Most of the MCEs habitats are positioned on limestone foundations or basaltic foundations as it is on the islands of Hawaii or the Azores (Sampaio, Í. et al., 2019; Pyle et al., 2016) and in the eastern tropical Pacific (Cortés, 2019; Easton et al. 2019) with both flat platforms with slopes < 10° and the slopes exceeding more than > 10°. According to studies by Sherman et al. (2019), the studied communities tend to follow ancient sea-level stands (limestone outcrops, buttresses, and ledges) and vertical walls with a structural complexity (ledges, caverns, caves, ridges, undercuts).

4.2.3. The Mediterranean Sea biodiversity

The Mediterranean Sea holds over 17,000 species with numbers still rising as new species are discovered, from which 20 to 30% of species are endemic (Mediterranean Action Plan, 2017). While at the same time, the sea is facing strong mainly anthropogenic-based threats on habitat loss and degradation due to tourism and growing demography in the region, fishing impacts, pollution, climate change, eutrophication, ocean acidification and the establishment of alien species. All these affect the great number of taxonomic groups in this region (Coll M., 2010).

The recent biota is mostly derived from the Atlantic Ocean, but due to unique historical events, it possesses temperate, cosmopolitan, subtropical fauna and Indo-Pacific taxa (Bianchi C.N., 2000; Coll M., 2010). Therefore all these unique conditions make the MS a true biodiversity hotspot (Mannino A. M. et al., 2017).

The achievement of this status might be connected with the general fact that MS has been studied more intensively in comparison with other seas as well as the rich geological history creating different scales of conditions. At first, the region possessed tropic and subtropic species. After the Messinian salinity crisis and Zanclean flood the door for temperate and cold water species opened from the Atlantic Ocean. The last mentioned found their way to the MS in glacial periods when the average temperatures of the sea dropped. On the other hand in recent years with the rising seawater temperatures, changing the conditions in the Nile delta and open doorway to the Indian Ocean, the recent tropic and subtropic species found their way as Lessepsian migrants (through the Suez Canal) (Mannino A. M. et al., 2017) or entry into the environment through the ballast water or hull fouling (Flagella M.M., 2005). While in the west The Atlantic brings the range-expanding species, currently more thermophilic as climate change favours these over others (Mannino A. M. et al., 2017).

While the MS is characterised by many interconnected smaller seas (Figure 3A), the biogeographical effect on endemic species abundance distribution is strongly north-west oriented (see Figure 4) contrary to invasive species located mainly in the south-eastern parts of the MS (see Figure 5) (Katsanevakis S. et al., 2014).

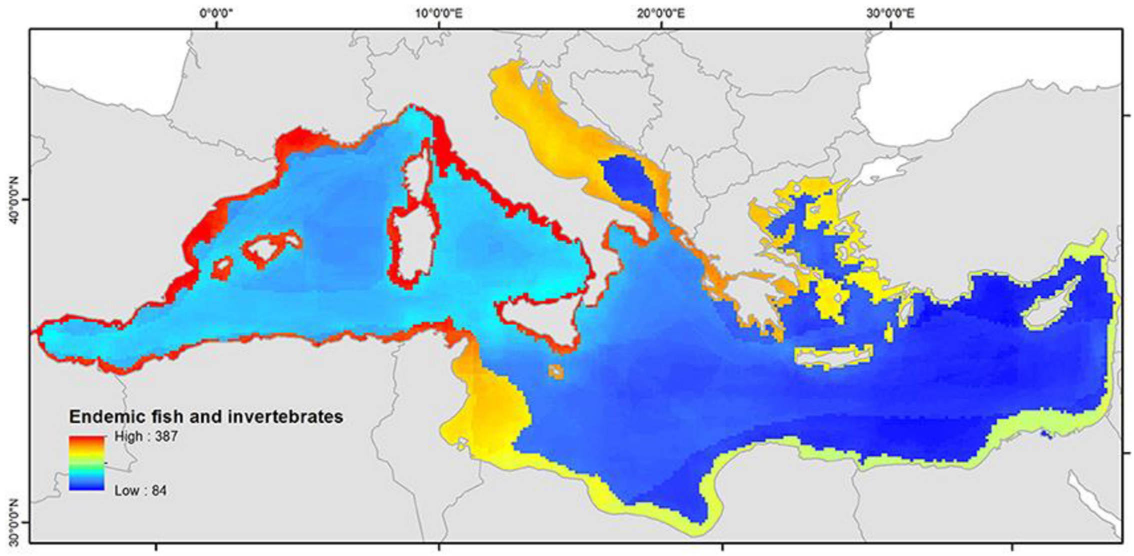


Figure 4: Species richness of native fish and invertebrates in the Mediterranean Sea (from: Katsanevakis, S. et al., 2014)

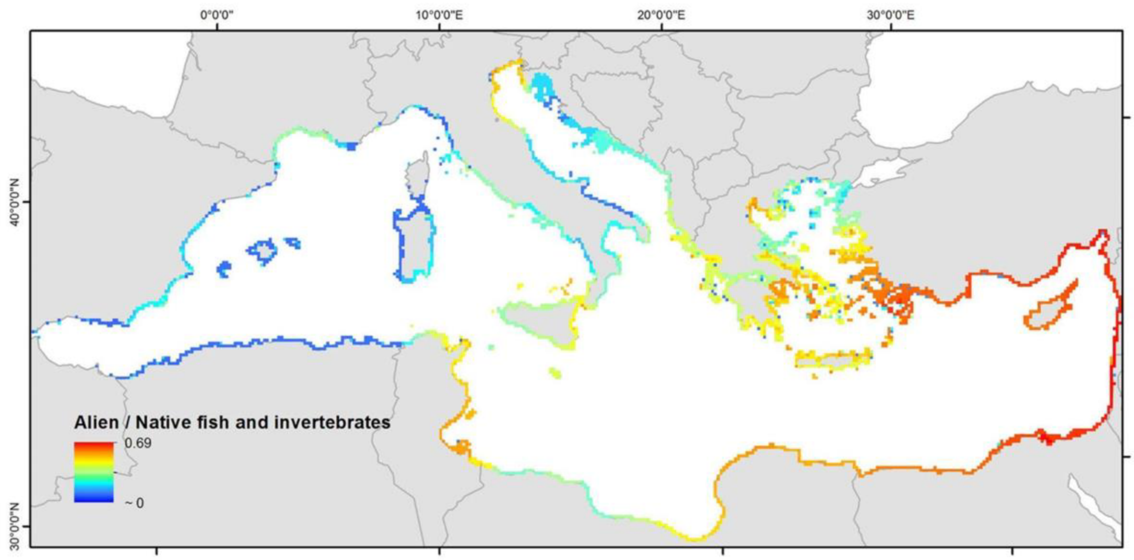


Figure 5: Alien-to-native ratio of fish and invertebrates in the coastal areas of the MS (from: Katsanevakis, S. et al., 2014)

4.3. Biology and Ecology of Corals in the Mediterranean Sea

4.3.1. Phylogeny of Anthozoans

For a better understanding of the recent studies, it is crucial to take into account the biology of the Anthozoa as understanding its fundamental knowledge can open ways for more effective conservation and protection efforts. Further chapters are introducing the basic knowledge and are not going to substitute thorough most recent phylogenetic studies as it is not within the scope of this study.

The Anthozoa class derived from the Greek meaning ‘flower animals’, are part of the Cnidaria phylum. The species are characterised as passive suspension feeders, sessile through most of their life cycle in the form of polyps. Usually can be found living in colonies but some prefer to live a solitary life. Their growth rates are very small (a few mm/year up to cm/year) in natural conditions and are known for their incredible life spans making them one of the oldest species on the planet (Bo M., Bavestrello G., Angiolillo M. et al., 2015; Cerrano C. et al., 2010).

The cnidarians are characterised by a distinctive feature of stinging cells called nematocysts or cnidocytes which are used for paralysing prey. Nowadays the Cnidaria phylum is divided into 3 subphyla: Anthozoa (anthozoans), Medusozoa (jellyfish and hydrozoans) and Myxozoa (parasites) (Hand C.H. et Gail F.D., 2023; Savoca S. et al., 2022; Chang E., 2015; Collins A.G., 2002). While the Medusozoa stays or partially develops into the medusa phase and remains in it throughout its whole life, Anthozoa remains in the polyp phase only (Aguilar R. et Pastor X., 2010).

Anthozoa is divided into 3 subclasses - Hexacorallia, Octocorallia and Ceriantharia. Hexacorallia consists of 6 orders: Actiniaria - sea anemones, Antipatharia - black coral, Corallimorpharia - corallimorphs, Rugosa (extinct), Scleractinia - stony corals and Zoantharia - zoanthids. Octocorallia has only 3 orders: Alcyonacea - soft corals and gorgonians, Helioporacea - blue corals, Pennatulacea - sea feathers, sea pens, or pennatules. The last subclass Ceriantharia - tube-dwelling anemones was recently created and consists of 2 orders Penicillaria and Spirularia (Daly M. et al., 2003).

Recent molecular studies have suggested that the traditional classification of anthozoans based on the number of tentacles and symmetry may not reflect their true evolutionary relationships. Instead, a new phylogeny has emerged based on molecular data, which divides anthozoans into two main clades: Hexacorallia and Octocorallia. It is important to note that the phylogeny of anthozoans is still an active area of research, and discoveries may lead to further refinements of the classification. Including the position of Octocorallia as a monophyletic group or the unclear relation of Hexacorallia and Ceriantharia, which are now considered closely related (Stampar S.N. et al., 2019; Zapata F. et al., 2015). Another suggested change seems to include Helioporacea and Pennutulacea into 1 order Calcaxonia-Pennutulacea and rename the Alcyonacea to Holaxonia-Alcyoniina, both part of subphylum Octocorallia (see Figure 6) (McFadden C.S., 2021).

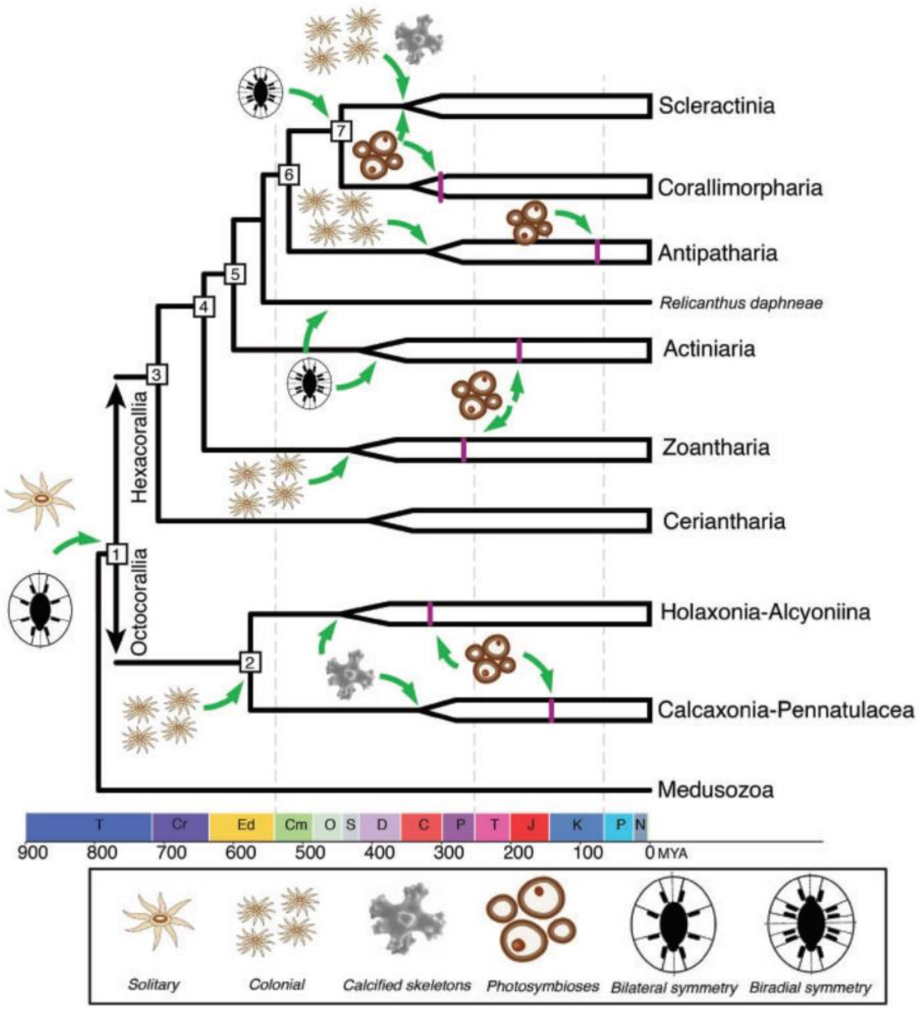


Figure 6: Simplified phylogeny of class Anthozoa according to McFadden C.S. et al. (2021), including key characters gained in different lineages, such as calcified skeletons, photosymbionts, biradial symmetry or colonial assemblages (from: McFadden C.S., 2021).

4.3.2. Life cycle of corals

In asexual reproduction, the Anthozoa can reproduce by budding in which new polyps grow from the existing polyps. In this process, a new polyp forms a bud on the side of the existing polyp, which grows and develops into a mature polyp. This process can continue to repeat, and a colony of Anthozoa can form. Another form of asexual reproduction is through fission, causing the colonies to split in half and fragmentation (Lewis B.M. et al., 2022), which is caused by mechanical disturbance of a colony whose debris restarts the colony on a new substratum. Last mentioned adaptability is abundantly used in active restoration and research.

In sexual reproduction, Anthozoa release eggs and/or sperm into the water column during lunar and temperature-dependent broadcasting events, where they fertilise and form a free-swimming larva called a planula. Some corals' planulae might be brooded, which can be defined as the inner fertilisation of an egg inside the corals' polyps and after it is mature and evolved into planulae, it spreads in the epibenthic layer immediately looking for a settlement. This behaviour can be observed for example in *Monomyces rubrum* or *Corallium rubrum* (Porcu C. et al., 2017; Heltzel P.S. et Babcock R., 2002) (see Figure 7). The planulae then settle on a suitable substrate and metamorphose into juvenile polyps, which grow into adult polyps. This process of sexual reproduction helps to increase the genetic diversity of the Anthozoa population.

The interesting mechanism of the planulae's choice of the right moment of settlement is dependent on abiotic conditions such as hydrostatic pressure, light (Sakai Y. et al., 2020; Gleason D.F. et al., 2006), sedimentation, temperature, water flow or biotic ones like chemical or acoustic (Lillis et al. 2016; Vermeij M.J.A. et al., 2010).

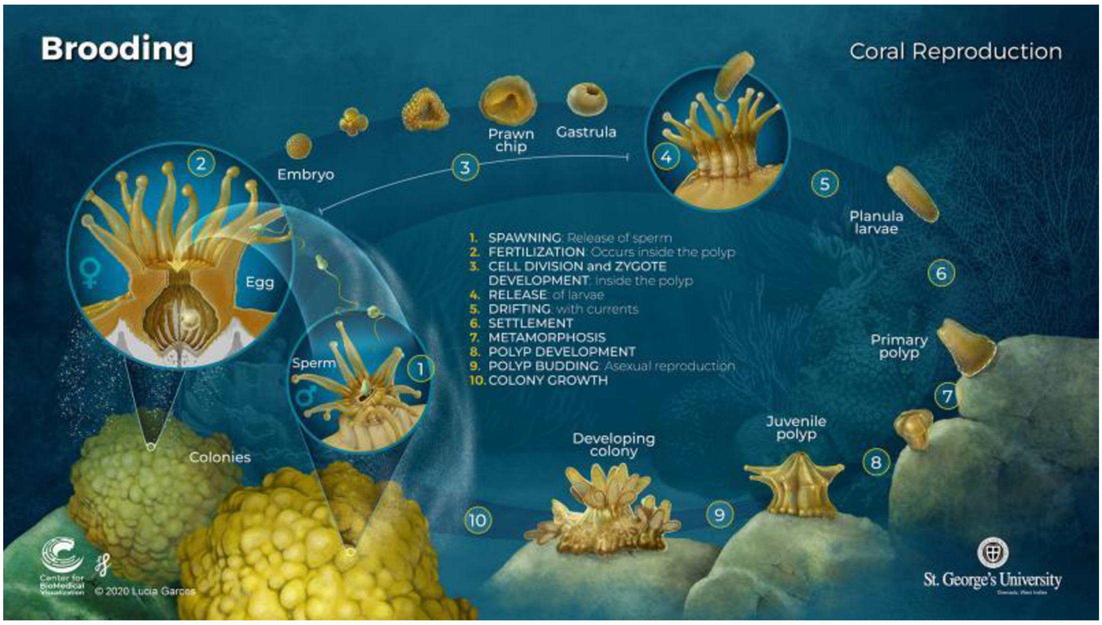


Figure 7: Sexual reproduction (brooding) of some species of Anthozoa

Brooding, as a form of sexual reproduction, serves a crucial role in promoting genetic diversity in corals. However, one of its key benefits is also the ability to establish new colonies at a distance from the parent coral. The coral species manage this process by synchronising the release of sperm during the new moon (1) and larvae during the full moon (4), following a period of brooding within the polyps (2-4). Subsequently, the coral larvae are transported by ocean currents until they settle and initiate the growth of a new colony (from: Imagenscience.com, 2021).

There are some differences in the life cycle of shallow corals and mesophotic ones. While both groups reproduce asexually through budding and sexually through the release of eggs and/or sperm, mesophotic corals have been found to have a lower reproductive output compared to shallow-water corals. Additionally, mesophotic corals have been found to have slower growth rates (Sartoretto S. et Francour P., 2012; Linares C. et al, 2007) and longer life spans compared to their shallow water counterparts. These differences may be due to the lower light levels and different environmental conditions found in the mesophotic coral ecosystems (Cerrano, C. et al., 2019). On the other hand, some recent studies show interesting sights on the fecundity of corals, where deep communities can prove higher fertility over shallower ones like it is in the Sardinian population of *Corallium rubrum* (Porcu C. et al., 2017).

4.3.3. Anthozoa species of the Mediterranean Sea

The Mediterranean Sea is home to a diverse array of Anthozoa families. This section does not substitute taxonomic reviews of anthozoans and all mentioned species are just presented on an introductory level which is found to be currently relevant for the study both in providing conditions by creating the animal-forest habitats and is concerned by the scientific community. The most dominated cnidarian-rich habitats are built with antipatharians, soft corals and gorgonians and scleractinians (Angiolillo M. et Canese S., 2018). Some of the most common families found in the Mediterranean can be presented (see Figure 8) below.

Hexacorallia consists of 6 orders:

- Actiniaria - sea anemones commonly known as sea anemones, this family includes over 1,000 species of sessile, predatory animals with a soft cylindrical body and a ring of tentacles surrounding a central mouth.

  Actinia equina (Linnaeus, 1758): This species is also known as the "beadlet anemone" due to the small, bead-like bumps on its surface. It is found in rocky areas and can form large aggregations or "carpets" at depths ranging from 1 to 50 metres.

  Bunodactis verrucosa (Pennant, 1777): This species has a distinctive, warty appearance due to the numerous bumps on its surface. It is usually found on rocky substrates at depths ranging from 5 to 100 metres.

- Corallimorpharia - corallimorphs are not the most abundant group in the MS. Currently only Corynactis viridis is the only jewel anemone confirmed (Otero M.M. et al., 2017).

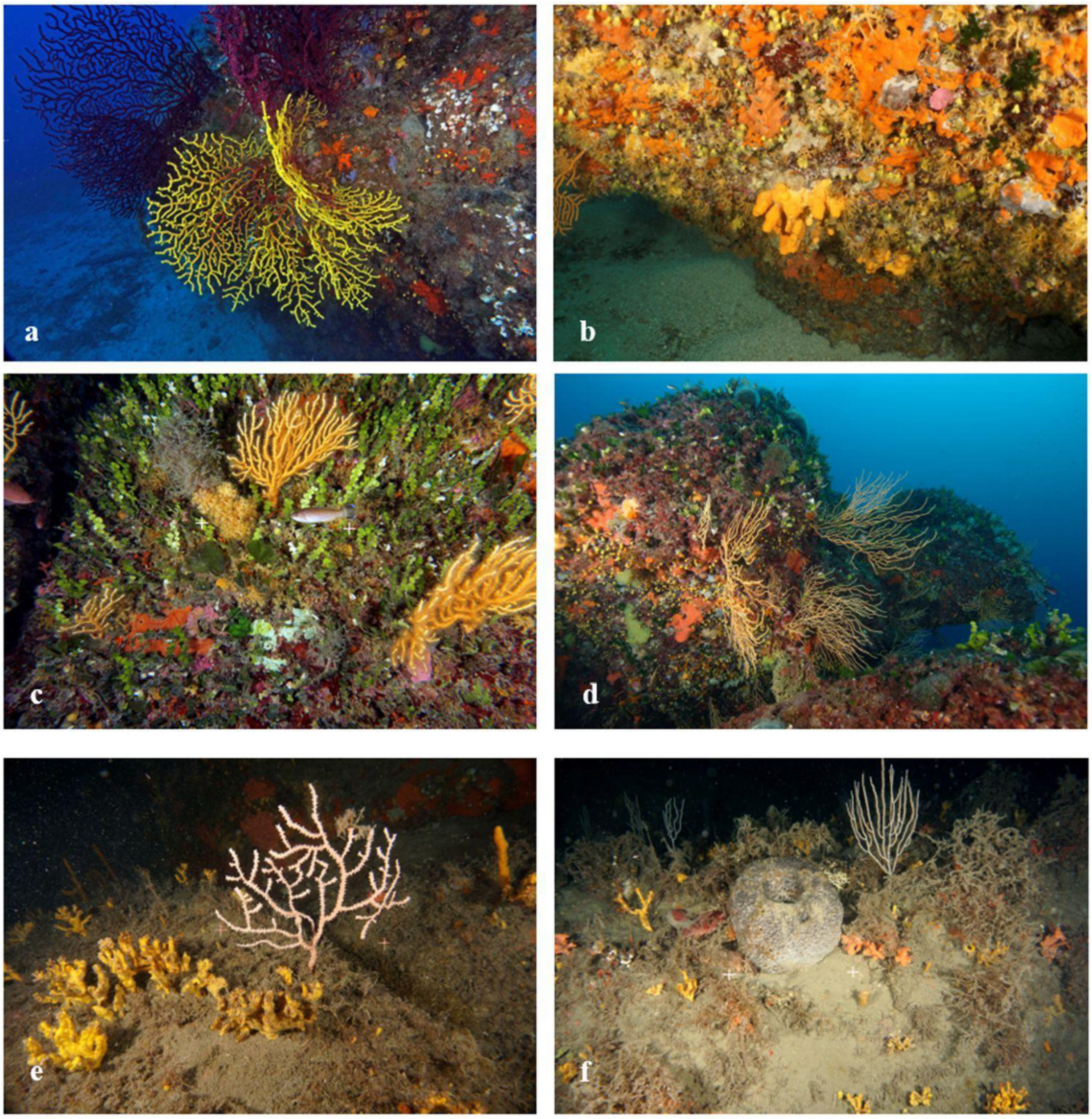


Figure 8: Corals in the Tavolara MPA, Sardinia - Italy

Different coralligenous and coral assemblages: (a) Paramuricea clavata facies at Picchi della Mandria; (b) rich sponge assemblage with the scleractinian Leptopsammia pruvoti and branched bryozoans at Papa Point; (c–d) Eunicella cavolini facies with sponges and green algae (Halimeda tuna and Codium sp.) at Tegghja Liscia and Occhio di Dio. Granite sites: (e) Axinella spp. facies with epibiontic Parazoanthus axinellae and rare colonies of E. cavolini at Mandria Shoal; (f) mixed facies with Axinella spp., Sarcotragus foetidus and Eunicella singularis (from: M. Canessa et al., 2020).

- Antipatharia - commonly known as black corals, this family includes around 30 species of colonial Anthozoa that form tree-like structures with a black, horny skeleton.

  Antipathella subpinnata (Ellis et Solander, 1786): is found in lower mesophotic zones around 80 m down to the rariphotic zone of 200 m (see Figure 9) (Bo M. et al., 2008). It is the most abundant species of black corals in the NW MS, associated with rocky bottoms and coralligenous assemblages both in coastlines and seamounts. Overall, they are considered extremely sensitive and are listed as indicator species of vulnerable marine ecosystems (VMEs) (Ingrassia M. et Bella L., 2021).

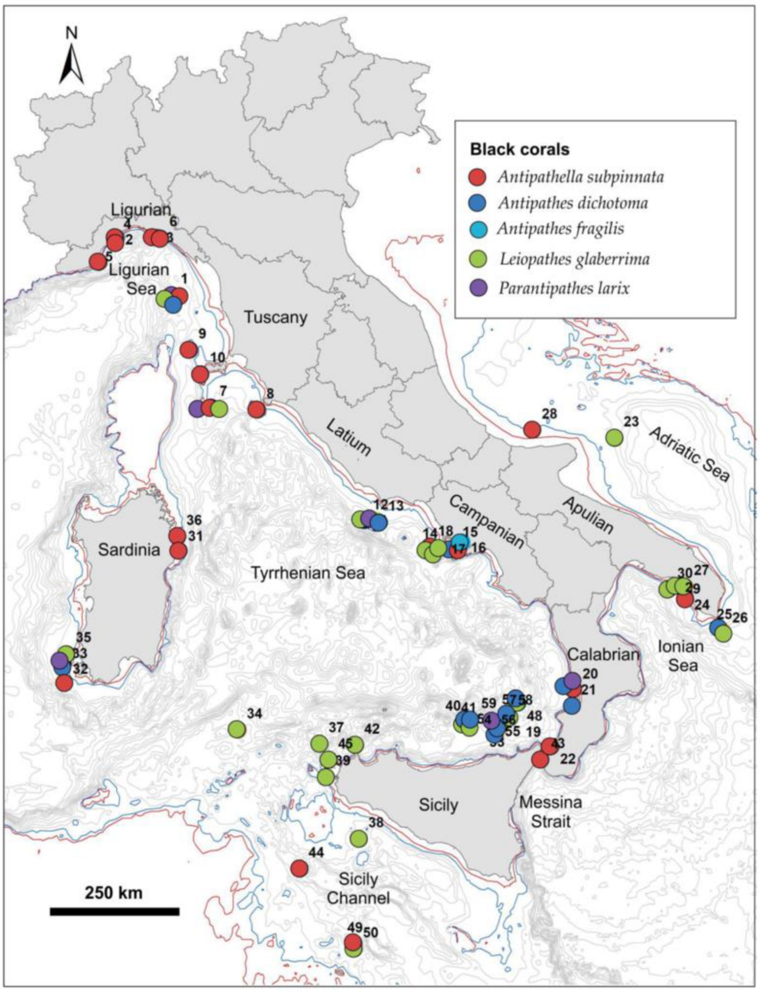


Figure 9: The distribution of antipatharians in the Mediterranean Sea, Italy with *Anipathella subpinnata* (red) comprises 34% abundance of all black coral species (from: Ingrassia M. et Bella L., 2021).

- Scleractinia - also known as stony corals, this is the largest order of Anthozoa, with over 1,500 species. They are important reef-building organisms and include a variety of forms, from small cup corals to massive branching colonies (Otero M.M. et al., 2017).

  Cladocora caespitosa (Linnaeus, 1767): this species is endemic to the MS as it is known for its symbiosis with zooxanthellae *Symbiodinium* clade A. Its colonies are boulder-forming or plate-forming, depending on the current and other conditions, living in depths up to 50m (Peirano A. et al., 1999). In rare conditions can create free-living nodular assemblages (Kersting D.K. et al., 2017a; 2017b).

  Dendrophyllia ramea (Linnaeus, 1758): in common name called tree coral, listed as Vulnerable (VU) in the IUCN Red List; generally thriving in the circalittoral zone on rocky substrates or bioconstruction with moderate currents, in depth between 40 to 240 m. It can be found in the Aegean Sea, the Levantine Sea, the Tyrrhenian Sea, the Gulf of Cadiz, the Ionian Sea, and the NW Mediterranean and in the Eastern Atlantic Ocean around the Azores and along the African coast (Angiolillo M. et al., 2022).

  Dendrophyllia cornigera (Lamarck, 1816): yellow tree coral listed as Endangered (EN) in the IUCN Red List. It can be found in a bathymetric range between 70 to 100 m and 733 m (see Figure 10), thus being categorised as partly mesophotic and partly CWC species (Castellan G. et al., 2019).

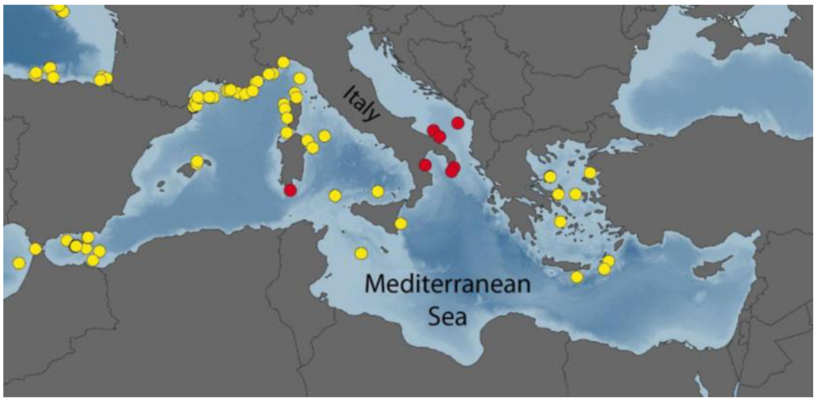


Figure 10: *Dendrophyllia cornigera* distribution in the MS with red dots representing ROV studies and yellow dots sources from publications (from: Castellan G. et al., 2019).

- Zoantharia - commonly known as zoanthids, this family includes about 200 species of colonial Anthozoa with a soft, tube-like body and a fringe of tentacles surrounding a central mouth. The yellow cluster anemone Parazoanthus axinellae is probably the most common Mediterranean species, typically found growing on sponges of the genus Axinella or on coralligenous substrate (Otero M.M. et al., 2017).

  Savalia savaglia (Bertoloni, 1819): the gold coral occupies an extensive bathymetric range from 15 to 700 m, creating tree-like colonies up to 2 m tall and 30 cm of maximum basal diameter. The curiosity about this species is its parasitic life strategy, living on gorgonians which it overgrows within a few years. After that it starts sexual reproduction to build new generations. It is subjected to partially legal and illegal fishing practices among other coral species (Otero M.M. et al., 2017). The colonies can be found in Italy, at Punta Manara and in the Portofino MPA (the Ligurian Sea), and along the western coast of Apulia (the Ionian Sea). Moreover a shallow population has been recorded in the Bay of Kotor, Montenegro (Giusti et al., 2015).

- Ceriantharia - also known as tube anemones or burrowing anemones, because of their cylindrical, tube-like shapes, which can range in length from a few centimetres to over a metre and are typically found in sandy or muddy sediments, where they burrow into substrate using their muscular base. They are sessile and do not move around, but they can retract and extend their tentacles to capture prey, which consists mainly of small fish, plankton, and other invertebrates. Unlike sea anemones, which have a circular arrangement of tentacles around their mouth, tube anemones have two rings of tentacles, with the inner ring used for capturing prey and the outer ring used for defence (Otero M.M. et al., 2017).

Octocorallia has only 3 orders:

- Alcyonacea - soft corals and gorgonians which have a flexible or fleshy skeleton made up of proteins and spicules of calcium carbonate and are found in a wide range of marine habitats, from shallow reefs to deep ocean trenches. They are typically found in areas with strong currents, as they rely on water movement to bring them food and remove debris and can form vibrant animal forests. *Ellisella paraplexauroides* (Stiasny, 1936) is one of the largest soft coral in the MS listed as Vulnerable (VU) in the IUCN Red List together with *Alcyonium acaule* (Marion, 1878) which is the most abundant and key ecosystem engineer species (Otero M.M. et al., 2017).

  Paramuricea clavata (Risso, 1827): the so-caled red gorgonian is one of the most important and abundant endemic species in the Mediterranean Sea. It has a tree-like growth form and can reach up to 2 metres in height. It is found in rocky areas at depths ranging from 10 to 200 metres in the western basin of the Mediterranean Sea, in the Adriatic Sea and some areas of the Aegean Sea. It is enlisted as Vulnerable (VU) in the IUCN Red List. Its populations can be found in the Medes Islands MPA in Spain, the Portofino or the Tremiti Islands MPAs in Italy (Otero M.M. et al., 2017).

  Eunicella cavolini (von Koch, 1887): the yellow gorgonian forms large, bushy yellow colonies with multiple branches. It is usually found at depths between 5 and 40 metres. It is protected within the Scandola MPA in Corsica and it is enlisted as Nearly Threatened (NT) in the IUCN Red List (Otero M.M. et al., 2017).

  Eunicella singularis (Esper, 1791): the white gorgonian is a relatively small symbiotic species, with colonies reaching up to 20 centimetres in height. It is found in rocky areas and is usually located at depths ranging from 10 to 60 metres (Gori A. et al., 2012). Symbiotic dinoflagellates of *Symbiodinium* clade A (the so-called zooxanthellae) live inside its tissues making it the only symbiotic gorgonian in the Mediterranean Sea (Forcioli D. et al., 2011). It is enlisted as Nearly Threatened (NT) in the IUCN Red List (Otero M.M. et al., 2017).

Corallium rubrum (Linnaeus, 1758): the red coral is an Endangered (EN) (the IUCN Red List) species that creates animal forests in the Mediterranean Sea. It forms dense aggregations on rocky substrates at depths ranging from 10 to 300 metres (see Figure 11). These coral banks can support a diverse community of marine organisms, including fish, crustaceans, and other invertebrates. The biogeographic region is mainly in the NW Mediterranean Sea and the Southern Adriatic and the Ionian Sea. This species represents important trading commodity with high fishing pressure from most of the countries in the MS basin as its fishing is still not prohibited. Currently is being protected within Tombant des Spélugues MPA in Monaco, Regno di Nettuno MPA in the Gulf of Naples or Portofino MPA in the Ligurian Sea among others (Otero M.M. et al., 2017).

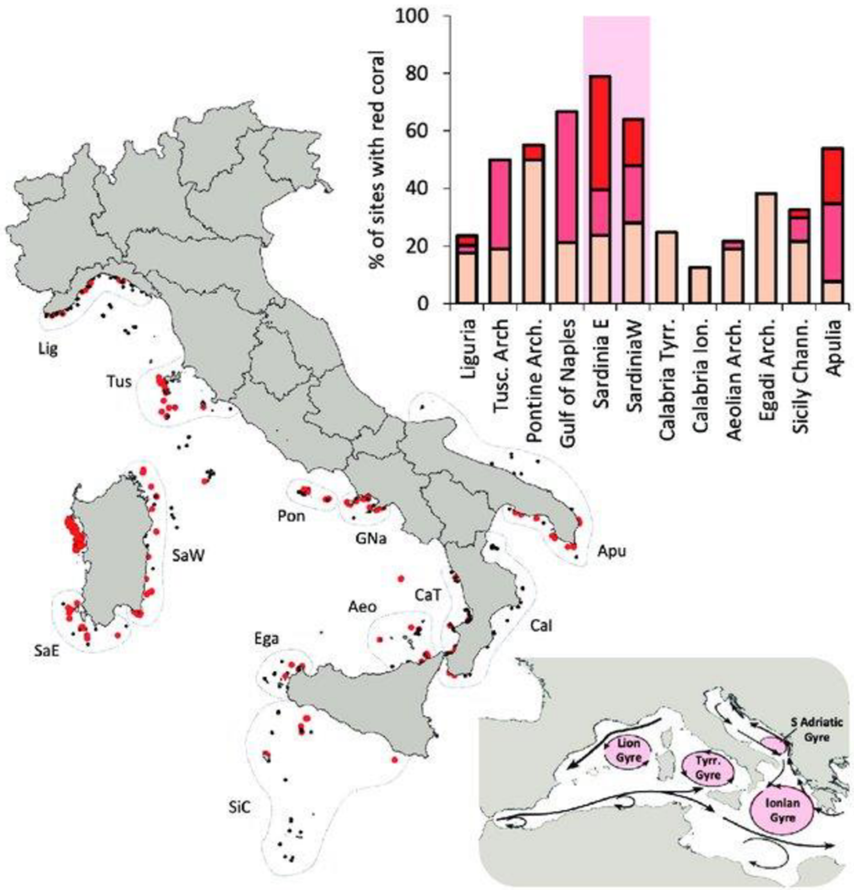


Figure 11: Distribution of *Corallium rubrum* along Italian coasts with detail of the main Mediterranean currents (bottom right) (from: Toma M. et al., 2022)

- Helioporacea - commonly referred to as blue corals due to their distinctive blue or greyish colour. They are colonial corals, not native to the MS. In tropical waters are important animal-forest builders (Otero M.M. et al., 2017).

- Pennatulacea - commonly known as sea feathers or sea pens, this order includes around 200 species of colonial Anthozoa with a soft, fleshy body and a central axis that supports a series of feathery polyps. They live in soft sediments. Important aggregations of *Funiculina quadrangularis* (Pallas, 1766) have been found in the Sicilian Channel, the Adriatic Sea, the Gulf of Lion, the Algerian waters or around the Balearic Islands, while *Pennatula* spp. and *Pteroeides spinosum* (Ellis & Solander, 1786) are abundant in several spots, including on or around seamounts in the Alboran and Tyrrhenian seas. The forests they form are considered Essential Fish Habitats (EFHs) by the General Fisheries Commission for the Mediterranean (GFCM) and the European Commission. They are characteristic species of CWC habitats together with bamboo corals (Isidiidae) (Otero M.M. et al., 2017).

4.3.4. Biological properties of corals

Corals, as mentioned before, are habitat-building species that use calcium carbonate (CaCO3) in the aragonite (scleractinians and some octocorals) or calcite (in Corallium rubrum and other octocorals) form to build their branched, whip, boulder or plate-like structure (Conci N. et al., 2021). In the gorgonians, the structure is sometimes supported with gorgonin, which is a group of scleroproteins (Conci N. et al., 2021) and in some cases, the calcite is substituted by calcium phosphate in the hydroxyapatite form (MacIntyre I. et al., 2000).

The distribution of phototrophic corals, that host zooxanthellae, is correlated to latitude-dependent factors like solar radiation, temperature and aragonite saturation, as well as to those factors affecting also heterotrophs like substrate, depth, hydrodynamics, salinity, dissolved oxygen or siltation regime (Mantas T. P. et al., 2022; Muir P., 2015; Kleypas J. A., 1999).

The findings about limited latitudinal gradient for corals as invertebrates occur due to their correlation to latitudinal attenuation of photosynthetically available solar radiance during winter months. It contradicts the general belief of switching tropical species of corals towards the poles as the warming of the world's oceans progresses. The MCEs in the tropics comprise different biodiversity to the higher latitudes (Muir P., 2015).

With a latitudinal range of about 30-45°N the Mediterranean Sea is on the very edge of the latitudinal extension of coral reefs, these latter generally tending to increase towards the equator. As an example, the species richness of staghorn corals seems to follow a latitudinal trend, regardless of the depth category (Muir P., 2015; Figure 12).

In the MS it is possible to find coral species that are zooxanthellate in shallow waters and azooxanthellate at upper mesophotic depths (e.g. Eunicella singularis in Gori A. et al., 2012).

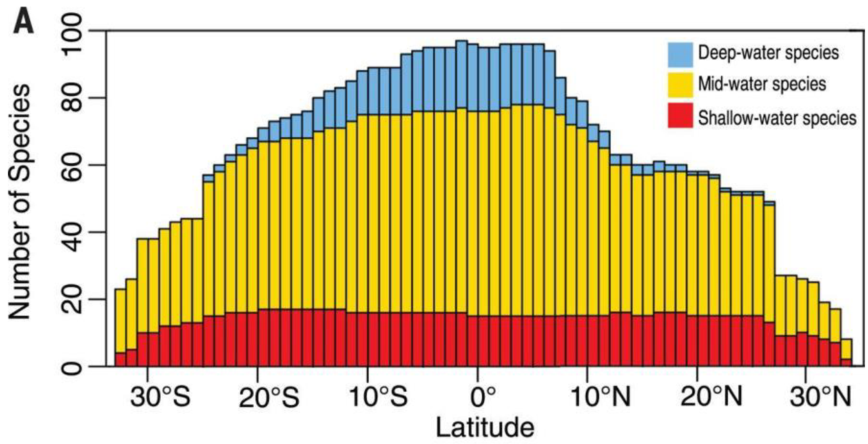


Figure 12: Global latitudinal trends in staghorn coral species richness (from: Muir, P. et al., 2015)

Recent studies focusing on species ecology in order to understand effective conservation efforts are slowly uncovering the mysteries about corals' preference in diet, temperature, and physical and chemical features of seawater. As regards temperature, investigations on Eunicella singularis reveal that deeper populations (-35m) of this species show higher tolerance to temperature changes in comparison with shallower (-15m) ones (Pey A. et al., 2011). In general, during the experimental study of Previati M. et al. (2010) gorgonians from the TMEs proved to follow Shelford's law of tolerance, indicating that an optimal temperature range exists for *Paramuricea clavata, E. singularis, E. cavolinii*, and *Corallium rubrum*.

Seasonality affects coral species on many levels regarding water movement, seston abundance (Coppari M. et al., 2019), temperature trends and irradiance itself, leading to Summer-induced lower activity due to scarcity of food sources (Coma R. et al., 2000) and in some species even to estivation (Summer dormancy; Bryozoa or *Alcyonium acaule* (Marion, 1878); Coma R. et al., 2000). This seasonal pattern in anthozoan species is sometimes affected by marine heat waves (MHWs) which have potentially negative effects due to weakened colonies leading to MME (Coma R. et Ribes M., 2003). The highest growth rates are observed from Winter until Spring, the same goes for zooxanthellae concentration, while in Spring and Autumn reproduction occurs following species-specific cycles (Semeraro D. et al., 2022; Grinyó J. et al., 2018; Rodolfo-Metalpa R. et al., 2008; Coma R. et al., 2000).

Particulate organic matter (POM) plays an important role in the diet of corals, especially at mesophotic depths, where POM can represent between 25 and 44% of the diet (Tsounis G. et al., 2006).

An essential part plays mucus secretion, which seems to be involved in the immunity system of corals. Its role mainly regards the lubrication of the epithelium against desiccation (in shallow waters), feeding (trapping and ingestion of POM), defence against pathogens and sediments (de-shedding) and the possible effect on commensal microbiota, while at the same time, mucus overproduction is one of the signs of stress (Savoca S. et al., 2022).

4.3.5. Ecosystem services of the MCEs/TMEs and their importance

The MCEs of the Mediterranean are living proof of the mid-domain effect, which describes the shift of species towards the centre of a shared geographic area, in this case of course in vertical perspective making it a key transition zone between shallow and deep waters (Cerrano, C. et al., 2019).

The species of MCEs form both algal and animal forests, which have an important role in Benthic-pelagic coupling (BPC) through changing water flows and particles compartment as well as regulative in competitive interactions through co-evolution leading in all sorts of mutualism, parasitism and commensalism. With their existence, they create a sort of buffer zone for the resuspension processes and shadowing of lower levels (Cerrano, C. et al., 2019) (see Figure 14). Through these properties and the creation of 3D-like structured habitats, they are important ecosystem engineers together with Porifera (Angiolillo M. et Canese S., 2018; Ponti M. et al., 2018; Valisano L. et al., 2016; Cau A. et al., 2015) and are providing habitats with high biodiversity accumulation.

Corals are known to play an important part in trophic, mutualistic and other nets, having a variety of symbionts, parasites and commensals such as sponges, polychaetes, platyhelminthes, nematodes, molluscs, bryozoans, barnacles, vermetid gastropods, bivalves, tunicates, hydroids, crustaceans or even other anthozoans (Mantas T. P., 2022; Chimienti G. et al., 2020; Angiolillo M. et Canese S., 2018; Liu J., Høeg J., Chan B., 2016; Bianchelli S. et al., 2013; Rowley S., 2008; Ben-Tzvi O. et al, 2006; Scaps P. et Denis V., 2007; Floros et al., 2005; Tapanila, 2004) but it is important to mention they provide crucial habitat for juvenile and small fish, squid and fish eggs and larvae too (Chimienti G. et al., 2020; Bo M., Bavestrello G., Angiolillo M. et al., 2015; Baillon et al., 2012; Etnoyer and Warrenchuk 2007).

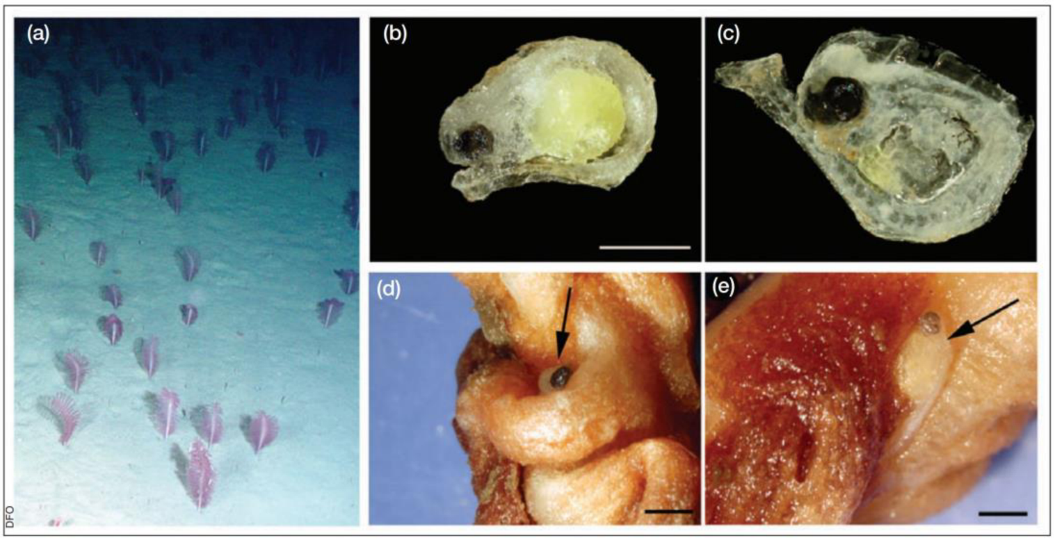


Figure 13: Field of sea pens and fish larvae of *Sebastes spp.*, potential Essential Fish Habitats

"(a) Field of sea pens. Larvae of redfish (Sebastes spp) were found with yolk sac either (b) present or (c) nearly resorbed. (d,e) Fish larvae (arrows) tucked among polyps of Anthoptilum grandiflorum. Scale bars = 1 mm." (From: Baillon et al., 2012)

The comprehensive net of relationships is still being studied and has been questioned in past decades, such as the hypothetical mutualistic relationship between tube-dwelling worms and stony corals (Dieni I. et Massari F., 2021) or if MCEs/TMEs not only being vulnerable marine ecosystems (VMEs) they should be categorised as essential fish habitats (EFHs). An example can be the study of Baillon S. (2014), where they found the strong bond of larvae of fish *Sebastes spp* to the sea pens (Pennatulacae) in the North Atlantic (see Figure 13) (Baillon S., Hamel J.F., et Mercier A., 2014). It is highly expected that MCEs and TMEs specific nets will be monitored in the upcoming years with a more dedicated focus on these newly studied environments with shared knowledge of other VMEs.

Some relationships seem to be crucial for corals such as the presence of calcareous encrusting algae which provides the necessary biogenic substratum crucial for the growth of some hard-substratum preferring species of corals forming together the coralligenous assemblages (Trainito E., 2021). Yet it is not the only known habitat typical for corals of the MS (Trainito E., 2021, Corriero G. et al., 2019). As it was incorrectly assumed that in Boka Kotorska Bay, Montenegro there are coralligenous assemblages, the outcomes proved that few species of corals can create their biogenic concretions which could be described as coral reefs in *sensu lato*.

The macrobenthic community seems to be generally understood while another role of corals functioning as holobionts needs to be studied to map the "nested" ecosystem of microorganisms living on or in the corals providing possible health and immunity responses (Pita L. et al., 2018). The exemplary and well-studied relation is with endosymbiotic dinoflagellates which provide 90% of the energy in corals in exchange for protection and even facilitate the calcification production in their exoskeleton (Savoca S. et al., 2022). One of the recent studies proved the linkage of temperature to the microbial structure of mesophotic coral holobionts suggesting the increasing temperature anomalies have a significant effect on MCEs/TMEs too (Corinaldesi C. et al., 2022).

In the reflection of the present research outcome, it is assumed that MCEs/TMEs have significant variability in alpha and beta diversity pointing to the heterogeneity of these distinguished habitats (Cau A. et al., 2015) and in some cases even highlighting their biodiversity hotspot role over shallow reefs (Pérez-Rosales G., 2022).

EUNIS habitat map (see Figure 15) is a recent technical modelling study on habitats not only in the Mediterranean Sea and completes the overall understanding of the habitat composition. The estimated substratum character of the MS is very diverse in the Western part in comparison to its Eastern habitats which are mainly characterised by the deep environments. The coral species are mainly connected to rock and other hard substrata composed with biogenic compositors of dead organisms (Corriero, G. et al., 2019) but on the other hand order Scleractinia - Fungiidae (Chadwick-Furman N., Loya Y., 1992), subphylum Ceriantharia (Shepard A. et al., 1986) or order Pennutulacea (Williams G.C., 2011) were found or is generally known they prefer soft sediments, creating animal forests in a relatively barren land.

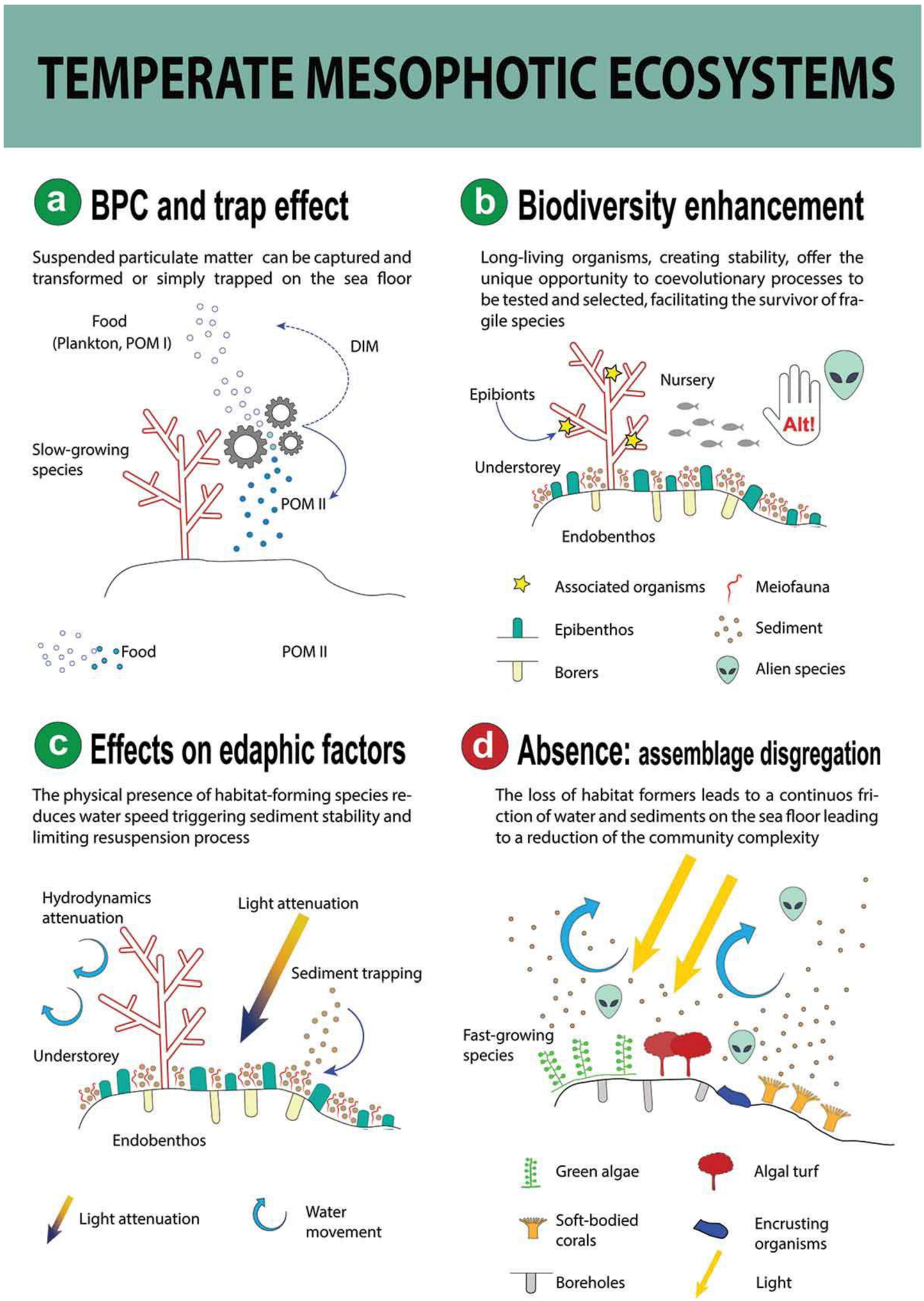


Figure 14: Schematic representation of the effects of presence and loss of Temperate Mesophotic Ecosystems (TMEs)

"(a–c) A healthy TME (green circles) has a three-dimensional architecture hosting five main levels of benthic organisms (long-living animal forests, epibionts, juveniles of vagile species, communities of the understorey and the endobenthos). This ecosystem regulates edaphic factors driving the development of sciaphilous communities (d) Unhealthy TME (red circles) shows loss of mesophotic forests, leading to a bi-dimensional ecosystem, dominated by fast-growing species tolerant to light exposure and sediment rain." (From: Cerrano, C. et al., 2019)

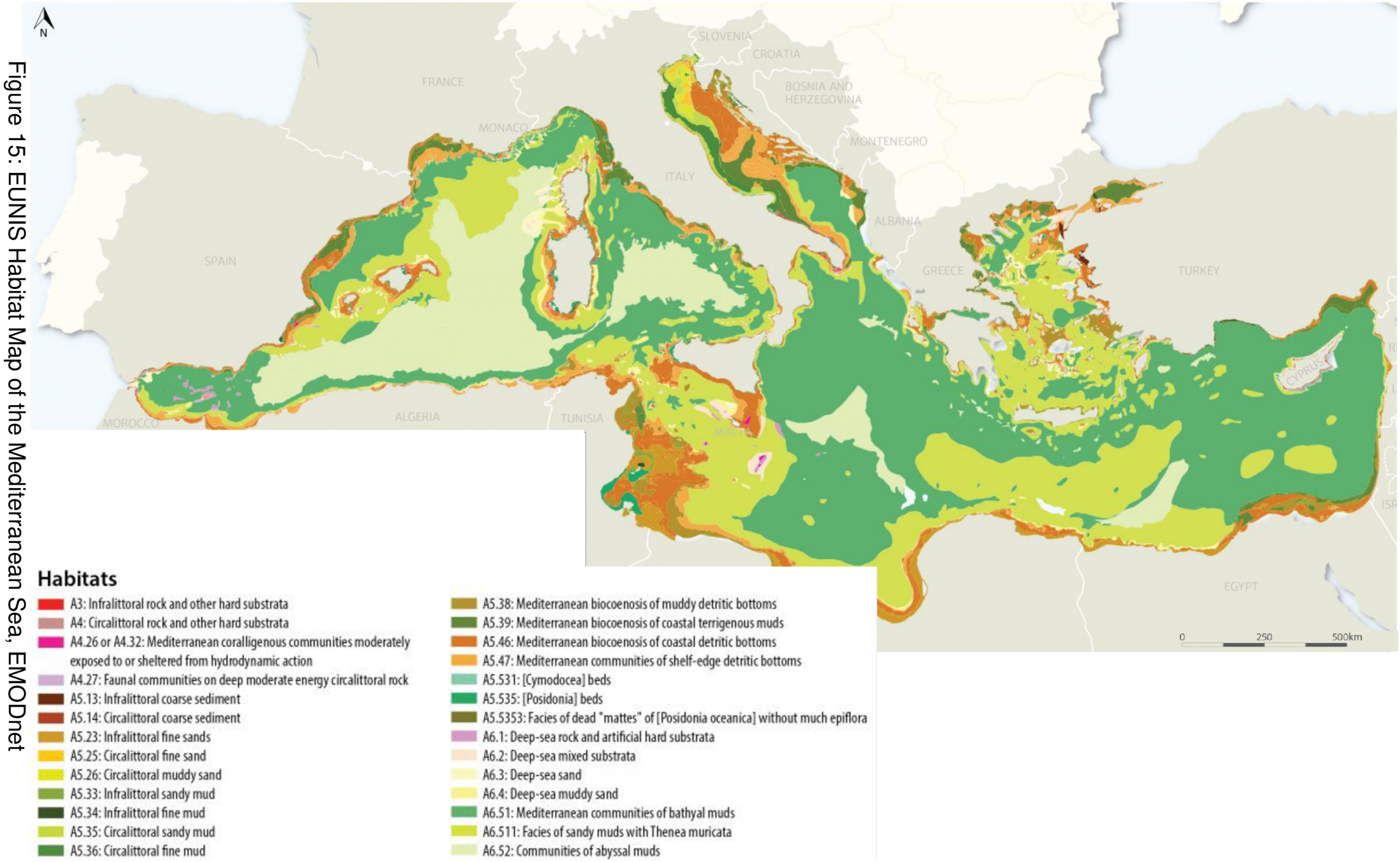


Figure 15: EUNIS Habitat Map of the Mediterranean Sea, EMODnet
(From: Jacques, P. et al., 2017)

4.4. The Mesophotic Coral Ecosystems

4.4.1. Mesophotic Coral Ecosystems (MCEs) and Temperate Mesophotic Ecosystems (TMEs) as a new term

Mesophotic coral ecosystems, further MCEs, can be characterised as light-dependent coral (and other species) reef communities occurring naturally in depths between 30m to 150m in some specific clear areas, geographically scattered mostly in tropic and subtropic oceans and seas (Hinderstein L. et al., 2010). They occupy the so-called circalittoral zones and continental shelves, along the coastal areas and seamounts (Angiolillo M. et Canese S., 2018). The upper limit is artificial, reflecting the limit for recreational SCUBA diving. The bottom limit is marked with the maximum depth at which the light-dependent zooxanthellae corals exist. More suitable definition is stated by Castellan G. (2022): "...the euphotic zone, where irradiances sustain net positive photosynthesis, whose lower bound (i.e., compensation point) is historically set at 1% of the surface Photosynthetically Active Radiation (PAR)." But nowadays we know that rare symbiotic communities can be observed below this depth due to adaptations of the species zooxanthellae, using chromatophores of its host, which emit amplified blue light suitable for photosynthesis (Gill G. et al., 2004).

The term MCEs is rather new and known only for the last decade and was formally established during the first International MCE workshop in Jupiter, Florida in 2008 (Pugliese K. et al., 2009; Hinderstein L. et al., 2010). The previous studies covering these zones were referring to deep-coral, twilight zone, twilight reefs or deep outer reefs (Loya Y., 2019). The main organisms representing habitat-forming groups are hard and soft corals (Anthozoa), encrusting algae and/or sponges (Porifera). The habitat is so unique that apart from containing species from shallow reefs there can be found endemic and wide groups of both generalists and specialists connected only to the MCEs (Loya Y., 2019).

On the other hand, the overall stability and complexity of the ecosystems of MCEs are roughly studied through diverse species and their interactions generally neglect the speciation processes in marine ecosystems. It is known that the geological and biological stability of habitats, their isolation, and avoidance of disturbances are the reason for emerging endemism in different areas around the world (Cerrano, C. et al., 2019). The novel term for the biogeography of MCEs called "Habitat Persistence

Hypothesis” has been formed by Pyle et al. (2016) mainly describing the situation of the MCEs in the Indo-Pacific region covering the evolution of shallow reef species which were eliminated in regions with steeper bathymetry and stuck only to sloped regions whereas the MCEs persist in all regions. The primary implication of this hypothesis is that cyclic recolonization of islands occurred on shallow parts due to changing sea levels in glacial times but remained relatively stable for the MCEs where speciation and endemism had a chance to strongly occur as it is known nowadays (Loya, Y. et al., 2019).

It is estimated that apart from MCEs holding an abundance of biodiversity the reefs make up more than 80% of all coral reefs in the world based on the depth perspective (Loya Y., 2019).

Nevertheless, the level of protection of MCEs is overall very low, as can be understood from the study of Eilat MPA, Israel, less than 13 % are protected on any level in this area (Eyal G., 2019). Another example is the Chagos MPA, in British Indian Ocean Territory, one of the largest protected areas, which covers only around 10 % of MCEs in the area of the Indian Ocean basin (Sheppard et al., 2012).

The deep reef refugia hypothesis, emerging with the newly studied MCEs, about the crucial role of the MCEs in the transition of species of the shallow reef has been partially proven in recent years (Laverick J.H. et al., 2018) and while it works only in some cases where vertical connectivity importance of the habitat is understood, the horizontal transition of the species between each MCEs is still unknown (Kahng S. E. et al., 2014). Yet Loya Y. states whereas there are locations where high connectivity is proven, it works better for mobile species over sessile ones and the full-scale studies on connectivity were still neglected in past years. Thus these statements should be considered preliminary and more focus should be pointed towards this perspective (Loya Y. et al., 2019).

Studies have discovered the richness of the MCEs in terms of unique biodiversity is possessing not only species freely transiting between shallow and mesophotic areas but holding a huge bank of depth specialists specifically adapted to the MCEs and lower light conditions (Kahng S. E. et al., 2014; Laverick, J.H. et al., 2018). While there was a generic description of MCEs as depth-dependent, with the top border mainly restricted by the limits of recreational SCUBA diving (30 m or 40 m for deep diving specialities)(Pyle 1996; Menza et al., 2008), the coral communities are better assorted by light factors rather than the depth or temperature itself (Kahng, S. et al., 2010).

Nevertheless, the area of the MS is relatively small in comparison to other world oceans and seas (with only 0.7% of the total size of these marine waters) it holds an enormous biodiversity bank of 8% of all discovered marine species (Costello, M. J., 2010). According to Bianchi and Mannino (Bianchi C. et Morri, C., 2000; Mannino A. M. et al., 2017), the scale is between 4 - 18% of world marine species. Yet it is important to realise that research is positively correlated to the GDP (Fisher et al., 2011; Loya, Y. et al., 2019) and more than 80% of oceans are still unexplored mainly due to their remoteness and extreme environments such as depth and high-pressure conditions (US Department of Commerce, N.O.and A.A., 2009).

The term MCEs or older used term twilight zone emerging in studies was analysed in the study of Cerrano C. et al. (2019), discovering that most articles were in the Tropical Atlantic, nearly 44.2% of all studies found. In comparison, the Mediterranean Sea, as a part of the Temperate Northern Atlantic, encompassed only 10.8% of all studies (Cerrano C. et al., 2019). This phenomenon can be understood from the map provided in the mentioned study (see Figure 16) and reflects the obvious focus at the lower latitudes where the generally known effect of a latitudinal gradient of biodiversity occurs and corals are no exception.

The region of the Mediterranean Sea should be referred to as the Temperate Mesophotic Ecosystems (TMEs), as it was called during the European Coral Reef Symposium in 2017 (Laverick, J. et Rogers, A., 2019). It is a part of the realm of the Temperate Northern Atlantic, and the term encompasses different conditions in comparison with well-studied tropical and subtropical regions of MCEs (Cerrano, C. et al., 2019). Yet this term has been newly introduced with a few studies using it in recent years. As it was stated by Loya Y. (2019), the term MCEs does not correctly cover the specificity of the Mediterranean Sea, and thus should not be considered in the MCEs definition (Loya, Y. et al., 2019). For these reasons, the Mediterranean Sea is often neglected in literature reviews and summary reports about MCEs. TMEs are instead habitats which have upper limits determined by the depth reached by 1% of surface irradiance and lower limits defined by the deepest extent of benthic primary producers (Cerrano, C. et al., 2019).

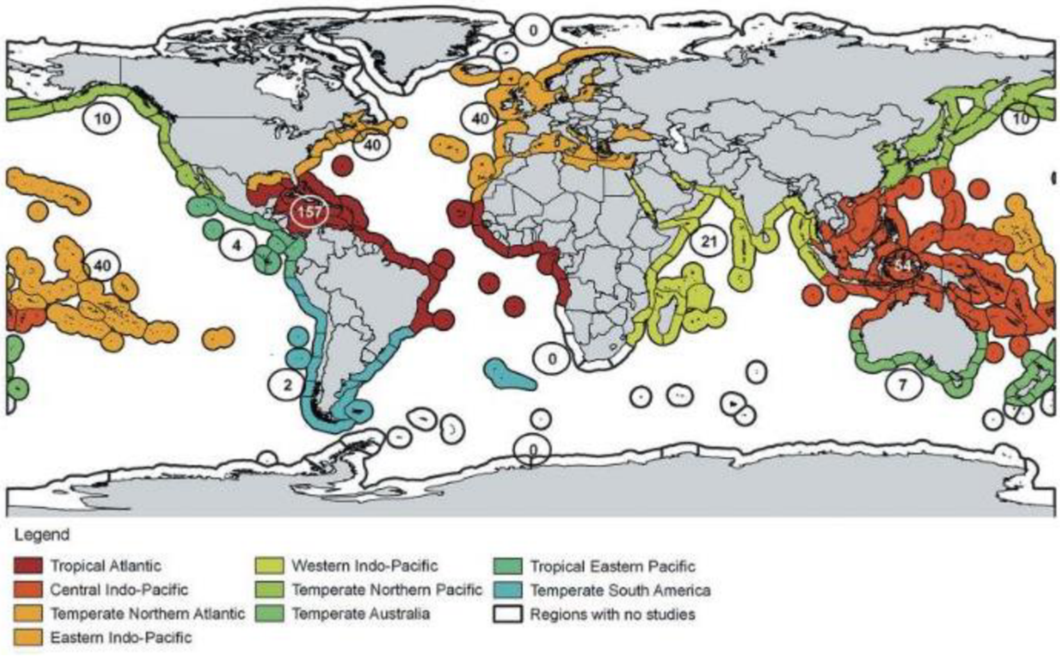


Figure 16: Geographic distribution of the studies on mesophotic ecosystems (MCEs) (from: Cerrano C. et al., 2019)

The MCEs have proved to be environments highly dependent on light levels penetration and water temperature. While in the tropics there are quite huge differences between each level with the thermoclines effect occurring at the different depths due to the changes in season of the year and the day (Loya, Y. et al., 2019).

4.4.2. The upper and the lower mesophotic zones

The mesophotic coral ecosystems are divided within the scientific community into upper mesophotic and lower mesophotic zones. The depth limit where is the transition happening is oriented around 60 m, on the other hand, the border still needs to be discussed as there are locations where the zone is at 55 m (Dustan P. et Lang J. C., 2019) and in some can be even reaching 70 or 80 m (Francini-Filho et al., 2019; Eyal et al., 2019). Few publications (i.e. Rocha et al., 2018; Goodbody-Gringley et al., 2019; Montgomery et al., 2019; Sinniger et al., 2019) even used a three-level approach with the upper, middle and lower mesophotic zones, with the borders set to 60 m and 90 m. But as Loya Y. (2019) stated, not all these studies reflected real biodiversity according to the bathymetry.

On the other hand, the robust meta-analysis on mesophotic conditions and the breaking point of the 60 m depth line has proven the general borders of change in the environments (Lesser M. P. et al., 2019) supported by studies on irradiances (Lesser M. et al., 2021; Tamir R. et al., 2019).

4.4.3. Confusion in the use of terms and possible Cold water corals (CWC) studies concerning MCEs/TMEs

While there is an established scientific community concerning the Mesophotic Coral Ecosystems, apart from the geographically correct inclusion, i.e. using TMEs when it is relevant to the temperate mesophotic locations, the community tends to refer to MCEs as Cold Water Corals (abb. CWC) too. The unclarity of bathymetry regions and the fact that many expeditions tend to focus on lower depths (Grinyó J.et al., 2020) due to the enormous costs of using remotely operated vehicles (abb. ROVs) and submersibles are leading to mixing the studies into generally described as CWC even if there are MCEs/TMEs studied (as in Estévez R. M. et al., 2022; Savoca S. et al., 2022; Montseny M. et al., 2021a; Lo Iacono C., Orejas C., Gori A. et al., 2011).

4.4.4. New nomenclature concerning the different depth zones

A new set of terms has emerged to differentiate between the various depth zones in the ocean. Although relatively new, the shallow coral reefs can now be designated as the altiphotic zone. The area with moderate light conditions, which starts with a recreational SCUBA diving limit and goes down to a depth of approximately 130 m, is known as the mesophotic zone. The most recent term, the rariphotic zone, refers to depths that extend beyond 130 m and reach at least 309 m (Baldwin, C.C. et al., 2018). The zoning system in this scenario was established by analysing the tropical reef and fish communities of the local Curacao area. However, while the classification is largely based on fish depth preferences, it does not perfectly align with the distribution of coral species. Instead, the grouping of zones is mainly determined by the families of fish that are closely associated with shallow-reef species (known as altiphotic families), rather than those found in typical deep-sea environments. This observation provides a significant indication of the interconnectedness of the various zones.

4.5. Challenges and Impacts on Ecology of Corals of the Mediterranean Sea

It is known that shallow coral reefs face many challenges in the Anthropocene and it is no different in MCEs around the world. Impacts such as climate change, ocean acidification (due to rising levels of CO_2), run-off from land and sedimentation, higher disease and bleaching risks, thermal stress, overfishing, and severe storms are just named the main stress effects on coral ecosystems (Loya, Y. et al., 2019; Smith et al., 2019; Weil E., 2019). The importance is to study each region and understand its physical properties and local stresses occurring. For example, the sedimentation might not be a general challenge for some parts of the MCEs but due to the direct connection to the shore and slope, there might be locations facing this stress abnormally, i.e. Bonaire and Curaçao (Frade P. R. et al., 2019) or the Philippines (Cabatian P.C. et al., 2019). The overall impression of MCEs remoteness from the daily heavy disturbances in shallow reefs, considering attenuation of wave energy (Kahng et al., 2010), reduced temperature including heat stress, and attenuation light (Glynn P.W., 1996; Bridge et al., 2013), has led to establishing a hypothesis "Deep Reef Refugia" in the scientific community (Pinheiro H. T.et al., 2019).

4.5.1. Deep reef refugia hypothesis (DRRH)

Concerning the stress and predicted threatened status by 2050 for all the shallow coral reefs (Zeitvogel, K., 2011), the hypothesis of deep-sea refugia appeared in the past decades and the crucial role of MCEs has been estimated since then. Especially from the perspective of being an active deposit of potentially threatened organisms from shallow waters (Bongaerts et Smith 2019; Rowley 2014; Smith, T. et al., 2013).

It was believed that MCEs were also less vulnerable due to their stability but this has been questioned in upcoming studies (e.g. Weiss K.R., 2017; Rocha et al. 2018; Pinheiro H. T. et al., 2019). While some populations are occurring in both shallow and mesophotic areas, it does not cover all the populations and species. It has been confirmed that MCEs work as short-term "refuges" especially for mobile species, on the other hand, there is still missing evidence for the "refugia" effect, which would work over a longer period (Loya, Y. et al., 2019).

Bongaerts (2019) describes another term connected with the deep reef refugia, ‘deep resilience areas’ which cover areas where disturbances occur yet the species have time to adapt or recover from it (Bongaerts et Smith, 2019). The current observations proved that MCEs, as well as TMEs, face the disturbances equally. For instance the expedition in the Bahamas, where SCUBA divers monitored the impacts of Hurricane Matthew (which occurred on 5 and 6 October 2016) and bleaching events from shallow to lower-mesophotic zone 135 m deep. In the MCEs were found heavily affected parts, covered with sedimentation and destructed parts, with fragments scattered from the shallow reefs together with terrigenous debris (Rocha L.A., 2018).

The concerns about the evaluation of the refugia effect of the MCEs have led Kavousi J. (2018) to form six factors which define the capacity of refugia. Key terms like long-term buffering or multi-stressor protection are essential for protecting coral reef species from anthropogenic factors, while terms like accessibility, microclimatic heterogeneity, size or low exposure to other disturbances determine the capacity of refugia and are rather important from a conservation planning perspective (Kavousi J. et Keppel G., 2018). It is important to realise that without the first two, the rest would be hardly considerable and should always reflect their superiority.

In addition to these factors, there appears a new idea of shallow coral reefs (SCRs) having a role as refugia for MCEs (Montgomery A. et al., 2021), and in general deepening and specifying the formulation of the hypothesis for individual areas of the regions. Next to it comes the uniqueness of each MCEs/TMEs or formulation of shared or isolated threats. Overall the MCEs/TMEs should be protected within existing MPAs, concerning the possibility of SCRs connectivity in biodiversity turnover, as well as establishing new areas focused specifically on unrivalled habitats (Montgomery A. et al., 2021).

4.5.2. Negative influence on the Ecology of the Anthozoa of the Mediterranean Sea

Once the role of TMEs is uncovered, with it comes the unfortunate state of these ecosystems. Most of them currently show signs of occurring stress. Following chapters are just highlighting some of these influences (see Figure 17), which might not be as difficult if occurring alone, but the complexity of these negative influences, which can work as multi stressors, is important to take into account during further studies of these environments, as has been discussed in the study of Bell J.J. et al. (2022).

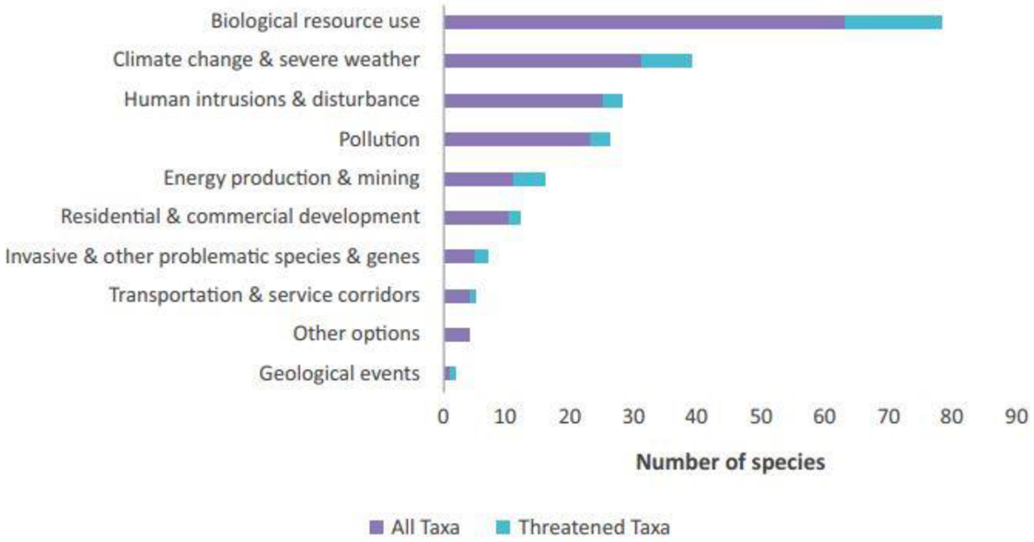


Figure 17: Summary of threats to all 136 native species assessed in the Mediterranean region as identified in the IUCN Major Threats Authority File. Biological resource use are fishing practices, being the major threat together with climate change and other anthropogenic disturbances like tourism (from: Otero M.M. et al., 2017).

4.5.3. Physical damage to the populations

According to Linares C., et al. (2007), TMEs corals as slow-growing species are potentially at risk of extinction and endangerment through anthropogenic disturbances. It is known that gorgonian population growth is shown to be more sensitive to changes in survival rates than to changes in growth, shrinkage, or reproductive rates. Stabilisation of the red gorgonian community can take up to 50 years according to models, which have predicted the distribution of stable communities pointing to their fragility since the populations are generally declining and facing a high risk of extinction within the next decades (Cupido R. et al., 2009; Linares C. et al., 2007; Linares C. et al. 2005).

Gorgonian colonies can sustain injuries from mechanical abrasion and predation, or necrosis of living tissue due to stress conditions caused not only by persistent thermal anomalies. These stress conditions can result in partial or total mortality of the colonies or lead to the recolonization of different species potentially overgrowing them and threatening the colony with competition pressures (Sini M., 2015).

Furthermore, the mechanical interactions with corals and other species can lead to changes in properties in their populations (Conover et al., 2009). Coral harvesting of *Corallium rubrum (Linnaeus, 1758)* has proved to have an effect on the size reduction and created colonies grass plain-like (small in size) in populations in the MS which had been historically overharvested (Garrabou J. et al., 2017). The Marine Protected Area of Portofino proved to efficiently change this trend after protecting this species from further harvesting in recent decades returning to the forest-like structure of the environment (Bavestrello G. et al., 2014).

While modern large-scale fisheries are known for their devastating influence on the ecosystem like using a technique of bottom trawling, trammel nets, longline fleets, mechanically disturbing the benthic communities and even obtaining corals as their bycatch (Williams A. et al., 2020). Fishing has an impact even if the fishermen discard the net into the sea and this marine litter known as Derelict Fishing Gear (DFGs) is causing another disaster in benthic communities (see a review of Angiolillo M. et Fortibuoni T., 2020). The marine litter is a huge part connected to the run-off of pollutants from land too and the MS is not spared of this pressure too. The physical entanglement and destruction or debris resuspension followed by siltation, the litter decomposition in the form of microplastics on the TMEs are one of the direct effects (Moccia D. et al., 2021).

The emerging socio-cultural heritage of small-scale fisheries (SSF) and the urgency to protect these activities can point to new ways to transform the fishing industry in the MS area. Historically the SSF are known to function in ecological manners as the artisanal fishers tend to respect and follow nature patterns, time of the year and mating periods. The importance is to highlight that due to the limitation of their vessels and their usual distribution in their regions within 25 miles, SSF tends to catch more sustainably in these environments.

Another emerging devastating impact, apart from the bottom trawling and other destructive fishing practices, can be caused by deep-sea mining (DSM) (or dredging and anchoring) whose no net loss is impossible to currently achieve and raise many concerns as is mainly destroying CWC habitats (and coastal benthic habitats) directly without uncovered impact on other ecosystems including the mesophotic (Niner H.J. et al., 2018). The increased turbidity and light penetration can be just a peak of the iceberg as well as the change in chemical properties of seawater affected directly by the activities up to the unknown transfer of pathogens stored in the sea detritus again resuspended in the water and the siltation effect on existing and newly forming benthic ecosystems (Jones R. et al., 2020; Erftemeijer P. et al., 2012).

4.5.4. Climate change, physical-chemical and meteorological influences

Global climate change has not been avoiding the Mediterranean basin and through temperature anomalies and to them connected Marine Heat Waves (abb. MHWs) the marine habitats have been exposed to new emerging stress.

A Marine Heat Wave refers to a temporary occurrence of unusually high surface temperatures. It is characterised by a period of at least five consecutive days during which there is a significant rise in daily temperatures above the warm temperature extreme anomaly level (Oliver E. et al., 2019). The warm temperature extreme anomaly level is determined by comparing the daily temperature distribution during a given time and place with the temperatures recorded during a climatological period that spans approximately 30 years. Specifically, any temperature that exceeds the 90th percentile of this climatological distribution is considered a daily warm extreme anomaly (Oliver E. et al., 2019).

As a matter of fact, the shape of the Mediterranean Sea is a semi-enclosed sea, and the impacts of climate change are 20% faster with respect to the global average (UNEPMAP, 2022). The MHW indices have increased rapidly in the past 4 decades showing an increasing long-lasting trend in the vertical distribution of the MHW effect, all temperature, salinity and density changes are observable in the altiphotic and mesophotic zone (down to 150m) (Melanie J., Fernandez-Mora A., Tintoré J., 2022).

One of the effects of climate change and rising average temperatures are vertical shifts of species which prefer shallow euphotic (altiphotic) zones and are transiting towards deeper cooler parts (Jorda G. et al., 2020). These events can potentially cause higher competition and rearrangements of trophic nets in the mesophotic due to compression of the suitable habitat. While this can favour fast-growing and evolving species, corals could be possible losers of this game for their known late maturity (10-15 years) and generally slow growth rates (< 1cm). The species *Oculina patagonica* proved to be one of the first adaptors in the Eastern MS already responding to the changes in its environment (Martinez S. et al., 2021).

Eunicella cavolini is one of the species vulnerable to rising temperatures and anomalies as it is proven by Mass mortality events (abb. MME) in the NW Mediterranean (Cerrano C. et al., 2000) or Tyrrhenian Sea (Gambi, M. C. et Barbieri F., 2012). While the rising temperature itself does threaten the corals (Garrabou J. et al., 2009), the exposure can cause lower immunity resilience to the opportunistic pathogens, represented by microorganisms such as protozoans and fungi, which can cause extensive attack during temperature anomalies leading to MME (Bally M. et Garrabou J., 2007; Cerrano C. et al., 2000).

While there can be still found some temperature generalists whose holobiont role is not strict to its microbial communities, making it true generalist (van de Water J. et al., 2020) such as *Antipathella subpinnata,* which under short-term experimental biological studies does not show any stress symptoms, necrosis nor mortalities even with highest predicted temperature levels for the MS in 2100 (Godefroid M. et al., 2022), the changing conditions might be favouring other species who might become stronger competitors such as algae (Chimienti G. et al., 2021) and it is likely that species will not face one threat at the time but might be exposed to a complex scale of direct and indirect stress factors.

The MME has recently grown in abundance in connection to the MHW in the MS so it has led to the creation of a database which monitors such events. One of the most threatened groups reported is pointing at Cnidaria (especially Anthozoa) and Porifera, which accounted for 85% of observations between the year of 1979 to 2017 (Garrabou J. et al., 2019). Yet it is important to highlight that both of these phyla are significant habitat-formers, thus are observable for divers and fishermen rather than small-size species which lead a cryptic or hidden way of life, potentially hiding the scope of the real problem. On the other hand, Anthozoa could be established as important bioindicators and overall habitat health information providers (Angiolillo M. et Canese S., 2018).

The slow life strategy of mesophotic corals has put them in threatening situations as an example from the Scandola MPA (the oldest MPA in the Mediterranean with strict protection) where *Paramuricea clavata* and *Corallium rubrum* have not recovered from the MHWs in 2003 (and further occurring until 2018) continuously leading to the general density reduction. The crucial effect of temperature anomalies is supported as the studied environments lacked other significant disturbances mostly of the physical character (Gómez-Gras D. et al., 2021).

The last mentioned, huge impacting phenomenon is ocean acidification (OA). Concerning corals, those who are symbiosis-dependent calcifiers and sessile are under the biggest threat as it has been studied in shallow coral reefs (Hassoun A.E.R. et al., 2022). The OA (decreasing pH) is influencing species from the larval settlement and development phase in *Astroides calycularis* (Pallas, 1766) (Carbonne C. et al., 2022) to the reduction of calcification (Hassoun A.E.R. et al., 2022). *Cladocora caespitosa* which is one of the potentially threatened species proved during experiments quite resistant to the OA expected by the end of the century (Carbonne C. et al., 2021; Rodolfo-Metalpa R. et al., 2011) same as *Balanophyllia europaea* (Risso, 1827) (Prada F. et al., 2017). Other species proved both negative and neutral reactions to the OA such as *Astroides calycularis* (Carbonne C. et al., 2021; Teixidó N. et al., 2020; Prada F. et al., 2017) or *Leptopsammia pruvoti* (Lacaze-Duthiers, 1897) (Prada F. et al., 2017; Movilla J. et al., 2015). From the TMEs animal forest species which were studied, *Corallium rubrum* experienced a significant decrease in the skeletal growth rate, aberrant spicules and possible effect of decreased metabolism during exposure to lower pH rates (Bramanti L. et al., 2013). The projected pH levels for the MS at the end of the century are suggesting a possible extinction risk for recent populations (Cerrano C. et al., 2013).

4.5.5. Sedimentation rains (floods, severe storms, erosions), eutrophication and pollution

The side effect of some practices like fishing or dredging or even ship traffic can cause sediment disturbances which increase the turbidity of water and can cover benthic ecosystems (Jones R. et al., 2020) or cause disease outbreaks (Chaves-Fonnegra A. et al., 2021), mesophotic ones are not an exception. Of course, turbidity is not caused mainly by anthropogenic influences but it can add to its extent. The natural and climate change-connected causes of turbidity are floods caused by heavy rainfalls, melting of snow, heavy storms and natural erosion caused by the activity of water and wind. While on a smaller scale, it brings nutrition (Bialik O. et al., 2023) to the oligotrophic waters, its overload can have devastating effects changing whole biocenosis and eutrophication might have consequences in hypoxia and extensive algal blooms (Micaroni V., 2022; Sellanes J. et al., 2021; Danovaro R. et al., 2020). The last mentioned is connected to human-induced activities like agricultural production and use of fertilisers (N and P) or fossil fuels, next to extensive aquaculture occurring in coastal areas the impacts can have cascading effects on many ecosystems in the MS area. For more information about the situation in the MS, pollution, and eutrophication see Cappelletto, M. et al. (2021).

Even if not in such power as is in the Tropical Atlantic or the Indo-Pacific Ocean, the MS faces tropical-like cyclones called “medicanes” (Mediterranean hurricanes; Cavicchia L. et al., 2013) in connection to the MHW. From the time of following measuring the weather patterns in the zone (1947 - 2021), there were over 89 medicanes, excluding severe storms which did not fall into this category, the number would be over 100 (Nastos P. et al., 2017). The effect of these events led to floods and landslides across the whole Mediterranean region. It is expected that the MCEs are affected the same way in the MS as in the regions like the Caribbean (Bongaerts et al., 2010), the Great Barrier Reef (Bongaerts et al., 2013) or Okinawa (White et al., 2013). But as a matter of fact that TMEs are generally still understudied, and the direct effect of medicanes on TMEs has not been studied thoroughly (using “keyword” research on mesophotic.org and scopus.com) apart from Betti F. et al. (2020) finding out the huge storm in 2018 caused a devastating effect on upper 25 m part of MPA Portofino, Italy or the Balearic Sea, Spain (Teixidó N. et al, 2013).

4.5.6. Invasive species and diseases

More and more the coral in the TMEs zones are under pressure from different species due to changing climate as well as an introduction through the Suez Canal, the Gibraltar Strait, ballast water or hull fouling from ships in the international shipping corridors. One of the most significant migration corridors of non-indigenous species has been even called by its name, the Lessepsian or Erythrean migration and is referencing the Suez Canal introduction of Indo-Pacific species in the MS zone. While there are known only a few successful anti-Lessepsian migrations, the entry from the Red Sea is for species from different taxa far easier. Especially because the current flows naturally into the MS due to the slope and altitude difference between the Red Sea and the Mediterranean Sea and also because the Red Sea ecological conditions have a higher salinity oligotrophic character (Howaida Y. Z., 2015). The introduction into the Eastern part of the MS is favouring the Red Sea species over native ones. The recent extension of depth to 24 m and the volume of the Canal have also enlarged the number of species introduced into the MS basin (Galil B.S. et al., 2019).

While Mannino A.M. et al. (2017) sees the introduction of Indo-Pacific species as the recolonization of Tethyan descendants instead of the drastic invasion of alien species the effect on TMEs is still hardly understudied, some others call these unnatural changes as tropicalization of the eastern Mediterranean Sea (Bianchi C. et Morri C., 2003). The conditions are changing as can be supported by *Oculina patagonica*, zooxanthellae stony coral which is “invading” the whole MS, growing in the shallow artificial and barren substrate where algae had been grazed by urchins. While some consider this species invasive (Serrano E. et al., 2018), others see it only as an opportunistic species natural to the MS taking advantage of the changing environment. The genetic evidence is not supporting any connectivity with the Atlantic populations and thus is contradictory to the invasive character which is generally assumed about this coral (Leydet K. et Hellberg M., 2015).

On the other hand, few Lessepsian species have been observed in depths greater than 200 m pointing to the underestimation of these species in entirely new and colder conditions. But as has been illustrated in the chapter about climate change, the conditions might be changing much faster favouring this invasion (Galil B.S. et al., 2019). The invasive Lessepsian nomadic jellyfish, *Rhopilema nomadica,* lionfish, striped eel catfish, rabbitfish or pufferfish are just a few mentioned from more than 452 species only from the Israel coast (Spanier E. et Zviely D., 2022). There are 986 species introduced in the whole basin, of which are 775 in the eastern Mediterranean, 249 in the central Mediterranean, 190 in the Adriatic Sea and 308 in the western Mediterranean (Zenetos A. et al., 2012).

With these specific conditions of semi-enclosed basin, the occurrence of a faster incline in water temperature down to the mesophotic zones, MHWs and the invasive species introduced through 2 main connections to the world oceans, the MS should be observed as the world model environment of these multi-level impacts on ecosystems. Next to the intensive ship traffic bringing more potential invasive species on their hulls and ballast water, as we already know from Mar Piccolo near Taranto, Italy (Longo C. et al., 2012). The MS is an ideal laboratory to study marine ecosystems under different stresses to bring closer the evolution of ocean ecosystems around the world facing climate change and anthropogenic-based pressures (Coll et al., 2010).

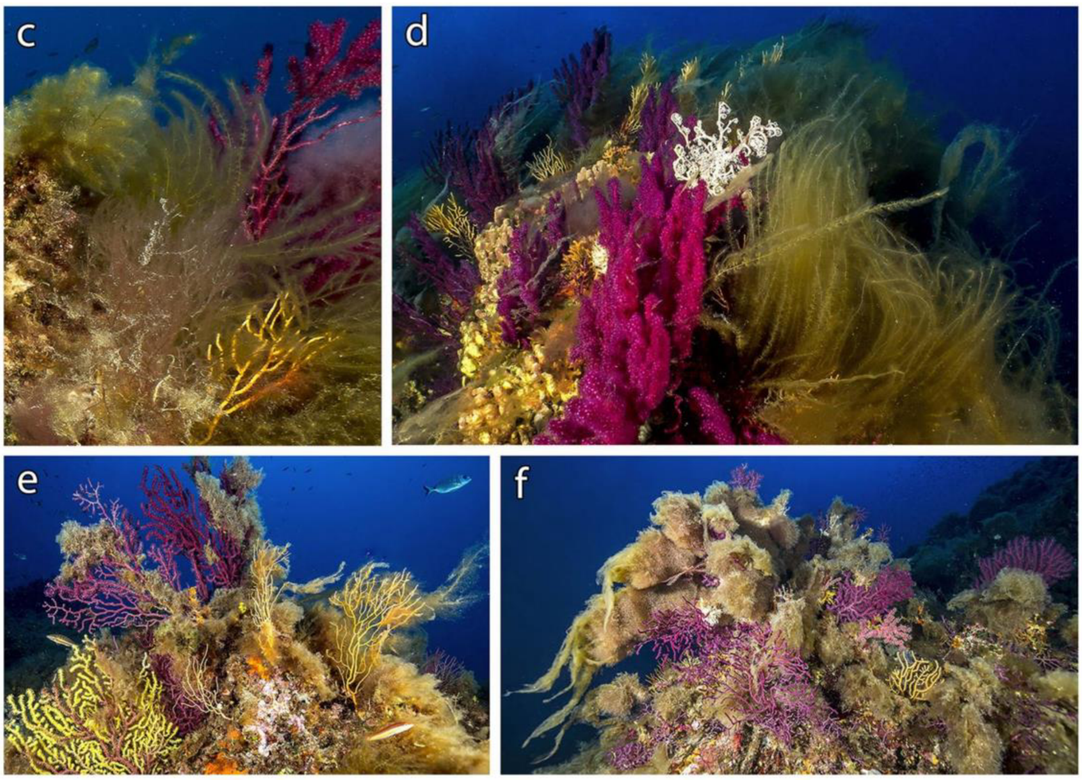


Figure 18: Macroalgae overgrowth and epibiosis on gorgonians on different parts of the MS. Tuscan Archipelago: (c–d) Mezzocanale Shoal (45–50 m depth) with abundant presence of large thalli of *Sporochnus pedunculatus*. Tavolara Marine Protected Area: (e–f) Papa Shoal (35 to 40 m depth) (pictures by Vincenzo Mattei , from: Chimienti G. et al., 2021).

However, TMEs in the Mediterranean might not be spared of such pressures as one might think. As an example, *Ruglopteryx okmaurae,* invasive algae (see invasive algae mats in Figure 18 on *Paramuricea clavata*) from Asia was found in the Alboran Sea, covering habitats in the incredible depth of 48 m, and was found on the eastern border of the Spanish coast in Punta de la Mona (Granada) epiphytic the coral *Dedrophyllia ramea* (Estévez R. M. et al., 2022).

Another view on invasive species could be taken from the spread of viruses, bacteria and pathogens. The correlation between global climate change and the spread has been widely observed (Danovaro, R. et al., 2009) affecting many benthic communities in the MS zone. One of the observations of disbalance is described as mucilaginous blooms which can be characterised as gelatinous aggregates on a surface (Danovaro R. et al., 2009) or on benthic coralligenous assemblages (Piazzi L. et al., 2018) causing hypoxia and concentration of microorganisms and pathogens not beneficial for corals (Montalbetti E. et al., 2022; Bianchi C.N. et al., 2019). Mucilaginous aggregates are composed of gelatinous organic matter with colloidal properties, primarily composed of high molecular weight polysaccharides that are secreted by marine organisms (Piazzi L. et al., 2018) like algae. Another form of epibiont algae can cause huge mats covering whole coral ecosystems having the same effect as mucilage. Massive events have been observed in the NW MS (Schiaparelli S., 2007; Mistri M. et Ceccherelli V.U., 1996), the Adriatic Sea (Chimienti G. et al., 2021) or the Dardanelles and the Sea of Marmara, Turkey (Özalp H. B, 2021). The effect of such events resulted in a 47% rate of mortality of *Paramuricea clavata* in Tremiti islands MPA between 2014 and 2019 (Chimienti G. et al., 2021).

4.6. Conservation of the TMEs in the Mediterranean Sea

While the holistic approach to the research on TMEs is still needed, and it is lacking the complex understanding of what would the disappearance of such habitats mean for the ecosystems and society, with more revealed information there are raised concerns about the fragility and turn to point of no return of these habitats (Aguilar R., Perry A. L. et López J., 2017). According to the IUCN report from 2017, there are over 13% of species of Anthozoa threatened with extinction including some endemic species which are found only in the Mediterranean Sea (IUCN, 2022). After global climate change, the rapid biodiversity loss is another huge ecological crisis mankind is currently facing (Castellan G. et al., 2022b), the two-thirds of marine environments have been severely altered or lost only in the last 40 years (Díaz S. et al., 2019) even if our society is highly dependent on its ecosystem services (Worm B. et al., 2006). Yet the total protection of marine species and resources is far from realistic (Brooks T. M. et al., 2006) in the reflection of the socio-economic needs of the states within the MS area, the priorities are needed to be critically evaluated in cooperation with fisheries and other stakeholders. In light of these facts and that more than 240.000 marine species were described from an estimated 1.5 million species (Bouchet P., 2006), the question is how to protect these ecosystems effectively.

4.6.1. Legal framework for conservation in the Mediterranean Sea

The passive way of conservation is done by tools such as national MPA - Marine protected areas, Natura 2000 sites (within EU area) and OECM - other effective area-based conservation measurements where conservation is not the primary goal but rather aligned next to the effective management of the specific area. Good examples are fishing grounds where status OECM is active.

There is currently an ongoing global initiative to protect at least 30% of the area of the Mediterranean Sea by 2030 to maintain and restore biodiversity. The MPA and OECM are the key tools to preserve and restore biodiversity, and benefit in increasing fish stocks, protecting species and supporting biodiversity, enhancing ecosystem resilience and carbon storage, enabling sustainable tourism and building an understanding of the ocean among other functions (WWF, 2021).

A bit of extension is the international MPAs, which are declared under the international convention of law yet fall under the national jurisdiction of the country or countries responsible for their declaration (European Commission-DG MARE, 2013) such as Pelagos Sanctuary for Marine Mammals, Biosphere reserves (UNESCO), Ramsar sites or the Specially Protected Areas of Mediterranean Importance (SPAMIs) which are part of wider international effort shortly described as Barcelona Convention. The Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention) was adopted in 1976 by countries with shores in the MS. The main goal was to reduce pollution and protect and improve the marine environment in the Mediterranean Sea. Few MPAs belong to SPAMIs (J. Amengual, D. Alvarez-Berastegui, 2018).

Another term established by the Convention on Biological Diversity, which is currently more effectively supporting the identification and prioritisation of TMEs, is the Ecologically or Biologically Significant Areas (abb. EBSAs) which are areas in the ocean supporting healthy functioning through its services and unique structure, like providing food sources or reproduction. CBD scientific criteria for EBSAs found in annexe I, decision IX/20 are a rarity, special importance for life history stages of species, threatened, endangered or other declining vulnerable species habitats, fragility, sensitivity and slow recovery, biological productivity, biodiversity and naturalness of the area (CBD, 2023).

In addition, restoring degraded habitats entails high costs and uncertainties regarding its success, it is still considered a crucial priority for the next few decades next to the MPAs and OECM. In March 2019, the UN General Assembly declared the period from 2021 to 2030 as the UN Decade on "Ecosystem Restoration." Furthermore, in 2015 the United Nations created a list of 17 Sustainable Development Goals (SDGs) to achieve by 2030 which goes hand in hand with this initiative as it is believed to be the last chance to prevent catastrophic impact on our ecosystem (Un decade on restoration, 2020). SDG14, "Life Below Water," focuses on the conservation and sustainable management of marine life, including the restoration of degraded marine habitats (*Sustainable Development*, 2023).

The policy framework such as The Habitats Directive (92/43/EEC) from 1992 is the main instrument for the establishment of binding measures on marine habitats in the MS Zone, yet it does not recognise animal forests and hard and soft bottoms, as it rather describes Posidonia beds (code 1120), sandbanks which are slightly covered by seawater all the time (code 1110) and biogenic reefs (1170) which cover reefs built by corals, coralligenous or oysters. The rest of the anthozoans which do not fall into the category are thus conserved and protected if their taxa are listed under Annex IV or other binding instruments. On the other hand in the binding policy framework, cnidarians cover over 53% of all species included, followed by sponges, arthropods and molluscs (Castellan G. et al., 2022b) acting as sort of key species when the knowledge gaps still exist.

4.6.2. International agreements and protection of coral species

Furthermore are introduced the main conventions and international agreements which are focusing on MCEs and corals. For a better demonstration see Figure 19 where is the timeline represented together with binding and non-binding instruments.

International Union for Conservation of Nature, Red List (IUCN)

In 1964, the IUCN Red List was created to serve as a comprehensive record of the endangered status of plants and animals worldwide, with the ultimate goal of promoting biodiversity and safeguarding species. The Red List's assessment process involves gathering data on a variety of factors, including geographic range, population size, habitat and ecology, and risk of extinction, resulting in the categorization of over 142,500 species into one of nine threat levels. While the Red List itself does not carry any legal weight or enforceable measures, it is frequently referenced by governmental agencies, wildlife departments, and other organisations as a guide for conservation efforts. The marine species still poorly represent less than 15% of the whole list, currently 136 species of anthozoans from the MS are on the Red list.

Convention on International Trade in Endangered Species of wild fauna and flora (CITES)

Established in 1973 and put into action in 1975, CITES (cites.org) aims to regulate the international trade of wild flora and fauna species and their by-products, with the ultimate goal of preserving these species and preventing them from being threatened by international commerce. Although CITES does not directly address issues of habitat destruction or biodiversity loss, it serves to supplement wildlife management and protection efforts by providing a functional mechanism to control commercial exploitation and reduce pressure on wild populations (Vincent et al., 2014).

One of the key features of CITES is its legally binding nature for the states that have ratified the convention, making it one of the most powerful tools for wildlife conservation worldwide. The species covered by CITES are divided into three appendices, each with varying degrees of trade restrictions. Appendix I includes species for which trade is completely forbidden, while Appendix II covers species for which trade is restricted and must be authorised through an international licensing system supported by national managing and scientific authorities. Appendix III pertains to species that are protected in at least one country, which can impose controls on trade. The appendices are amended and updated every two to three years at the Conference of the Parties, which involves the participation of 184 states. At present, the lists contain approximately 1,000 marine species (Castellan G. et al., 2022b).

The Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention)

The Barcelona Convention, which was established in Barcelona in 1976 and implemented by the European Union in 1978, includes amendments that were enforced in 2004. This convention features a protocol designed to promote the establishment of protected areas and the conservation and regulation of endangered or threatened species of flora and fauna. Annex I of the convention outlines the criteria for identifying marine areas that require protection, while Annexes II and III provide lists of species that are endangered or threatened and those whose exploitation necessitates regulation. These lists consist of around 130 marine species, and around 20 Anthozoa species (SPA/RAC, 2017).

The Council of Europe's Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention)

Enacted in 1982, the Bern Convention (82/72/EEC) was one of the earliest international agreements aimed at preserving habitats and wild species. This convention establishes broad guidelines for developing conservation measures and comprises a roster of specific species that require protection. Despite being introduced when knowledge of marine environments was still in its infancy, its lists are consistently updated through biannual reports. The list of species in the Bern Convention that necessitate protection includes roughly 200 marine species, consisting of invertebrates, fishes, mammals, and algae and circalittoral coral reefs are in Resolution 4 habitat type (Castellan G. et al., 2022b).

Council Directive (92/43/EEC) - Habitats Directive

The European Habitats Directive was established in 1992 by the European Union (92/43/EEC) as an obligatory law that must be implemented into the national laws of EU member countries. Unlike the Bern Convention, which is not legally binding, the Habitats Directive, along with the Birds Directive, is the primary legislation governing Europe's nature conservation policy. The directive's annexes contain a list of protected habitats and species in the EU and have undergone several revisions, with the last one in 2007. Annexes II and IV, which describe the types of habitats (SAC - Special area of conservation) and species needing strict protection and conservation measures, form the basis for the protected species lists in many European countries. The Habitats Directive, along with the Birds Directive, constitutes the backbone of Natura 2000, the world's most extensive network of Sites of Community Importance (SCIs) and conservation areas, aimed at ensuring the survival of species and habitats of community interest. However, the directive's annexes, unlike the Bern Convention, have remained practically unchanged since its establishment and only include five marine habitats and 18 marine species (Castellan G. et al., 2022b).

General Fisheries Commission for the Mediterranean - GFCM

The FAO-GFCM is a regional organisation for fishery management under the Food and Agriculture Organization of the United Nations that focuses on the conservation and sustainable use of living marine resources, including aquaculture systems, in the Mediterranean and Black sea. It was founded in 1949 and has 22 contracting partners, including 19 Mediterranean states, three Black Sea states, and the European Union. The organisation has the authority to create binding recommendations for fishery monitoring and management. The Scientific Advisory Committee on Fisheries identified a list of priority species for the Mediterranean and Black seas during the Ninth Session in 2006. Although the FAO-GFCM primarily regulates fishing and aquaculture activities, the priority species list includes roughly 100 marine species, with cetaceans, sharks, and rays being the majority, while only five benthic species, including four decapod species and the cnidarian *Corallium rubrum*, are represented (Castellan G. et al., 2022b).

FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas

In 2004, the United Nations General Assembly (UNGA) formally defined the concept of vulnerable marine ecosystems (VMEs) as groups of species, communities, or habitats that may be vulnerable to the impact of fishing activities. The FAO

International Guidelines for the Management of Deep-sea Fisheries in the High Seas, built on UNGA Resolution 61/105, provide details on VME criteria and examples of vulnerable species groups, communities, and habitats. However, these guidelines are non-binding, and management measures are limited to restricting fishing activities through Fishery Restricted Areas (FRAs). The list of taxa that may form VMEs is included in Annex 1.C of the methodology for data collection for monitoring the incidental catch of vulnerable species in the Mediterranean and Black Sea fisheries.

The Natura 2000 sites network, based on the Habitats Directive (92/43/EEC), is currently the most significant instrument for the creation of conservation areas in the European Union's marine environment. The Directive requires updates and amendments to the list of habitats each time a new country joins the EU, but no significant modifications have been made solely based on new knowledge. Therefore, the current annexes of the Habitats Directive rely on outdated information, and some habitats of community interest are not yet considered (Castellan G. et al., 2022b).

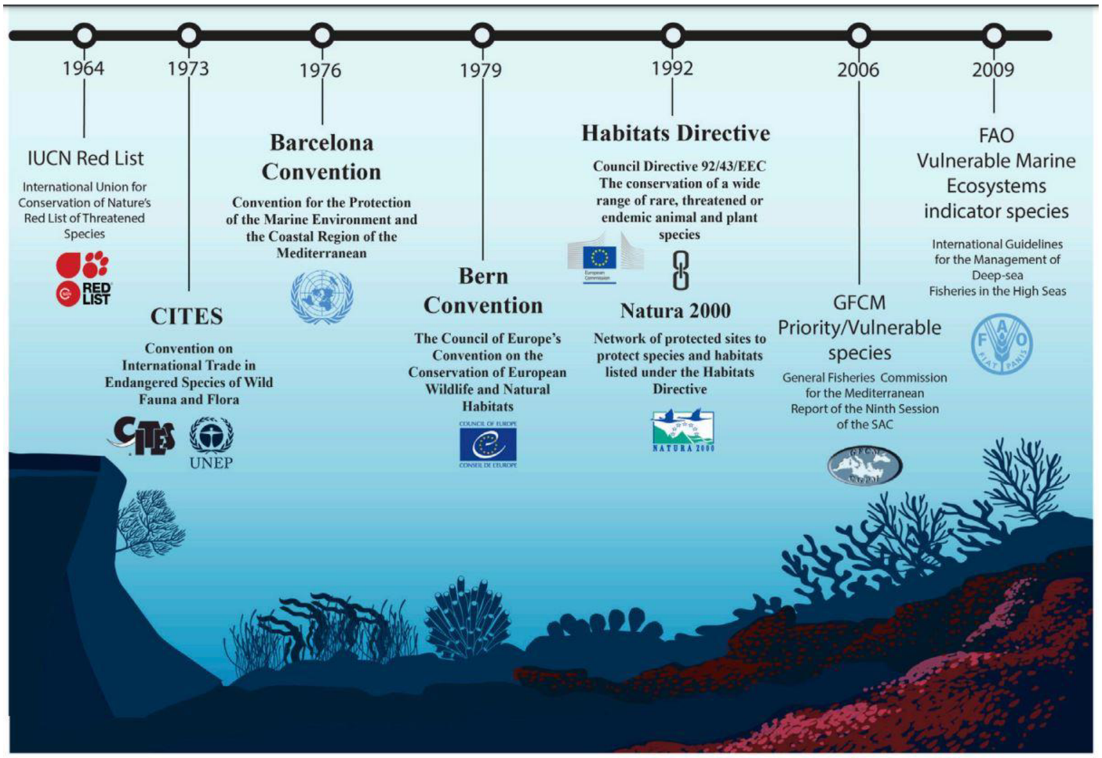


Figure 19: Legal framework covering Mesophotic Coral Ecosystems in the Mediterranean Sea (from: Castellan G. Et al., 2022b)

“The bold are International Legislative Framework, comprising binding (bold font) and not-binding instruments, which also includes Mediterranean mesophotic habitats and taxa. The establishment years and depositary organisms are reported.“

4.6.3. Marine Protected Areas

In real numbers from 2020, MPAs cover 8.33% of the Mediterranean Sea (i.e. 257 national MPAs, 829 marine Natura 2000 sites and the Pelagos Sanctuary for Marine Mammals) where only 18% have effective plans implemented at least partially and 0.04% are fully protected areas (no-go zones) (MedPAN and UNEP/MAP-SPA/RAC, 2021). In the next years, the efforts should be thus very goal-oriented and concentrated to achieve the 30% protective goal. It is expected that the protection of 30% of the area of the Mediterranean Sea will have a positive effect on rebuilding fish stocks, mitigation of the global climate effect, security of the future fisheries and local tourism, as well as food, livelihood and well-being of local communities. There are around 505.000 people dependent on the Mediterranean Sea directly, 55% of which are small-scale fishers and 16% work in tourism linked to the MS. Nevertheless the “blue gold rush” in the MS is expected to grow in the next few decades, increasing anthropogenic pressures on already fragile and stressed ecosystems and the sustainable management of these resources is the only way to preserve this complex ecosystem for future generations (WWF, 2021).

Sadly, in connection with the UN Convention on Biological Diversity in Aichi Target 11 (among others): *“By 2020, …, 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes”* only several states achieved the target, but it is important to mention that 90% of MPAs in the MS zone are not managed effectively and do not have an effectively implemented management plan (WWF, 2021).

It is highly questionable how the further goals for 30 by 30 wanted to be achieved and maintained as was estimated by Amengual-Alvarez (2018) the MPAs in the MS held only 7% of the ideal budget for fulfilling the Aichi Target 11 and they estimated the goals for 2020 will be achieved in the MS zone by 2040.

Another phenomenon is that MPAs were created in the past 60 years, sometimes reflecting only regional and national needs, so most of the MPAs are coastal and highly correlated to the GDP (Amengual J. et Alvarez-Berastegui D., 2018) without a deeper understanding of all habitats and their species which are only recently understood a bit more thoroughly (EBSAs) and new findings should be reflected in the MPA area and priority management zones. The 77.27% of all MPAs and OECM cover less than 50km2 and 97.33% of the protected area is located in the EU member countries' water and the MPAs usually cover only a little portion of the known deep extent of mesophotic and other ecosystems and deeper ecosystems are generally underrepresented (J. Amengual et D. Alvarez-Berastegui, 2018).

Even if most of the MPAs have zoning included, only 16.5% of 200 were a consequence of the management plan and only 31% had efficient patrolling and surveillance, with 10% sufficient staff to meet conservation requirements and 5% of MPA managers content with their budgets in 2015 (MEDPAN & UNEP-MAP-SPA/RAC, 2017).

In light of the event of the world pandemia of COVID-19 the general decline in fishing pressure might have favoured the ETP species (endangered, threatened, protected) (Coro G. et al., 2022) but at the same time put many MPAs on the edge of limits on funding, unclear organisation during pandemia, drops on conducted surveillance and management activities as tourism and other forms of funding dropped rapidly (Waithaka J. et al., 2021).

In concern to the mesophotic ecosystems, 16.99% of MPA and OECM cover depths 0-50m with coralligenous assemblages (and *Posidonia oceanica* meadows) and 13.18% cover 50-200m depth zone mainly with national and Natura 2000 sites. EUNIS habitat classes for the coralligenous communities (composed mainly by encrusting algae with other species such as anthozoans) are included in 39.78% of all MPAs and OECMs (MEDPAN & UNEP-MAP-SPA/RAC, 2017). It is important to highlight though that coralligenous habitat does not include deeper anthozoan habitats and animal forests built not only by Alcyonacea, Antipatharia, Scleractinia and Zoantharia. While the shallow coastal habitats are under direct anthropogenic pressures, the TMEs are currently still overlooked and with their biological characteristics even short-term neglect can have a non-reversible impact on changing the benthic communities when bottom trawling and other fishing practices occur in these habitats. The mesophotic communities are, as suggested by Castellan G. et al. (2022b), ideal habitats for testing if the current state of MPAs is fulfilling the ecological needs in their whole life cycle or if there are some additional interventions needed.

As was observed by Sini M. et al. (2015), the effective management of MPA can have a positive effect on communities, in this case, widespread gorgonian *Eunicella cavolini* whose colonies in NW Mediterranean's MPAs showed juvenile colonies in shallower euphotic depths with high densities, while in the N Aegean Sea in unprotected parts the colonies were less abundant and composed by older individuals proving the recruitment of new colonies was not occurring (Sini M. et al., 2015). *Eunicella cavolini* is a species ideal for model studying as it occupies all parts of the Mediterranean Sea and its depth preferences occur between 10 to 100 m (Molina, A.C., et al., 2018; Sini M. et al., 2015).

But as is known from metapopulation theory, it is important to create a network of protected areas, which allows the species to spread across the whole region, providing habitats and interconnecting existing fish and other invertebrate communities in their whole life cycles (Fox A. et al., 2016). The dispersion of species in marine environments is known for their heterogeneity, mostly highly reliant on the current dynamics in the planktonic strategies of dispersal. While not all species prefer this strategy, the ongoing plan of planned and existing MPA's management should be reflecting all possible scenarios providing connectivity for multiple dispersal mechanisms (Kinlan, B. et Gaines S., 2003). The good reflection provides a DNA study of *Antipathella subpinnata* pointing at the genetic uniqueness of remote seamount locations in comparison to coastal populations which do not distinguish between each other (Terzin M. et al., 2021).

The only MPA specifically targeting TMEs' animal forests for protection is in Montenegro, in the Boka Botorska Bay (Trainito E., 2021). Sadly to mention that the TMEs are often part of MPAs not in Zone A (No take, no entry zone) but in Zone B (Highly protected zone), Zone C (partially protected zone) or sometimes are excluded in the MPA allowing trawling and other fishing practices. One of the recent examples can be Tremiti islands, Apulia - Italy, where the DFGs were highly occurring even in the highly protected zone, entangled on the benthic communities built mainly by *Antipathella subpinnata* colonies (Chimienti G. et al., 2020). This unfortunately supports the report of Gomei M. et al. (2019) whose technical report reflects the ineffective or non-existent management of MPAs in most of the areas declared in the MS zone. They are more paper MPAs than active forms of protection supporting biodiversity.

4.6.4. Applied methods of studying, monitoring, conservation and management of TMEs

The most used method of studying MCEs/TMEs currently is still SCUBA (i.e. Self-Contained Underwater Breathing Apparatus) with many diverse applications and air mixes (mesophotic.org, 2023). It is important to highlight that citizen science can help to scope and monitor habitats, especially those closer to recreational diving with the deep limit of 40 m (i.e. PADI), which can point out the possible existence of the mesophotic communities below. While deeper regions are generally studied through scientific diving, on the other hand, it is important to highlight other options for cooperation with technical divers associations around the Mediterranean basin.

With the technological development in the past decade, the options of studying MCEs/TMEs broadened rapidly and submersible devices and especially unmanned remotely operated vehicles (abb. ROVs) are a necessary part of the modern research of these environments. Lately, there appear more and more low-cost ROVs on the market, allowing large-scale applications (Teague J., Allen M. J., et Scott T.B., 2018). ROVs are unmanned, 2-3 knots moving robots operated through umbilical cable, transmitting video and sensor data information to the operating vessel. General information about depth, a compass, an Ultra Short Baseline underwater acoustic tracking position system, and navigation Sonar are standard equipment of ROVs while the digital high-definition camera, underwater strobes, HD video camera, laser beams for providing the metric scale of the pictures, videos and manipulation arms for biological samples collecting are likely to be implemented in research specific configurations (Angiolillo M. et Canese S., 2018).

While a Multibeam echo sounder (MBES) provides a highly detailed morpho-bathymetric three-dimensional profile of the terrain for a revelation of rocky outcrops and biogenic concretions. It transmits a broad acoustic fan-shaped pulse from a transducer every second providing information about its surroundings analysed from the reflected sound waves into a 3D model including depth (Angiolillo M. et

Canese S., 2018). MBES works well in combination with the direct use of ROVs and SCUBA.

Furthermore, sampling through trawling, dredges and other direct physical methods can cause unnecessary stress to the corals manifested by increased mucus creation, tissue damage or retraction of polyps for longer periods (Orejas C. et al., 2019). On the other hand, bycatch of fishing vessels (Sampaio et al., 2012) can be a relatively cheap option in comparison to other direct sampling and observing methods, it is important to point out, the samples are taken without any further information about its habitat, permanently barring the bottom habitats of species which are well known for its slow growth rates. In any case, the samples are exposed to the enormous stress induced by pressure and temperature changes which leads to the loss of energy of these sampled corals, degrading the potential survival rates on board and in the research aquariums.

To prolong the survival rates of corals on board, it is important to supply their containers with temperature-controlled local deep-sea water, captured by Niskin bottles of CTD Rosette or deep water pump, and consistent oxygenated flow rather than feeding which will influence the quality of water. Apart from that mimicking the light conditions are important too and avoidance of exposure to the air can prevent some of the corals from oxidising, turning black and dying (Orejas C. et al., 2019).

Furthermore, the methodology for evaluation and monitoring mesophotic ecosystems are evolving too. For example, the multi-parametric index (MACS) can be used as a proper sensitive index to evaluate the conditions of areas which fall into the TMEs category in comparison with other indices such as MAES and CBQI. Using a relatively easy technique of video-mapping of the environment through remote operating vehicles (ROVs) or SCUBA can help to finely distinguish between regional differences in ecosystems (Moccia D. et al., 2022; Enrichetti F. et al., 2019).

There are a few ongoing projects focused on coral transplantation in the Mediterranean Sea. One example is the "MERCES" project, which focuses on the restoration and conservation of marine ecosystems and includes the transplantation of cold-water corals in the Mediterranean Sea. The project targets several sites across the Mediterranean, including the Aegean Sea, the Ligurian Sea, and the Adriatic Sea (Koningsveld M. et al., 2017).

Furthermore, one of the first participatory coral reef restoration projects in the MS region, the NGO Coral Guardian together with Coral Soul has started similar transplantation in Spain in cooperation with the public. On the other hand, coral transplantation is a relatively new conservation technique, and its effectiveness in the Mediterranean Sea is still being studied and evaluated, as in some species it has been less effective (Villechanoux J. et al., 2022; Santangelo G. et al., 2012).

Another emerging approach has been used on bycatch gorgonians *Eunicella cavolini,* which were caught by artisanal fishermen to be successfully recovered and re-planted in the NW Mediterranean Sea in Cap de Creus MPA in the depth ranging between 80 to 90 m with the survival rates of transplanted colonies been around 87.5% (see Figure 20) (Montseny M. et al., 2021b; Montseny M. et al., 2019).

Figure 20: Low cost restoration procedure for gorgonians *Eunicella cavolini* in the MS.

"(A) Drilled and painted natural cobbles (photo credit ICM-CSIC); (B) Gorgonian fragment attached to a natural cobble using epoxy potty (photo credit L. Sabaté); (C and D) Gorgonian transplant gently dropped from a boat (photo credit ICM-CSIC and N. Viladrich)." (From: Montseny M. et al., 2021b)

In American Samoa, the research team focuses on picking generalists from both MCEs and SCRs and applying transplantation methods (U.S. National Park Service, 2021). For a better understanding of the method: the living sample of the shallow coral species is collected and put in the deeper prepared place to study if they are able to adapt and survive and successfully reproduce. The chosen species are usually depth generalists from the area, i.e. the species which are found in both mesophotic and shallow reefs. Each area has different species and thus is carefully chosen individually in each area of the study, where this method is going to be applied. An important step to successfully implement this method is to make both MCEs and SCRs corals long-term acclimation, otherwise, the depth change can cause fatal stress for the specimen. This method has been applied to *Corallium rubrum* in the MS zone by Villechanoux J. et al. (2022), proving it is possible to successfully introduce shallow-water populations in deep and vice-versa. The interesting outcome of this implementation might be the potential confirmation of human fishing-induced stress on shallow populations leading to their reduction in size while this behaviour is not expected in deep-water colonies transplanted in the shallow water.

On the other hand, the outcomes of new research should be implemented in the new restoration techniques too, as suggested by Cau A. et al. (2018), the colonies from deeper populations of *Corallium rubrum* might be more resistant to thermal stress over shallow ones. The results were obtained in a controlled experiment *ex situ* but might have promising lead to the general properties of these communities. In contrast, Villechanoux J. et al. (2022) during their transplantation experiments of *Corallium rubrum,* using different materials such as PVC, epoxy or grids and substratum, estimated on previous similar studies that shallow-water colonies might be more resistant to thermal stress. It is convenient to continue in transplantation experiments as it is suggested also with the deep population samples to gain a complex picture and with the proposed bigger population sizes.

5. Results and Discussion

As presented in the recent findings, the TMEs represent around 15 % of the Mediterranean Sea area, estimated to be around 377.000 km^2 (Castellan G., 2022). The analysis did model estimation based on the PAR and Diffuse Attenuation Coefficient Kd^{490} and bathymetric profile of the Mediterranean Sea (Castellan G., 2022) (see the red shaded area in Figure 21). In contrast in Figure 22 are current MPAs and OECM covering depths below 200m which are in the rariphotic zone, yet the situation for the TMEs is not expected to be any better. Further analysis should be conducted regarding the TMEs, and a species-specific approach to understanding how all EUNIS habitats (Jacques, P. et al., 2017) and species are protected.

As it is known today, there are only around 8.33% of areas protected (MedPAN and UNEP/MAP-SPA/RAC, 2021) with less effective management, sufficient budgeting in the MPAs or enough staff (WWF, 2021; Amengual J. et Alvarez-Berastegui D., 2018). From the MPAs status report from 2016 is known that 16.99% are protecting coralligenous assemblages in 0 to 50 m (where Anthozoa take a little part) and 13.18% cover depths considering TMEs in the limit of 50 to 200 m (Castellan G., 2022; MEDPAN & UNEP-MAP-SPA/RAC, 2017).

The current status report of MPAs in the MS for 2020 has not been released yet but in the light of pandemia and further economic impacts (Waithaka J. et al., 2021) it is estimated not most positive situation for the current conservation goals. Especially when it is aligned with the Global Biodiversity Framework 30 by 30 strategy (WWF, 2021), which is highly ambitious and the experience is known for missed or on-paper fulfilled goals stated by Aichi Targets (Lo V. et Jang N., 2022).

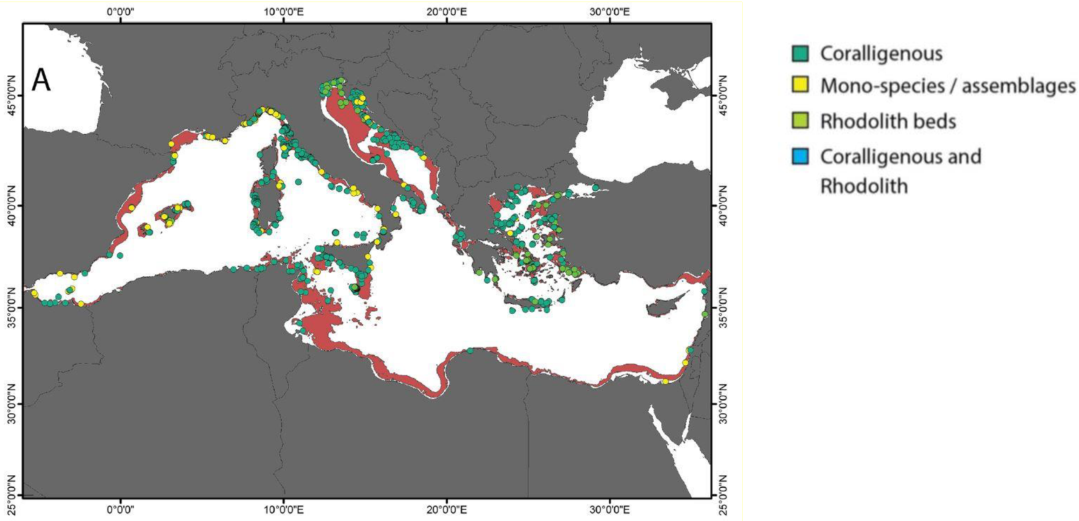


Figure 21: Illustrative map showing the distribution of mesophotic assemblages (sourced from literature and MEDISEH database).

"The red shaded area indicates the portions of seabed characterised by mesophotic conditions (from the study of Castellan G., 2022). The mesophotic conditions and data from studies are 30 to 175.5 m. Map generated using ArcMap 10.5 software (© ESRI, https://desktop.arcgis.com)." The upper limit for the TMEs is defined by the depth of 30 m (the limit for recreational SCUBA diving) with the bottom limit represented as 0.000 1 mol photons m^{-2} day^{-1}" (From: Castellan G., 2022)

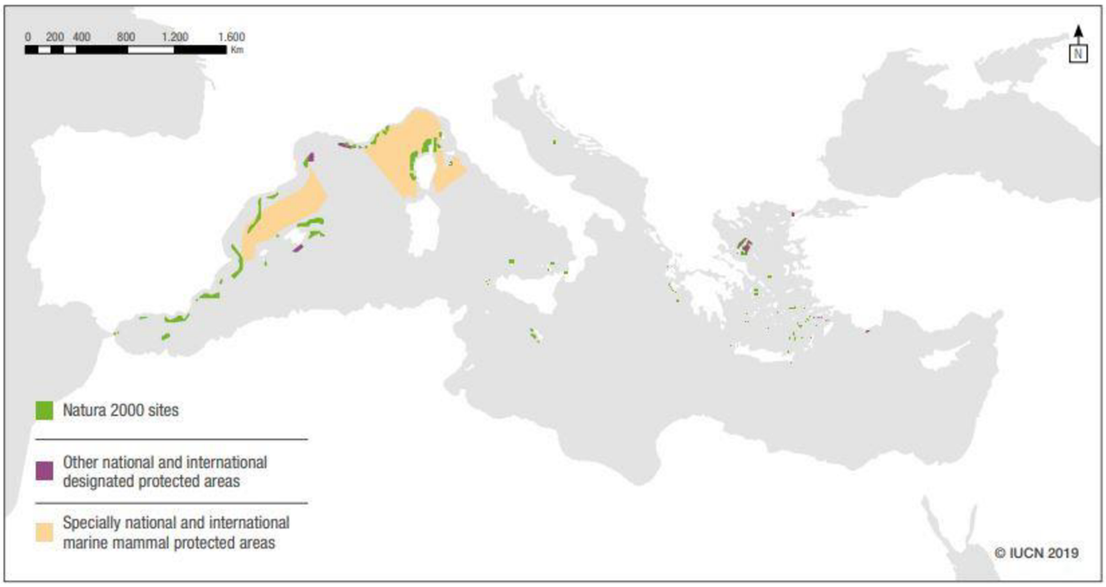


Figure 22: The MPAs covering areas below 200 m depth. Adapted by IUCN, 2019 (from: MAPAMED database MedPAN, UNEP/MAP/RAC-SPA, 2018)

Important is to highlight the fact that MCEs model analysis in the case of Castellan G. (2022) does not cover only corals living in the mesophotic conditions but there are many habitats typical for these depths including coralligenous habitats, gorgonian forests, sponge grounds to rhodolith beds etc. The biogeographic regions for corals are getting more attention recently (Toma M., Bo M. et al., 2022; Ingrassia M., Bella L., 2021; M. Canessa et al., 2020) leading to the known regions of few highly studied corals in the MS (Figure 24 (A), Figure 24 (B) for endemic species).

The term MCEs itself does not distinguish between different seabed typologies like sandy, coastal detritic, coralligenous outcrops or maërl beds (Cerrano, C. et al., 2019) and is a rather generic term which at this moment tries to cover zones below the altiphotic zone. It is expected the further categorization approach as suggested by studies on compositions of the substratum, to overall dominant species habitats (Trainito E., 2021, Corriero G. et al., 2019) and depth zonation like in the case of upper and lower mesophotic zones (Lesser M. P. et al., 2019).

Last but not least, the imbalance of conducted studies across the Mediterranean Sea is generally the GDP correlated (Amengual J., Alvarez-Berastegui D., 2018), with 97.33% of MPAs being inside the waters of the EU zone. The studies are generally focused on the Western Mediterranean ecoregion (47.8%), followed by the Ionian Sea (20.8%), the Levantine Sea (8.3%), the Adriatic Sea (6.3%), the Aegean Sea and the Tunisian Plateau (both 4.2%), the Alboran Sea (2.1%) and remaining % of studies were insufficiently described without specified location (Cerrano, C. et al., 2019).

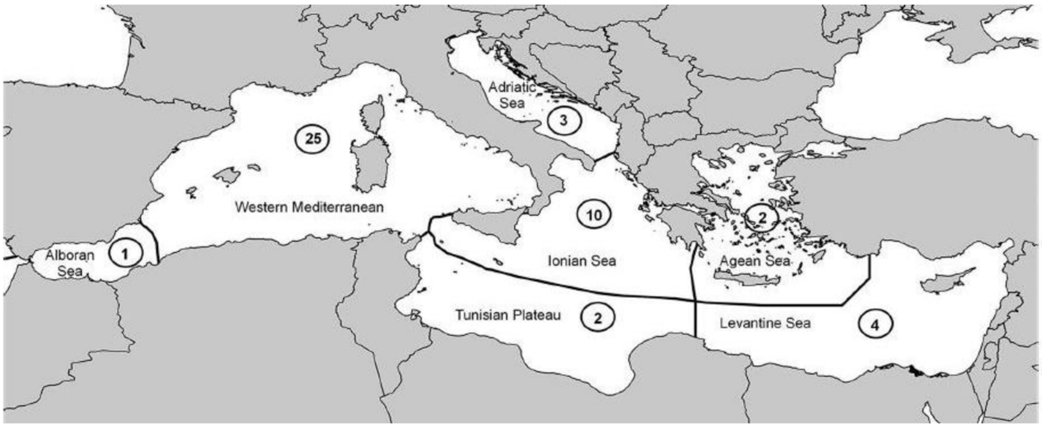


Figure 23: The distribution of study sites of publications from the bibliographic research by Cerrano, C. et al. (2019) using the queries “twilight” AND “Mediterranean” and “mesophotic” AND “Mediterranean”. The outcome shows the inequality of distribution of studies in the MS region, where generally exposed to alien species regions are still neglected for thorough studying of the condition of MCEs. (From: Cerrano, C. et al., 2019)

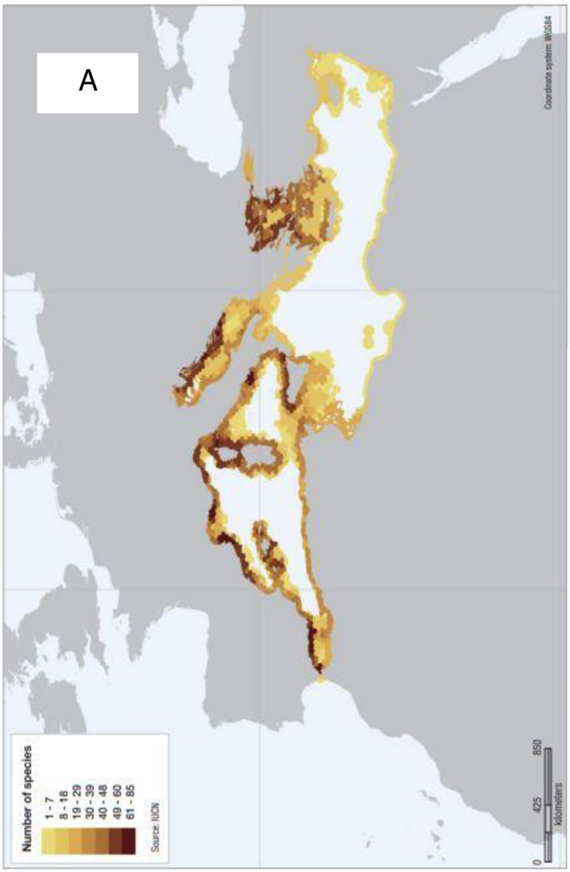
The least studied regions (Aegean Sea, Alboran Sea, Tunisian Plateau, and Levantine Sea) were exposed only to remote research methods such as niche modelling, literature review, Web Ecological Knowledge or ROVs and trawling, but never to SCUBA. The study highlights the overall bias in the use of direct and indirect research in favour of indirect ones, where for instance only a few studies below 60m were conducted using SCUBA. The reason is mainly due to its required specialised and costly training of scientific divers (Cerrano, C. et al., 2019).

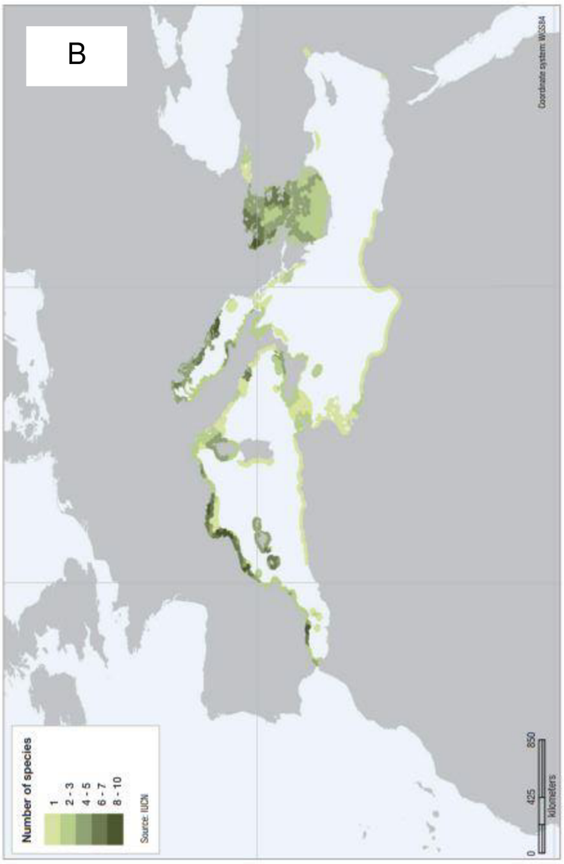
Brief bibliographic research in this study covering the topic of MCEs was conducted using scopus.com with results given for the “mesophotic AND Mediterranean AND coral” around 67 units until February 2023. On the other hand, when the more specified term “temperate” was added to the search pattern, the system found only 7 results without further cleaning of data. Thus it is expected that TMEs are highly likely going to appear in upcoming years when authors will learn to sort the Mediterranean Sea zone according to the outcomes of the previously mentioned European Symposium from 2017 (Laverick, J., Rogers, A., 2019). On the other hand, the TMEs studying community should pay closer attention to the tropicalization of the MS (Bianchi C., Morri C., 2003), especially after deepening the Suez Canal to 24m (Galil B.S. et al., 2019) and consider relevant research for the MCEs which cover lower latitudes, specifically the Red Sea and the Indian Ocean.

When confronting the research-focused area of the species distribution within the MS, there are seen high shortcomings of unbalanced research efforts. While the corals are highly distributed in the Tyrrhenian, the Ligurian, the Balearic, the Adriatic, the Aegean or the Alboran Sea (see Figure 24 (A)), the equivalent research effort is not reflected. Particular research efforts should be oriented towards the regions with high endemism, such as the Adriatic (Longo C. et al., 2012) but especially the Aegean Sea, which is at the same time under the Lessepsian migration pressures (Spanier E., Zviely D., 2022; Galil B.S. et al., 2019) (see Figure 24 (B) for endemic corals and Figure 24 (C) for threatened corals).

The concerning situation is the lacking knowledge of the southern coast, so even if Figure 24 (A, B, C) is showing no to the low distribution of coral species, it is highly important to realise this is due to indirect methods of studying and more systemic approach is needed to fill these gaps and imbalance prevailing in the MS. It is highly recommended to improve the monitoring situation in these regions, especially in connection with strong Lessepsian migration (Zenetos A. et al., 2012) which is already tropicalizing the south-eastern coast of the MS and any early hints of changes in the environment are discovered with delay.

While the draft of the spatial distribution of MCEs in the MS has been recently described, it still represents demanding human-involved research unless there are used recent technologies through computer science. The technology is moving forward highly boosted by the business sector and might bring many positive effects on different segments - as demonstrated in the paper of Sonogashira et al. (2020), machine and deep-learning can fasten the pace to map the seafloor through superresolution and thus to understand these unexplored environments without the actual need to costly scout the waters with special devices.





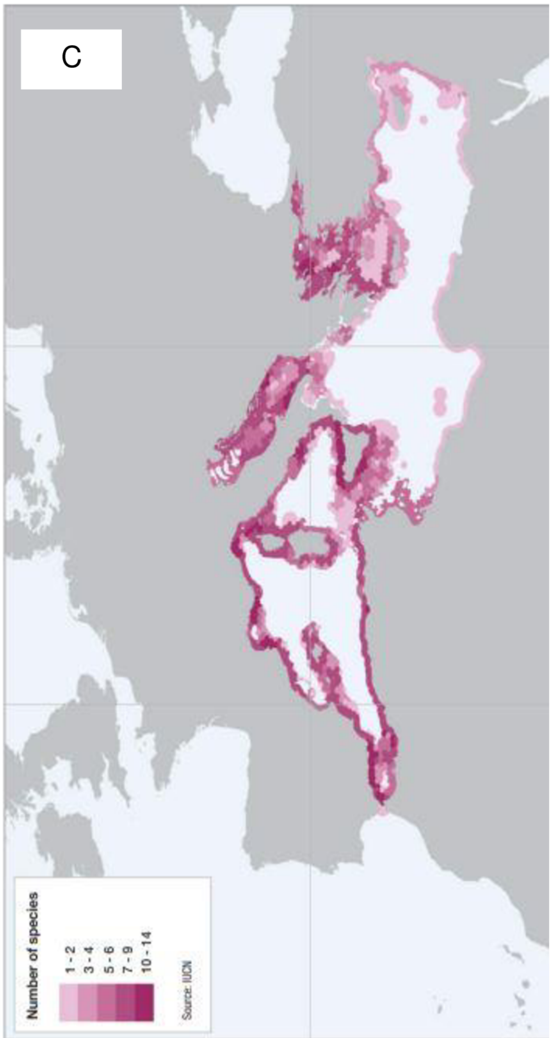


Figure 24: The map of distributions of Anthozoa in the MS: (A) all anthozoans, (B) endemic species, (C) threatened species. (From: Otero M.M. et al., 2017)

The research community started to use the MCEs term yet there is no clarity about zonation and the depth limit changes in various research papers and books. While it might reflect the regional ecology of MCEs, general standardisation is highly needed as the definition differs from source to source. The newly formed term needs to find a way to everyday use which comprises the needs of the Mediterranean Sea and the TMEs should be used to distinguish the localization of the studied ecosystems. The depth limits are set according to a recent bibliographic study extrapolated in comparison to usual tropical levels of MCEs. That concerns both the upper level by tens of metres and the lower limit, which greatly exceeds in some cases even by hundreds of metres (Cerrano, C. et al., 2019).

Another question raised is the limit zonation concerning the Mediterranean Sea since original ideas of MCEs are defined by the depth limit where the reef-building corals (Scleractinians) and other organisms can still occupy a niche together with their symbiotic zooxanthellae. The symbiotic species are quite rare for the Mediterranean Sea and the term MCEs does not cover the real scope in this region. The proper correction has been proposed by Cerrano C. in 2019 for the lower limit by "the extent of benthic primary producers, delineated by the compensation irradiance (i.e. absolute irradiance) for growth ($E_{cgrowth}$)", "*the irradiance at which gross primary production balances the carbon losses (respiration, herbivory, exudation of dissolved organic carbon, and reproduction) for a particular organism*" (Gattuso et al., 2006). This correction would also cover the different changes in irradiance due to water transparency. The upper limit is defined as: "*1% of surface irradiance…, traditionally considered the lower limit of the euphotic zone … and the limit of the infralittoral zone, where the euphotic zone intersects the seabed. …*" (Cerrano, C. et al., 2019).

The TMEs in the MS zone are important habitat formers (e.g. Angiolillo M. et Canese S., 2018; Ponti M. et al., 2018; Valisano L. et al., 2016; Cau A. et al., 2015) with broad trophic, mutualistic and other nets (e.g. Mantas T. P., 2022; Chimienti G. et al., 2020; Angiolillo M. et Canese S., 2018), yet are still understudied (Castellan G. et al., 2022b; Willmer, G., 2020), little protected and facing many increasing stressors such as climate change with emerging prolonged heat waves (UNEPMAP, 2022; Melanie J. et al., 2022;), ocean acidification and eutrophication (Micaroni V., 2022; Sellanes J. et al., 2021) or pollution in the coastal areas. With direct pressures from fishing, littering and even facing their harvesting, these slow-growing animals are at stake (Corinaldesi C. et al., 2022; Bally M. et Garrabou J., 2007; Cerrano C. et al., 2000). While the scientific community and the framework in ecology realise their role and emerging problems (Cupido R. et al., 2009; Linares C. et al., 2007), the public and governmental systems are still not reflecting the needed approach to management and protection of these environments (Waithaka J., Dudley N., Álvarez M. et al., 2021; MEDPAN & UNEP-MAP-SPA/RAC, 2017). The fact that *Corallium rubrum*, actively harvested coral, is still not included in the highly protected species, even if it is Endangered (EN) by the IUCN Red List, is a prime example of an approach to nature conservation in the MS zone.

It is highly speculative what the situation will be during the next decade. The positive thing is that with each research it is known more and more about these environments, the previous simplification is confronted with the complexity of these underwater environments and the approach is modified - for example by the aforementioned introduction of new terms that better describe the needs of the ecosystem. If there will be a connection between research and the application of its output, especially concerning the geopolitical issues of the Mediterranean Sea, and an approach to its effective protection and management, while preserving the socio-economic needs of society, the hope is that the habitats could be successfully protected. And those populations that are the most resilient for the coming period of physical-chemical changes can persevere, but biodiversity will likely continue to decline. However, it is necessary to limit or modify fishing methods in areas where these fragile systems exist, or to set up a system of interconnected protected areas with defined fishing areas, which will be respected, especially by large-scale fisheries. In any case, there is a need to conduct a broad dialogue with a sufficiently powerful and effective solution in the following years. The author judges that it is unlikely to achieve the highly ambitious 30 to 30 plan. Small local projects for the restoration of benthic communities will be important, which would be directly connected to the fishing industry and would at least focus on mitigating the impact of existing activities, together with ecotourism and projects involving communities like scuba diving schools.

6. Conclusion

Corals in the Mediterranean Sea are dominant in the depths described as mesophotic with unique adaptations to these conditions, like slow growth and longevity, making them very fragile species. They form specific habitats with an accumulation of biodiversity and play an important role as a refuge, a reproduction ground for mobile species or carbon storage. The mesophotic coral ecosystems in the Mediterranean Sea received better characterisation defined as Temperate Mesophotic Ecosystems (TMEs), as the original definition connected to the zooxanthellate coral species did not suit exactly these environments, since the biocenosis is compounded mainly with soft and azooxanthellate corals. On the other hand, the term TMEs still needs to consolidate in the scientific literature, especially in reflection of deliberate omission in the MCEs reviews and meta-analyses and incorrect use of Cold Water Corals or older terms such as twilight zone which still appears in the literature.

The TMEs in the MS face many challenges and negative anthropogenic impacts, with inadequate fishing as the most destructive, together with the climate change effect which results in ocean acidification, severe weather conditions and Marine Heat Waves (abb. MHWs) which cause Mass Mortality Events (abb. MME). Followed by marine littering prevailing of the Derelict Fishing Gears (DFGs), pollution, eutrophication, other coastal anthropogenic activities (anchoring, diving, recreational fishing) as well as rising invasive pressures dominated by the Lessepsian migrants through the Suez Canal, ballast water and the Gibraltar Strait, put the coral species at stake. Nevertheless, the research mainly focuses on ex-situ experiments without the known impact of the multi-stressor effect on these ecosystems and the field impact of the severe storms on these ecosystems is still unknown.

According to recent research, the TMEs represent around 15 % of the MS zone, which includes all kinds of different habitats not formed only by corals, but also sponges, algae, bivalves, bryozoans etc. However, only a tiny percentage is included within the MPAs, whose extent is mainly in the EU countries' waters, pointing to a disbalance of protection in the Mediterranean Sea, favouring the North-west over the South-eastern MS. The same phenomenon is reflected in the recent research activities which are in the same gradient, omitting Southeastern waters and if studies are released, they lack the use of direct research methods. With the fact of occurring tropicalization and the introduction of the Lessepsian migrants, it is important to aid the countries in this area to monitor occurring changes in the habitats, where the non-native species predominate over native species to timely discover any incoming invasions. In light of the current framework 30 by 30 of protecting 30% of the area of the MS, and the generally known fact of underfinancing of the conservation within the MPAs, the change needs to be done to achieve these goals in the following decade.

7. Bibliography

1. Aguilar R., Perry A. L. et López J., 2017: *Conservation and management of vulnerable marine benthic ecosystems.* In S. Rossi (Ed.), *Marine animal forests: The ecology of benthic biodiversity hotspots of the world*. Major Reference Book (pp. 1–43). New York, NY: Springer.
2. Amengual J., D. Alvarez-Berastegui, 2018: *A critical evaluation of the Aichi Biodiversity Target 11 and the Mediterranean MPA network, two years ahead of its deadline,* Biological Conservation, Volume 225, p. 187-196. DOI:10.1016/j.biocon.2018.06.032.
3. Angiolillo M. et Canese S., 2018: *Deep Gorgonians and Corals of the Mediterranean Sea.* DOI:10.5772/intechopen.69686.
4. Angiolillo M., Fortibuoni T., 2020: *Impacts of Marine Litter on Mediterranean Reef Systems: From Shallow to Deep Waters.* Frontiers in Marine Science. 7. DOI 10.3389/fmars.2020.581966.
5. Angiolillo M., Giusti M., Rossi L., Tunesi L., 2022: *A Dendrophyllia ramea Population in the Ionian Sea (Central Mediterranean Sea) Threatened by Anthropogenic Impacts*. Frontiers in Marine Science. (9). DOI 10.3389/fmars.2022.838274.
6. Angiolillo M., Gori A., Canese S., Bo M., Priori C., Bavestrello G., Salvati E., Erra F., Greenacre M., Santangelo G., 2016: *Distribution and population structure of deep-dwelling red coral in the Northwest Mediterranean.* Mar Ecol, 37: 294-310. DOI: 10.1111/maec.12274.
7. Baillon S., Hamel J.F., et Mercier A., 2014: *Diversity, Distribution and Nature of Faunal Associations with Deep-Sea Pennatulacean Corals in the Northwest Atlantic.* PloS one. 9. e111519. DOI: 10.1371/journal.pone.0111519.
8. Baillon S., Hamel J.-F., Wareham V.E., Mercier A., 2012. *Deep cold-water corals as nurseries for fish larvae*. Frontiers in Ecology and the Environment 10:351–356. DOI: 10.1890/120022.
9. Baker E., Puglise K. et Harris P., 2016: *Mesophotic Coral Ecosystems - A Lifeboat for Coral Reefs?* The United Nations Environment Programme and GRID-Arendal, Nairobi and Arendal, ISBN: 978-82-7701-150-9.
10. Baldwin, C.C., Tornabene, L. & Robertson, D.R., 2018: *Below the Mesophotic*. Sci Rep 8, 4920. DOI: 10.1038/s41598-018-23067-1.
11. Bally M. et Garrabou J., 2007: *Thermodependent bacterial pathogens and mass mortalities in temperate benthic communities: a new case of emerging disease linked to climate change.* Global Change Biology, 13: 2078-2088. DOI: 10.1111/j.1365-2486.2007.01423.x.
12. Bavestrello G., Bo M., Bertolino M., Betti F., Cattaneo-Vietti R., 2014: *Long-term comparison of structure and dynamics of the red coral metapopulation of the Portofino Promontory (Ligurian Sea): A case-study for a Marine Protected Area in the Mediterranean Sea*. Marine Ecology. 36. DOI: 10.1111/maec.12235.
13. Bell J.J., Micaroni V., Harris B., Strano F., Broadribb M., Rogers A., 2022: *Global status, impacts, and management of rocky temperate mesophotic ecosystems*. Conservation Biology, 00, e13945. DOI: 10.1111/cobi.13945.
14. Ben-Tzvi O., Einbinder S., Brokovich E., 2006: *A beneficial association between a polychaete worm and a scleractinian coral?* Coral Reefs. 25. 98-98. DOI: 10.1007/s00338-005-0084-3.
15. Betti F., Bavestrello G., Bo M. et al., 2020: *Effects of the 2018 exceptional storm on the Paramuricea clavata (Anthozoa, Octocorallia) population of the Portofino Promontory (Mediterranean Sea).* Regional Studies in Marine Science. 34. 101037. DOI: 10.1016/j.rsma.2019.101037.

16. Bialik O., Gadol O., Micallef A., Betzler C., Nativ H., Einbinder S., Makovsky Y., 2023: *Internal waves and bottom currents interactions around mesophotic reefs, southeastern Mediterranean*. DOI: 10.31223/X56W88.
17. Bianchelli S., Pusceddu A., Canese S., Greco S., Danovaro R., 2013: *High Meiofaunal and Nematodes Diversity around Mesophotic Coral Oases in the Mediterranean Sea*. PLoS ONE 8(6): e66553. DOI: 10.1371/journal.pone.0066553.
18. Bianchi C. N., Azzola A., Bertolino M., Betti F., Bo M., Cattaneo-Vietti R., et al., 2019: *Consequences of the marine climate and ecosystem shift of the 1980-90s on the Ligurian Sea biodiversity (NW Mediterranean)*. The European Zoological Journal, 86:1, 458-487. DOI: 10.1080/24750263.2019.1687765.
19. Bianchi C., Morri C., 2003: *Global sea warming and "tropicalization" of the Mediterranean Sea: Biogeographic and ecological aspects*. Biogeographia. 24. 319-327. 10.21426/B6110129.
20. Bianchi C.N., Morri C., 2000: *Marine biodiversity of the Mediterranean Sea: Situation, problems and prospects for future research*. Marine Pollution Bulletin 40: 367–376.
21. Bo M., Bavestrello G., Angiolillo M. et al., 2015: *Persistence of Pristine Deep-Sea Coral Gardens in the Mediterranean Sea (SW Sardinia).* PloS one. 10. e0119393. DOI: 10.1371/journal.pone.0119393.
22. Bo M., Tazioli S., Spanò N., Bavestrello G., 2008: *Antipathella subpinnata (Antipatharia, Myriopathidae) in Italian seas.* Italian Journal of Zoology. 75. 185-195. DOI: 10.1080/11250000701882908.
23. Bongaerts P. et al., 2019: *Mesophotic.org: a repository for scientific information on mesophotic ecosystems Background & Summary.* Database. 2019. DOI: 10.1093/database/baz140.
24. Bongaerts P., Muir P., Englebert N., Bridge T. C. L., Hoegh-Guldberg O., 2013: *Cyclone damage at mesophotic depths on Myrmidon Reef (GBR)*. Coral Reefs 32:935.
25. Bongaerts P., Ridgway T., Sampayo E. M., Hoegh-Guldberg O., 2010: Assessing the ‘deep reef refugia’ hypothesis: focus on Caribbean reefs. Coral Reefs 29:309–327.
26. Bongaerts P., Smith T.B., 2019: *Beyond the “Deep Reef Refuge” hypothesis: a conceptual framework to characterize persistence at depth*. In: Loya Y., Puglise K.A., Bridge T.C.L. (eds) *Mesophotic coral ecosystems*. Springer, New York, pp 881–895. DOI: 10.1007/978-3-319-92735-0.
27. Bosc E., Bricaud A., Antoine D., 2004: *Seasonal and interannual variability in algal biomass and primary production in the Mediterranean Sea, as derived from 4 years of SeaWiFS observations*. Global Biogeochemical Cycles 18. DOI: 10.1029/2003GB002034.
28. Bouchet P., 2006: *The magnitude of marine biodiversity* in *The exploration of marine biodiversity: Scientific and technological challenges.* Editor C. M. Duarte (Madrid: Fundación BBVA), 31–62.
29. Bramanti L., Movilla J., Guron M., Calvo E., Gori A., et al., 2013: *Detrimental effects of ocean acidification on the economically important Mediterranean red coral (Corallium rubrum)*. Global change biology. 19. DOI: 10.1111/gcb.12171.
30. Bridge T. C. L., Hughes T. P. , Guinotte J. M., Bongaerts P., 2013: *Call to protect coral reefs.* Nature Climate Change 3:528–530. DOI: 10.1038/nclimate1879.
31. Brooks T. M., Mittermeier R. A., da Fonseca G. A. B., Gerlach J., Hoffmann M., Lamoreux J. F. et al., 2006: *Global biodiversity conservation priorities.* Science 313, 58–61. DOI:10.1126/science.1127609.

32. Buhl-Mortensen L., Mortensen P.B., 2004: *Gorgonophilus canadensis n. gen., n. sp. (Copepoda: Lamippidae), a Gall Forming Endoparasite in the Octocoral Paragorgia arborea (L., 1758) from the Northwest Atlantic.* Symbiosis, 37, 155-168. Print ISSN: 0334-5114.
33. Cabaitan P.C., Quimpo T.J.R., Dumalagan E.E. Jr., Munar J., Calleja M.A., Olavides R.D.D., Go K., Albelda R., Cabactulan D., Tinacba E.J.C., Doctor M.A.A., Villanoy C., Siringan F.P., 2019: *The Philippines*. In: Loya Y., Puglise K.A., Bridge T.C.L. (eds) *Mesophotic coral ecosystems*. Springer, New York, pp 265–284. DOI: 10.1007/978-3-319-92735-0.
34. Canessa M., G. Bavestrello, M. Bo, E. Trainito, P. Panzalis, A. Navone, A. Caragnano, F. Betti, R. Cattaneo-Vietti, 2020: *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, Volume 35, 101159, DOI: 10.1016/j.rsma.2020.101159.
35. Cappelletto, M. et al., 2021: *The Mediterranean Sea we want*. Ocean and Coastal Research. 69. DOI: 10.1590/2675-2824069.21019mc.
36. Carbonne C., Comeau S., Chan P., Plichon K., Gattuso J.-P., Teixidó N., 2022: *Early life stages of a Mediterranean coral are vulnerable to ocean warming and acidification.* DOI: 10.5194/egusphere-2022-240.
37. Carbonne C., Teixidó N., Moore B., Mirasole A., Guttierez T., Gattuso J. P., et al., 2021: *Two temperate corals are tolerant to low pH regardless of previous exposure to natural CO2 vents.* Limnology Oceanography. 66 (11), 4046–4061. DOI: 10.1002/lno.11942.
38. Castellan G., Abbiati M., Angeletti L., Foglini F. et al., 2022b: *What are we protecting? An analysis of the current conservation framework addressing Mediterranean mesophotic habitats*. Frontiers of Environmental Science & Engineering in China. DOI: 10.3389/fenvs.2022.1009033.
39. Castellan G., Angeletti L., Taviani M., Montagna P., 2019: *The Yellow Coral Dendrophyllia cornigera in a Warming Ocean.* Frontiers in Marine Science. (6). DOI: 10.3389/fmars.2019.00692.
40. Castellan G., Angeletti, L., Montagna, P. et al., 2022: *Drawing the borders of the mesophotic zone of the Mediterranean Sea using satellite data.* Sci Rep 12, 5585. DOI: 10.1038/s41598-022-09413-4
41. Cau A., Bramanti L., Cannas R., Moccia D., Padedda B. et al., 2018: *Differential response to thermal stress of shallow and deep dwelling colonies of Mediterranean red coral Corallium rubrum (L., 1758).* Advances in Oceanography and Limnology. 9. DOI: 10.4081/aiol.2018.7275.
42. Cau A., Follesa M., Moccia D., Alvito A., Bo M., Angiolillo M. et al., 2015: *Deepwater corals biodiversity along roche du large ecosystems with different habitat complexity along the south Sardinia continental margin (CW Mediterranean Sea)*. Marine Biology. 162. 1865-1878. DOI: 10.1007/s00227-015-2718-5.
43. Cavicchia L., Von Storch H., Gualdi S., 2013: *A long-term climatology of medicanes*. Climate Dynamics. 43. DOI: 10.1007/s00382-013-1893-7.
44. Cerrano C., Bastari A., Calcinai B., Di Camillo C., Pica D., Puce S., Valisano L. et Torsani F., 2019: *Temperate mesophotic ecosystems: gaps and perspectives of an emerging conservation challenge for the Mediterranean Sea*. The European Zoological Journal, 86:1, 370-388, DOI: 10.1080/24750263.2019.1677790.
45. Cerrano C., Bavestrello G., Bianchi N., Cattano-Vietti R., Bava S., Morganti C., et al., 2000: *A catastrophic massmortality episode of gorgonians and other organisms in the Ligurian Sea*

(North-western Mediterranean), summer 1999. Ecol Lett. 2000; 3: 284–293. DOI:10.1046/j.1461-0248.2000.00152.x

46. Cerrano C., Cardini U., Bianchelli S., Corinaldesi C., 2013: *Red coral extinction risk enhanced by ocean acidification*. Scientific reports. 3. 1457. DOI: 10.1038/srep01457.
47. Cerrano C., Danovaro R., Gambi C. et al., 2010: *Gold coral (Savalia savaglia) and gorgonian forests enhance benthic biodiversity and ecosystem functioning in the mesophotic zone.* Biodivers Conserv 19, 153–167. DOI: 10.1007/s10531-009-9712-5.
48. Chadwick-Furman N., Loya Y., 1992: *Migration, habitat use, and competition among mobile corals (Scleractinia: Fungiidae) in the Gulf of Eilat, Red Sea. Marine Biology* 114, 617–623 (1992). DOI: 10.1007/BF00357258.
49. Chang E., Neuhof M., Rubinstein N., Diamant A., Phillipe H., Huchon D., Cartwright P., 2015: *Genomic insights into the evolutionary origin of Myxozoa within Cnidaria.* Proceedings of the National Academy of Sciences. 112. DOI: 10.1073/pnas.1511468112.
50. Chaves-Fonnegra A., Panassiti B., Smith T., Brown E., Clemens E., Sevier M., Brandt M., 2021: *Environmental and biological drivers of white plague disease on shallow and mesophotic coral reefs.* Ecography. 44. DOI: 10.1111/ecog.05527.
51. Chimienti G., 2020: *Vulnerable Forests of the Pink Sea Fan Eunicella verrucosa in the Mediterranean Sea*. Diversity 12, no. 5: 176. DOI: 10.3390/d12050176.
52. Chimienti G., De Padova D., Adamo M., Mossa M., Bottalico A. et al., 2021: *Effects of global warming on Mediterranean coral forests*. Scientific Reports. 11. 20703. DOI: 10.1038/s41598-021-00162-4.
53. Chimienti G., De Padova D., Mossa M. et Mastrototaro F., 2020: *A mesophotic black coral forest in the Adriatic Sea*. Scientific reports, 10(1), pp.1-15.
54. Coll, M., et al., 2010: *The biodiversity of the Mediterranean Sea: estimates, patterns, and threats.* PloS one, p. 5(8). DOI: 10.1371/journal.pone.0011842.
55. Collins A.G., 2002: *Phylogeny of Medusozoa and the evolution of cnidarian life cycles*. Journal of Evolutionary Biology, 15: 418-432. DOI: 10.1046/j.1420-9101.2002.00403.x.
56. Coma R., Ribes M., 2003: S*easonal energetic constraints in Mediterranean benthic suspension feeders*. Oikos. 101. 205 - 215. DOI: 10.1034/j.1600-0706.2003.12028.x.
57. Coma R., Ribes M., Gili J.M., Zabala M., 2000: *Seasonality in coastal benthic ecosystems.* Trends in Ecology & Evolution. 15. 448-453. DOI: 10.1016/S0169-5347(00)01970-4.
58. Conci N., Vargas S., Wörheide G., 2021: *The Biology and Evolution of Calcite and Aragonite Mineralization in Octocorallia.* Frontiers in Ecology and Evolution. 9. 623774. DOI: 10.3389/fevo.2021.623774.
59. Conover, D., Munch S., Arnott S., 2009: *Reversal of evolutionary downsizing caused by selective harvest of large fish.* P Roy Soc B–Biol Sci. Proceedings. Biological sciences / The Royal Society. 276. 2015-20. DOI: 10.1098/rspb.2009.0003.
60. Coppari M., Ferrier-Pagès C., Castellano M., Massa F., et al., 2019: *Seasonal variation of the stable C and N isotopic composition of the mesophotic black coral Antipathella subpinnata (Ellis & Solander, 1786).* Estuarine, Coastal and Shelf Science. 233. 106520. 10.1016/j.ecss.2019.106520.
61. Corinaldesi C., Varrella S., Tangherlini M., Dell'Anno A., Canensi S., Cerrano C. et Roberto Danovaro, 2022: *Changes in coral forest microbiomes predict the impact of marine heatwaves on habitat-forming species down to mesophotic depths*, Science of The Total Environment, Volume 823, 2022, 153701, ISSN 0048-9697, DOI: 10.1016/j.scitotenv.2022.153701.

62. Coro G., Tassetti A.N., Armelloni E.N. et al., 2022: *COVID-19 lockdowns reveal the resilience of Adriatic Sea fisheries to forced fishing effort reduction*. Sci Rep 12, 1052. DOI: 10.1038/s41598-022-05142-w.
63. Corriero G. et al., 2019: *A Mediterranean mesophotic coral reef built by non-symbiotic scleractinians.* Scientific Reports, p. 9. DOI: 10.1038/s41598-019-40284-4.
64. Cortés J., 2019: *Isla del Coco, Costa Rica, Eastern Tropical Pacific*. In:Loya Y., Puglise K.A., Bridge T.C.L. (eds) *Mesophotic coral ecosystems*. Springer, New York, pp 465–475. DOI: 10.1007/978-3-319-92735-0
65. Costello, M.J. et al., 2010: *A census of marine biodiversity knowledge, resources, and future challenges.* PLoS One. 5(8). DOI: 10.1371/journal.pone.0012110
66. Cupido R., Cocito S., Barsanti M., Sgorbini S., Peirano A., Santangelo G., 2009: *Unexpected long-term population dynamics in a canopy-forming gorgonian following mass mortality.* Mar Ecol Prog Ser. 394: 195–200. DOI: 10.3354/meps08260.
67. Da Ros Z., Dell'Anno A., Morato T., Sweetman A.K., Carreiro-Silva M., Smith C.J., Papadopoulou N., Corinaldesi C., Bianchelli S., et al., 2019: *The deep sea: The new frontier for ecological restoration*, Marine Policy, Volume 108, 103642. DOI: 10.1016/j.marpol.2019.103642.
68. Daly M., Fautin D.G., Cappola V.A., 2003: *Systematics of the Hexacorallia (Cnidaria: Anthozoa)*, Zoological Journal of the Linnean Society, Volume 139, Issue 3, November 2003, Pages 419–437, DOI: 10.1046/j.1096-3642.2003.00084.x.
69. Danovaro R., Fanelli E., Canals M., Ciuffardi T., et al., 2020: *Towards a Marine Strategy for the Deep Mediterranean Sea: Analysis of current ecological status*. Marine Policy. 112. DOI: 10.1016/j.marpol.2019.103781.
70. Danovaro, R., Fonda-Umani S., Pusceddu A., 2009: *Climate Change and the Potential Spreading of Marine Mucilage and Microbial Pathogens in the Mediterranean Sea.* PloS one. 4. e7006. DOI: 10.1371/journal.pone.0007006.
71. Díaz S., Settele J., Brondízio E. S., Ngo H. T., Agard J., Arneth A. et al., 2019: *Pervasive human-driven decline of life on Earth points to the need for transformative change*. Science 366 (6471), Eaax3100. DOI:10.1126/science.aax3100.
72. Dieni I. et Massari F., 2021: *The coral Synastrea bellula (d'Orbigny) in the Berriasian of Venetian Prealps (NE Italy). A key for interpreting the palaeobathymetry of the Maiolica on the Trento Plateau*, Cretaceous Research, Volume 125, 104871, ISSN 0195-6671, DOI: 10.1016/j.cretres.2021.104871.
73. Dustan P., Lang J.C., 2019: *Discovery Bay, Jamaica*. In: Loya Y., Puglise K.A., Bridge T.C.L. (eds) *Mesophotic coral ecosystems*. Springer, New York, pp 85–109. DOI: 10.1007/978-3-319-92735-0.
74. Easton E.E., Gorny M., Mecho A., Sellanes J., Gaymer C., Spalding H.L., Aburto J., 2019: *Chile and Salas the y Gómez Ridge*. In: Loya Y., Puglise K.A., Bridge T.C.L. (eds) *Mesophotic coral ecosystems*. Springer, New York, pp 477–490. DOI: 10.1007/978-3-319-92735-0
75. Emig C., Geistdoerfer P., 2005: *The Mediterranean deep-sea fauna: Historical evolution, bathymetric variations and geographical changes.* ArXiv preprint qbio/0507003v1.
76. Enrichetti F., Bo M., Morri C., Montefalcone M., Toma M., et al., 2019: *Assessing the environmental status of temperate mesophotic reefs: A new, integrated methodological approach,* Ecological Indicators, Volume 102, p. 218-229. DOI: 10.1016/j.ecolind.2019.02.028.

77. Erftemeijer P., Riegl B., Hoeksema B., Todd P., 2012: *Environmental impacts of dredging and other sediment disturbances on corals: A review*. Marine pollution bulletin. 64. 1737-65. DOI: 10.1016/j.marpolbul.2012.05.008.
78. Estévez R. M., Palacios M., Cervera J. L., et González-Duarte M. M., 2022: *Expansion of the invasive alga rugulopteryx okamurae (dictyotaceae, ochrophyta) in the mediterranean sea: First evidence as epiphyte of the cold-water coral dendrophyllia ramea (cnidaria: Scleractinia).* BioInvasions Records, 11(4), 925-936. DOI:10.3391/bir.2022.11.4.11.
79. Estrada M (1996) Primary production in the northwestern Mediterranean. Scientia Marina 60 (Suppl. 3): 55–64.
80. Etnoyer P. et Warrenchuk J., 2007: *A catshark nursery in a deep gorgonian field in the Mississippi Canyon,* Gulf of Mexico. Bull Mar Sci 81: 553–59.
81. Eyal G., Tamir R., Kramer N., Eyal-Shaham L., Loya Y., 2019: *The Red Sea: Israel*. In: Loya Y., Puglise K.A., Bridge T.C.L. (eds) *Mesophotic coral ecosystems*. Springer, New York, pp 199–214. DOI: 10.1007/978-3-319-92735-0.
82. Fisher R., Radford B.T., Knowlton N., Brainard R.E., Michaelis F.B., Caley M.J. , 2011: *Global mismatch between research effort and conservation needs of tropical coral reefs.* Conserv Lett 4(1):64–72.
83. Flagella, M.M., Abdulla, A.A. *Ship ballast water as a main vector of marine introductions in the Mediterranean Sea*. WMU J Marit Affairs 4, 95–104 (2005). DOI: 10.1007/BF03195066.
84. Floros C., Samways M. et Armstrong B., 2005: *Polychaete (Spirobranchus giganteus) loading on South African corals*. Aqua. Con: Mar. and Freshwater Ecosystems. 15, 289-298. DOI: 10.1002/aqc.666.
85. Forcioli D., Merle P.L., Caligara C., Ciosi M., Muti C., Francour P., Cerrano, C., Allemand D., 2011: *Symbiont diversity is not involved in depth acclimation in the Mediterranean sea whip Eunicella singularis.* Marine Ecology Progress Series. 439. 57-71. DOI:10.3354/meps09314.
86. Fox A., Henry L.-A., Corne D., Roberts J.,2016: *Sensitivity of marine protected area network connectivity to atmospheric variability*. Royal Society Open Science. 3. 160494. DOI: 10.1098/rsos.160494.
87. Frade P.R., Bongaerts P., Baldwin C.C., Trembanis A.C., Bak R.P.M., Vermeij M.J.A., 2019: *Bonaire and Curaçao*. In: Loya Y., Puglise K.A., Bridge T.C.L. (eds) *Mesophotic coral ecosystems*. Springer, New York, pp 149–162. DOI: 10.1007/978-3-319-92735-0.
88. Francini-Filho R.B., Velásquez V.M., da Silva M.B., Rosa M.R., Sumida P.Y.G., Pinheiro H.T., Rocha L.A., Ferreira C.E.L., Francini C.L.B., Rosa R.S., 2019: *Brazil*. In: Loya Y., Puglise K.A., Bridge T.C.L. (eds) *Mesophotic coral ecosystems*. Springer, New York, pp 163–198. DOI: 10.1007/978-3-319-92735-0.
89. Galil B.S., Danovaro R., Rothman S.B.S. et al., 2019: *Invasive biota in the deep-sea Mediterranean: an emerging issue in marine conservation and management*. Biol Invasions 21, 281–288. DOI: 10.1007/s10530-018-1826-9.
90. Gambi, M. C., Barbieri F., 2012: *Population structure of the gorgonian Eunicella cavolinii in the "Grotta Azzurra" cave off Palinuro after the mass mortality event in 2008*. Biologia Marina Mediterranea. 19. 174-175.
91. Garcia-Castellanos D., Estrada F., Jiménez-Munt I., Gorini C., Fernandez M., et al., 2009: *Catastrophic flood of the Mediterranean after the Messinian salinity crisis.* Nature 462. DOI: 10.1038/nature08555.
92. Garrabou J., Coma R., Benssoussan N., Bally M., Chevaldonné P., Cigliano M., et al., 2009: *Mass mortality in NW Mediterranean rocky benthic communities: effects of the 2003 heat wave.* Glob Change Biol. 2009; 15: 1090–1103. DOI: 10.1111/j.1365-2486.2008.01823.x.

93. Garrabou J., Gómez-Gras D., Ledoux J.-B., Linares C., Bensoussan N., López-Sendino P. et al., 2019: *Collaborative Database to Track Mass Mortality Events in the Mediterranean Sea*. Frontiers in Marine Science. 6. DOI: 10.3389/fmars.2019.00707.
94. Garrabou J., Sala E., Linares C. et al., 2017: *Re-shifting the ecological baseline for the overexploited Mediterranean red coral.* Sci Rep 7, 42404. DOI: 10.1038/srep42404.
95. Gasol J., Cardelús C., Morán X.A., Balagué V., Forn I., Marrasé C., Massana R., Pedrós-Alió C., Montserrat S.M., Simó R., Vaqué D., Estrada M., 2016: *Seasonal patterns in phytoplankton photosynthetic parameters and primary production at a coastal NW Mediterranean site.* Scientia Marina. 80. 63-77. DOI: 10.3989/scimar.04480.06E.
96. Gattuso J.P. et al., 2006: *Light availability in the coastal ocean: Impact on the distribution of benthic photosynthetic organisms and contribution to primary production.* Biogeosciences Discussions 3, 895–959. DOI: 10.5194/bgd-3-895-2006.
97. Gill G., Santantonio M., Lathuilière B., 2004: *The depth of pelagic deposits in the Tethyan Jurassic and the use of corals: An example from the Apennines*. Sedimentary Geology - SEDIMENT GEOL. 166. 311-334. DOI: 10.1016/j.sedgeo.2004.01.013.
98. Giusti M., M. Bo, M. Angiolillo, R. Cannas, A. Cau, M.C. Follesa, S. Canese, 2017: *Habitat preference of Viminella flagellum (Alcyonacea: Ellisellidae) in relation to bathymetric variables in southeastern Sardinian waters,* Continental Shelf Research, Volume 138, p. 41-50, DOI: 10.1016/j.csr.2017.03.004.
99. Gleason D.F., Edmunds P.J., Gates R.D., 2006: *Ultraviolet radiation effects on the behavior and recruitment of larvae from the reef coral Porites astreoides*. *Marine Biology* 148, 503–512. DOI: 10.1007/s00227-005-0098-y.
100. Glynn P. W., 1996: *Coral reef bleaching: facts, hypotheses and implications.* Global Change Biology 2: 495–509. DOI: 10.1111/j.1365-2486.1996.tb00063.x
101. Godefroid M., Zeimes T., Bramanti L., Pascal R., Bo M. et al., 2022: *Low vulnerability of the Mediterranean antipatharian Antipathella subpinnata (Ellis & Solander, 1786) to ocean warming.* Ecological Modelling. 475. 110209. DOI: 10.1016/j.ecolmodel.2022.110209.
102. Gomei M., Abdulla A., Schröder C., Yadav S., Sánchez A., Rodríguez D. et Abdul Malak D., 2019: *Towards 2020: How Mediterranean countries are performing to protect their sea.* WWF
103. Gómez Mestres S. et Lloret J., 2017: *The Small-Scale Fisheries Guidelines as a Tool for a Marine Stewardship: The case of Cap de Creus Marine Protected Areas, Spain*. In Jentoft S., Chuenpagdee R., Barragán-Paladines M.J., Franz N. (Eds.), *The small-scale fisheries guidelines – Global implementation*. Dordrecht: Springer. DOI: 10.1007/978-3-319-55074-9_19.
104. Gómez-Gras D., Linares C., López-Sanz A., Amate R., Ledoux J.B., Bensoussan N. et al., 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. DOI: 10.1098/rspb.2021.2384.
105. Goodbody-Gringley G., Noyes T., Smith S.R., 2019: *Bermuda*. In: Loya Y., Puglise K.A., Bridge T.C.L. (eds) *Mesophotic coral ecosystems*. Springer, New York, pp 31–45. DOI: 10.1007/978-3-319-92735-0.
106. Gori A., Bramanti L., López-González P., Thoma J., Gili J.M., Grinyó J., et al., 2012: *Characterization of the zooxanthellate and azooxanthellate morphotypes of the Mediterranean gorgonian Eunicella singularis.* Mar Biol. 2012; 159: 1485–1496. DOI: 10.1007/s00227-012-1928-3.

107. Grinyó J., A.G. Costa, Membrives A., Muriel A.S., Ambroso S., López-González P., Díaz D., 2020: *Soft corals assemblages in deep environments of the Menorca Channel (Western Mediterranean Sea).* Progress In Oceanography. DOI: 10.1016/j.pocean.2020.102435.
108. Grinyó J., Viladrich N., Díaz D., Muñoz A., Mallol S., Salazar J., et al., 2018: *Reproduction, energy storage and metabolic requirements in a mesophotic population of the gorgonian Paramuricea macrospina.* PLoS ONE 13(9): e0203308. DOI: 10.1371/journal.pone.0203308.
109. Hassoun A.E.R., Bantelman A., Canu D., Comeau S., Charles G. et al., 2022: *Ocean acidification research in the Mediterranean Sea: Status, trends and next steps*. Frontiers in Marine Science. DOI: 10.3389/fmars.2022.892670.
110. Heltzel P.S., Babcock R., 2002: *Sexual reproduction, larval development and benthic planulae of the solitary coral Monomyces rubrum (Scleractinia: Anthozoa)*. Marine Biology. 140. 659-667. DOI: 10.1007/s00227-001-0745-x.
111. Hinderstein L., Marr J.C.A., Martinez F.A., Dowgiallo M.J., Puglise K.A., Pyle R.L., Zawada D.G., Appeldoorn R., 2010: *Theme section on "Mesophotic coral ecosystems: characterization, ecology, and management."* Coral Reefs 29(2):247–251.DOI: 10.1007/s00338-010-0614-5.
112. Howaida Y. Z., 2015: *Lessepsian migration of zooplankton through Suez Canal and its impact on ecological system,* The Egyptian Journal of Aquatic Research, Volume 41, Issue 2, p. 129-144. DOI: 10.1016/j.ejar.2015.04.001.
113. Ingrassia M., Bella L., 2021: *Black Coral Distribution in the Italian Seas: A Review.* Diversity. 13. 334. DOI: 10.3390/d13070334.
114. Jacques, P. et al., 2017: *EUSeaMap, a European broad-scale seabed habitat map.* DOI: 10.13155/49975.
115. Jones R., Fisher R., Francis D., Klonowski W. et al., 2020: *Risk Assessing Dredging Activities in Shallow-Water Mesophotic Reefs Final Report*. DOI: 10.13140/RG.2.2.36023.47524.
116. Jorda G., Marbà N., Bennett,S. et al., 2020: *Ocean warming compresses the three-dimensional habitat of marine life.* Nat Ecol Evol 4, 109–114. DOI: 10.1038/s41559-019-1058-0.
117. Kahng S. E., Copus M. et Wagner D., 2014: *Recent advances in the ecology of mesophotic coral ecosystems (MCEs).* Current Opinion in Environmental Sustainability, Volume 7, 72-81, DOI: 10.1016/j.cosust.2013.11.019.
118. Kahng S.E., Akkaynak D., Shlesinger T., Hochberg E.J., Wiedenmann J., Tamir R., Tchernov D., 2019: *Light, temperature, photosynthesis, heterotrophy, and the lower depth limits of mesophotic coral ecosystems*. In: Loya Y., Puglise K.A., Bridge T.C.L. (eds) *Mesophotic coral ecosystems*. Springer, New York, pp 801–828. DOI: 10.1007/978-3-319-92735-0.
119. Kahng, S.E. et al., 2010: *Community ecology of mesophotic coral reef ecosystems.* Coral Reefs. 29. 255-275. DOI: 10.1007/s00338-010-0593-6.
120. Katsanevakis, S. et al. , 2014: *Invading the Mediterranean Sea: Biodiversity patterns shaped by human activities.* Frontiers in Marine Science. DOI: 10.3389/fmars.2014.00032.
121. Kavousi J. et Keppel G., 2018: *Clarifying the concept of climate change refugia for coral reefs.* ICES Journal of Marine Science, Volume 75, Issue 1, pp 43–49. DOI: 10.1093/icesjms/fsx124.
122. Kersting D.K., Cebrian E., Verdura J. et al., 2017a: *Rolling corals in the Mediterranean Sea*. Coral Reefs 36, 245. DOI: 10.1007/s00338-016-1498-9.
123. Kersting D.K., Cebrian E., Verdura J., Ballesteros E., 2017b: *A new Cladocora caespitosa population with unique ecological traits*. Mediterranean Marine Science. 18. 38-42. DOI: 10.12681/mms.1955.

124. Kim, S., Wild, Ch., Tilstra, A., 2022: *Effective asexual reproduction of a widespread soft coral: comparative assessment of four different fragmentation methods.* PeerJ. 10. e12589. DOI: 10.7717/peerj.12589.
125. Kinlan B., Gaines S., 2003: *Propagule dispersal in marine and terrestrial environments: A community perspective*. Ecology. 84. DOI: 10.1890/01-0622.
126. Kleypas J. A., et al., 1999: *Environmental Limits to Coral Reef Development: Where Do We Draw the Line?1*. American Zoologist. 39. 146–159.
127. Koningsveld M. van , Hofstede R. ter, Elzinga J., et al., 2017: *ReefGuard: A Scientific Approach to Active Reef Rehabilitation*. Terra et Aqua. 147. 5-16.
128. Laverick, J., Rogers, A., 2019: *Mesophotic Coral Ecosystems.* 10.1016/B978-0-12-409548-9.11904-9.
129. Laverick, J.H. et al., 2018: *To what extent do mesophotic coral ecosystems and shallow reefs share species of conservation interest? A systematic review.* Environ Evid. 7, 15. DOI: 10.1186/s13750-018-0127-1
130. Lesser M. P., Slattery M., Laverick J. H., Macartney K. J. & Bridge T. C., 2019: *Global community breaks at 60 m on mesophotic coral reefs*. Glob. Ecol. Biogeogr. 28, 1403–1416. DOI: 10.1111/geb.12940.
131. Lesser M., Mobley C., Hedley J. et Slattery M., 2021: *Incident Light on Mesophotic Corals is Constrained by Reef Topography and Colony Morphology.* Marine Ecology Progress Series. 670. DOI: 10.3354/meps13756.
132. Letelier R.M., Karl D.M., Abbott M.R., Bidigare R.R., 2004: *Light driven seasonal patterns of chlorophyll and nitrate in the lower euphotic zone of the North Pacific Subtropical Gyre.* Limnology and Oceanography 49., 508–519. DOI: 10.4319/lo.2004.49.2.0508.
133. Levy N. et al., 2023: *Evaluating biodiversity for coral reef reformation and monitoring on complex 3D structures using environmental DNA (eDNA) metabarcoding.* Science of The Total Environment, Volume 856, Part 2, 159051, ISSN 0048-9697, DOI: 10.1016/j.scitotenv.2022.159051.
134. Lewis B.M., Suggett D.S., Prentis P.J. et al., 2022: *Cellular adaptations leading to coral fragment attachment on artificial substrates in Acropora millepora (Am-CAM). Sci Rep* 12, 18431. DOI: 10.1038/s41598-022-23134-8.
135. Leydet K., Hellberg M., 2015: *The invasive coral Oculina patagonica has not been recently introduced to the Mediterranean from the western Atlantic*. BMC evolutionary biology. 15. 79. DOI: 10.1186/s12862-015-0356-7.
136. Lillis A., Bohnenstiehl D., Peters J.W., et Eggleston D., 2016: *Variation in habitat soundscape characteristics influences settlement of a reef-building coral*. PeerJ 4:e2557. DOI:10.7717/peerj.2557.
137. 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. DOI: 10.3354/meps305127.
138. Linares C., Doak D., Coma R., Diaz D., Zabala M., 2007: *Life history and population viability of a long-lived marine invertebrate: the octocoral Paramuricea clavata.* Ecology. 2007; 88: 918–928. PMID: 17536708.
139. Liu J., Høeg J., Chan B., 2016: *How do coral barnacles start their life in their hosts?*. Biology Letters. 12. 20160124. DOI: 10.1098/rsbl.2016.0124.
140. Lo Iacono C., Orejas C., Gori A. et al., 2011: *Habitats of the Cap de Creus continental shelf and Cap de Creus Canyon, Northwestern Mediterranean.* DOI: 10.13140/RG.2.1.1846.3843.

141. Longo C., Pontassuglia C., Corriero G., et Gaino E., 2012: *Life-Cycle Traits of Paraleucilla magna, a Calcareous Sponge Invasive in a Coastal Mediterranean Basin*. PloS one. 7. e42392. DOI: 10.1371/journal.pone.0042392.
142. López-Márquez V. et al., 2021: *Asexual reproduction in bad times? The case of Cladocora caespitosa in the eastern Mediterranean Sea*. Coral Reefs 40, p. 663–677. DOI: 10.1007/s00338-020-02040-3.
143. Loya, Y. et al., 2019: *Mesophotic coral ecosystems*. Springer, New York. DOI: 10.1007/978-3-319-92735-0.
144. MacIntyre I., Bayer F., Logan M. et Skinner H., 2000: *Possible vestige of early phosphatic biomineralization in gorgonian octocorals (Coelenterata)*. Geology. 28. DOI: 10.1130/0091-7613(2000)28<455:PVOEPB>2.0.CO;2.
145. Maldonado A., 1985: *Evolution of the Mediterranean basins and a detailed reconstruction of the Cenozoic paleoceanography.* In: Margalef R., ed. *Key Environments: Western Mediterranean*. Oxford: Pergamon Press. pp 17–59.
146. Mannino A. M., Balistreri P., Deidun A., 2017: *The marine biodiversity of the Mediterranean Sea in a changing climate: the impact of biological invasions.* In B. Fuerst-Bjelis (Eds.), *Mediterranean identities - environment, society, culture* (pp. 101-127). London: INTECH.
147. Mantas T. P., Varotti C., Roveta C., Palma M., Innocenti C. et al., 2022: *Mediterranean Sea shelters for the gold coral Savalia savaglia (Bertoloni, 1819): An assessment of potential distribution of a rare parasitic species,* Marine Environmental Research, Volume 179, 105686, ISSN 0141-1136, DOI: 10.1016/j.marenvres.2022.105686.
148. Martinez S., Bellworthy J., Ferrier-Pagès C. et al., 2021: *Selection of mesophotic habitats by Oculina patagonica in the Eastern Mediterranean Sea following global warming. Sci Rep* 11, 18134. DOI: 10.1038/s41598-021-97447-5.
149. McFadden C.S., Quattrini A.M., Brugler M.R., Cowman P.F., Dueñas L.F., Kitahara M.V., Paz-García D.A., Reimer J.D., Rodríguez E., 2021: *Phylogenomics, Origin, and Diversification of Anthozoans (Phylum Cnidaria)*. Systematic Biology, Volume 70, Issue 4, July 2021, Pages 635–647. DOI: 10.1093/sysbio/syaa103.
150. MedECC, 2020: *Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future. First Mediterranean Assessment Report.* Cramer W., Guiot J., Marini K. (eds.), Union for the Mediterranean, Plan Bleu, UNEP/MAP, Marseille, France, 632pp. ISBN 978-2-9577416-0-1. DOI: 10.5281/zenodo.4768833.
151. Melanie J., Fernandez-Mora A., Tintoré J., 2022: *Sub-Regional Marine Heat Waves in the Mediterranean Sea From Observations: Long-Term Surface Changes, Sub-Surface and Coastal Responses.* Frontiers in Marine Science. 9. DOI: 10.3389/fmars.2022.785771.
152. Menza, C., Kendall M. et Hile S., 2007: *The deeper we go the less we know.* Revista de Biología Tropical. 56. DOI: 10.15517/rbt.v56i0.5575.
153. Micaroni V., 2022: *Effects of anthropogenic stressors on temperate mesophotic ecosystems.* Victoria University of Wellington. Doctoral thesis.
154. Mistri M. et Ceccherelli V.U., 1996: *Effects of a mucilage event on the Mediterranean gorgonian Paramuricea clavata. I - Short term impacts at the population and colony levels.* Italian Journal of Zool*ogy, 63,* 221-230.
155. Moccia D., Carugati L., Follesa M.C., Cannas R., Carbonara P., Pusceddu A., et Cau A., 2022: *Environmental Status and Geomorphological Characterisation of Seven Black Coral Forests on the Sardinian Continental Shelf (NW Mediterranean Sea)*. Biology 11, no. 5: 732. DOI: 10.3390/biology11050732.

156. Moccia D., Cau A., Bramanti L., et al., 2021: *Spatial distribution and habitat characterization of marine animal forest assemblages along nine submarine canyons of Eastern Sardinia (central Mediterranean Sea)*, Deep Sea Research Part I: Oceanographic Research Papers, Volume 167, 103422, ISSN 0967-0637, DOI: 10.1016/j.dsr.2020.103422.
157. Molina A.C., et al., 2018: *From depth to regional spatial genetic differentiation of Eunicella cavolini in the NW Mediterranean*. Comptes Rendus Biologies. 341. DOI: 10.1016/j.crvi.2018.09.002.
158. Montalbetti E., Cavallo S., Azzola A., Montano S., Galli P., Montefalcone M., Seveso D., 2022: *Mucilage-induced necrosis reveals cellular oxidative stress in the Mediterranean gorgonian Paramuricea clavata*. Journal of Experimental Marine Biology and Ecology. 559. 151839. DOI: 10.1016/j.jembe.2022.151839.
159. Montgomery A., Fenner D., Donahue M., Toonen R., 2021: *Community similarity and species overlap between habitats provide insight into the deep reef refuge hypothesis*. Scientific Reports. 11. 23787. DOI: 10.1038/s41598-021-03128-8.
160. Montgomery AD, Fenner D, Kosaki RK, Pyle RL, Wagner D, Toonen RJ, 2019: *American Samoa*. In: Loya Y., Puglise K.A., Bridge T.C.L. (eds) *Mesophotic coral ecosystems*. Springer, New York, pp 387–407. DOI: 10.1007/978-3-319-92735-0.
161. Montseny M., Linares C., Carreiro-Silva M., Henry L.-A., Billett D., Cordes E.E., Smith C.J., Papadopoulou N., et al., 2021a: *Active Ecological Restoration of Cold-Water Corals: Techniques, Challenges, Costs and Future Directions*. Front. Mar. Sci. 8:621151. DOI: 10.3389/fmars.2021.621151.
162. Montseny M., Linares C., Viladrich N. et al., 2019: *First attempts towards the restoration of gorgonian populations on the Mediterranean continental shelf.* Aquatic Conservation: Marine and Freshwater Ecosystems. 29. DOI: 10.1002/aqc.3118.
163. Montseny M., Linares C., Viladrich N., et al., 2021b: *Involving fishers in scaling up the restoration of cold-water coral gardens on the Mediterranean continental shelf.* Biological Conservation, 262, art. no. 109301. DOI: 10.1016/j.biocon.2021.109301.
164. Movilla J., Calvo E., Coma R., López-Sanz A., Serrano E., Pelejero C., 2015: *Long-term response of two Mediterranean azooxanthellate temperate corals to low-pH and high-temperature conditions*. Effects ocean acidification Mediterr. coral, 93.
165. Muir, P. et al., 2015: *Limited scope for latitudinal extension of reef corals.* Science, New York. 348. DOI: 1135-8. 10.1126/science.1259911.
166. Nastos P., Karavana-Papadimou K., Matsangouras I., 2017: *Mediterranean tropical-like cyclones: Impacts and composite daily means and anomalies of synoptic patterns*. Atmospheric Research. 208. DOI: 10.1016/j.atmosres.2017.10.023.
167. Niner H.J., Ardron J.A., Escobar E.G., Gianni M. et al., 2018: *Deep-Sea Mining With No Net Loss of Biodiversity—An Impossible Aim.* Frontiers in Marine Science. 5. DOI: 10.3389/fmars.2018.00053. ISSN: 2296-7745.
168. Oliver E., Burrows M., Donat M., et al., 2019: *Projected Marine Heatwaves in the 21st Century and the Potential for Ecological Impact*. Frontiers in Marine Science. 6. 734. DOI: 10.3389/fmars.2019.00734.
169. Orejas C. et Jimenez C., 2019: *Mediterranean Cold-Water Corals : Past, Present and Future.* Coral Reefs of the World, Springer, ISBN: 978-3-319-91607-1.
170. Orejas C., Taviani M., Ambroso S., Andreou V., et al., 2019: *38 Cold-Water Coral in Aquaria: Advances and Challenges. A Focus on the Mediterranean.* Coral Reefs of the World, 435–471. DOI: 10.1007/978-3-319-91608-8_38.

171. Otero M.M., Numa C., Bo M., Orejas C. et al., 2017: *OVERVIEW OF THE CONSERVATION STATUS OF MEDITERRANEAN ANTHOZOA*. DOI: 10.2305/IUCN.CH.2017.RA.2.en.
172. Özalp H. B, 2021: *First massive mucilage event observed in deep waters of Çanakkale Strait (Dardanelles) Turkey*. 21. 49-66.
173. Peirano A., Morri C., Bianchi C. N., 1999: *Skeleton growth and density pattern of the temperate, zooxanthellate scleractinian Cladocora caespitosa from the Ligurian Sea (NW Mediterranean).* Marine Ecology Progress Series, 185, 195–201.
174. Pérès J.M., 1982: *Major benthic assemblages.* In: Kinne O, editor. Chichester: Wiley and Sons. pp. 373–521
175. Pérès J.M., Picard J., 1964: *Noveau manuel de bionomie benthique de la mer Méditerranée.* Recueil Des Travaux De La Station Marine d'Endoume 31:5–137.
176. Pérez-Rosales G., Pichon M., Rouzé H., Villéger S., Torda G., Bongaerts P., 2022: *Mesophotic coral ecosystems of French Polynesia are hotspots of alpha and beta generic diversity for scleractinian assemblages.* Diversity and Distributions. 28. DOI: 10.1111/ddi.13549.
177. Pey A., Zamoum T., Allemand D., Furla P., Merle P.-L., 2011: *Depth-dependant thermotolerance of the symbiotic Mediterranean gorgonian Eunicella singularis: Evidence from cellular stress markers.* Journal of Experimental Marine Biology and Ecology. 404. DOI: 10.1016/j.jembe.2011.05.007.
178. Piazzi L., Atzori F., Cadoni N., Cinti M. F., Frau F., Ceccherelli G., 2018: *Benthic mucilage blooms threaten coralligenous reefs. Marine environmental research, 140,* 145–151. DOI: 10.1016/j.marenvres.2018.06.01.
179. Pinheiro H. T., Eyal G., Shepherd B., Rocha L.A., 2019: *Ecological insights from environmental disturbances in mesophotic coral ecosystems.* Ecosphere 10(4). DOI: 10.1002/ecs2.2666.
180. Pita L., Rix L., Slaby B.M. et al., 2018: *The sponge holobiont in a changing ocean: from microbes to ecosystems*. Microbiome 6, 46 (2018). DOI:10.1186/s40168-018-0428-1.
181. Ponti M., Turicchia E., Ferro F., Cerrano C., Abbiati M., 2018: *The understorey of gorgonian forests in mesophotic temperate reefs*. Aquatic Conserv: Mar Freshw Ecosyst. 28: 1153–1166. DOI: 10.1002/aqc.2928.
182. Porcu C., Follesa M., Cannas R., Cau A. et al., 2017: *Reproductive patterns in deep versus shallow populations of the precious Mediterranean gorgonian Corallium rubrum (Linnaeus, 1758) (Sardinia, Central-Western Mediterranean)*. Mediterranean Marine Science. 18. 64-76. DOI: 10.12681/mms.1854.
183. Prada F., Caroselli E., Mengoli S., Brizi L., Fantazzini P., Capaccioni B., et al., 2017: *Ocean warming and acidification synergistically increase coral mortality.* Sci. Rep. 7 (1), 1–10. DOI: 10.1038/srep40842.
184. Previati M., Scinto A., Cerrano C., Osinga R., 2010: *Oxygen consumption in Mediterranean octocorals under different temperatures*. Journal of Experimental Marine Biology and Ecology. 390. 39-48. DOI: 10.1016/j.jembe.2010.04.025.
185. Puglise K., Hinderstein L., Marr J.C.A., Dowgiallo M.J., Martinez F.A., 2009: *Mesophotic Coral Ecosystems Research Strategy: International Workshop to Prioritize Research and Management Needs for Mesophotic Coral Ecosystems*, Jupiter, Florida, 12-15 July 2008. NOAA Technical Memorandum NOS NCCOS 98 and OAR OER 2.
186. Pyle R.L., Boland R., Bolick H., et al., 2016: *A comprehensive investigation of mesophotic coral ecosystems in the Hawaiian Archipelago.* PeerJ 4:e2475. DOI: 10.7717/peerj.2475

187. Pyle, R.L., 1996: *Exploring deep coral reefs: how much biodiversity are we missing?* Global Biodivers 6:3–7.
188. Rocha L.A., Pinheiro H.T., Shepherd B., Papastamatiou Y.P., Luiz O.J., Pyle R.L., Bongaerts P., 2018: *Mesophotic coral ecosystems are threatened and ecologically distinct from shallow water reefs.* Science 361:281–284. DOI: 10.1126/science.aaq1614.
189. Rodolfo-Metalpa R., Houlbrèque F., Tambutté É., Boisson F., Baggini C., Patti F. P., et al., 2011: *Coral and mollusc resistance to ocean acidification adversely affected by warming.* Nat. Climate Change 1 (6), 308–312. DOI: 10.1038/nclimate1200.
190. Rodolfo-Metalpa R., Reynaud S., Allemand D., Ferrier-Pagès C., 2008: *Temporal and depth responses of two temperate corals, Cladocora caespitosa and Oculina patagonica, from the North Mediterranean Sea*. Marine Ecology Progress Series. 369. 103-114. DOI: 10.3354/meps07608.
191. Rossi S., 2013: *The destruction of the 'animal forests' in the oceans: Towards an oversimplification of the benthic ecosystems.* Ocean & Coastal Management. 84. 77. DOI: 10.1016/j.ocecoaman.2013.07.004.
192. Rowley S.J., 2014: *Refugia in the 'twilight zone:' discoveries from the Philippines.* Mar Biol 2:16–17.
193. Rowley, S., 2008: *A critical evaluation of the symbiotic association between tropical tube-dwelling Polychaetes and their Hermatypic coral hosts, with a focus on Spirobranchus giganteus (Pallas, 1766)*. The Plymouth Student Scientist. 1. 335-353.
194. Ryther J., 1956: Photosynthesis in the ocean as a function of light intensity. Limnology and Oceanography 1:61–70. DOI: 10.4319/lo.1956.1.1.0061.
195. Sakai Y., Kato K., Koyama H. *et al.*, 2020: *A step-down photophobic response in coral larvae: implications for the light-dependent distribution of the common reef coral, Acropora tenuis. Sci Rep* 10, 17680. DOI: 10.1038/s41598-020-74649-x.
196. Sampaio Í., Braga-Henriques A., Pham C. et al., 2012: *Cold-water corals landed by bottom longline fisheries in the Azores (north eastern Atlantic)*. J Mar Biol Assoc UK 92:1547–1555.
197. Sampaio Í., Freiwald A., Porteiro F., Menezes G., Carreiro-Silva M., 2019: *Census of Octocorallia (Cnidaria: Anthozoa) of the Azores (NE Atlantic) with a nomenclature update.* Zootaxa. 4550. 451–498. DOI: 10.11646/zootaxa.4550.4.1.
198. Santangelo G., Bramanti L., Rossi S., Tsounis G., Vielmini I., Lott C., Gili J.M., 2012: *Patterns of variation in recruitment and post-recruitment processes of the Mediterranean precious gorgonian coral Corallium rubrum*. Journal of Experimental Marine Biology and Ecology, Volume 411, P 7-13. DOI: 10.1016/j.jembe.2011.10.030.
199. Sara M., 1985: *Ecological factors and their biogeographic consequences in the Mediterranean ecosystem*. In: Moraitous-Apostolopoulou M., Kiortsis V., eds. *Mediterranean Marine Ecosystems*. New York: Plenum Press. pp 1–17.
200. Sartoretto S. et Francour P., 2012: *Bathymetric distribution and growth rates of Eunicella verrucosa (Cnidaria: Gorgoniidae) populations along the Marseilles coast (France).* Scientia Marina. 76. 349-355. DOI: 10.3989/scimar.03262.16B.
201. Savoca S., Fresco D., Alesci A., Capillo G., Spanò N., 2022: *Mucus secretions in Cnidarian, an ecological, adaptive and evolutive tool.* Advances in Oceanography and Limnology. 13. DOI:10.4081/aiol.2022.11054.
202. Scaps P. et Denis V., 2007: *Association between the scallop, Pedum spondyloideum, (Bivalva: Pteriomorphia: Pectinidae) and scleractinian corals from the Wakatobi Marine National Park (southeastern Sulawesi, Indonesia)*. Raff. Bull. Zool. 55, 371-380.

203. Schiaparelli S., Castellano M., Povero P., Sartoni G., Cattaneo-Vietti R., 2007: *A benthic mucilage event in North-Western Mediterranean Sea and its possible relationships with the summer 2003 European heatwave: short term effects on littoral rocky assemblages.* Marine Ecology, 28: 341-353. DOI: 10.1111/j.1439-0485.2007.00155.x.
204. Sellanes J., Gorny M., Zapata-Hernández G., Alvarez G., Muñoz P., Tala F., 2021: *A new threat to local marine biodiversity: filamentous mats proliferating at mesophotic depths off Rapa Nui.* PeerJ 9:e12052. DOI: 10.7717/peerj.12052.
205. Semeraro D., Mastrodonato M., Mercurio M., Guglielmi M. V., Corriero G. et Marzano C. N., 2022: *Reproduction of reef-building scleractinians (Cnidaria, Anthozoa) from the Apulian coral reef: preliminary data and relationship with temperature.* 2022 IEEE International Workshop on Metrology for the Sea: Learning to Measure Sea Health Parameters (MetroSea), Milazzo, Italy, pp. 329-333. DOI: 10.1109/MetroSea55331.2022.9950993.
206. Serrano E., Ribes M., Coma R., 2018: *Demographics of the zooxanthellate coral Oculina patagonica along the Mediterranean Iberian coast in relation to environmental parameters*. Science of The Total Environment. 634. DOI: 10.1016/j.scitotenv.2018.04.032.
207. Shepard A., Theroux R.B., Cooper R.A., Uzmann J.R., 1986: *Ecology of Ceriantharia (Coelenterata, Anthozoa) of the northwest Atlantic from Cape Hatteras to Nova Scotia*. Fish. Bull. (United States). 84:3.
208. Sheppard, C. R. et al., 2012: *Reefs and islands of the Chagos Archipelago, Indian Ocean: why it is the world's largest no-take marine protected area.* Aquatic conservation: marine and freshwater ecosystems, 22(2), 232–261. DOI: 10.1002/aqc.1248
209. Sherman C.E., Locker S.D., Webster J.M., Weinstein D.K., 2019: *Geology and geomorphology.* In: Loya Y., Puglise K.A., Bridge T.C.L. (eds) *Mesophotic coral ecosystems.* Springer, New York, pp 849–878. DOI: 10.1007/978-3-319-92735-0.
210. Sini M., Kipson S., Linares C., Koutsoubas D., et Garrabou J., 2015: *The Yellow Gorgonian Eunicella cavolini: Demography and Disturbance Levels across the Mediterranean Sea.* PLOS ONE 10(5): e0126253. DOI: 10.1371/journal.pone.0126253.
211. Sinniger F., Harii S., Humblet M., Nakamura Y., Ohba H., Prasetia R., 2019: *Ryukyu Islands*, Japan. In: Loya Y., Puglise K.A., Bridge T.C.L. (eds) *Mesophotic coral ecosystems*. Springer, New York, pp 231–247. DOI: 10.1007/978-3-319-92735-0.
212. Smith T.B., Holstein D.M., Ennis R.S., 2019: *Disturbance in mesophotic coral ecosystems and linkages to conservation and management.* In: Loya Y., Puglise K.A., Bridge T.C.L. (eds) *Mesophotic coral ecosystems*. Springer, New York, pp 911–929. DOI: 10.1007/978-3-319-92735-0.
213. Smith, T., Glynn, P., Mate, J., Toth, L., Gyory, J., 2013: *A depth refugium from catastrophic coral bleaching prevents regional extinction*. Ecology. 2014. 1663-1673. DOI: 10.1890/13-0468.1.
214. Sonogashira M, Shonai M, Iiyama M, 2020: *High-resolution bathymetry by deep-learning-based image superresolution.* PLoS ONE 15(7): e0235487. DOI: 10.1371/journal.pone.0235487
215. Spanier E., Zviely D., 2022: *Key Environmental Impacts along the Mediterranean Coast of Israel in the Last 100 Years*. Journal of Marine Science and Engineering. 11. 2. DOI: 10.3390/jmse11010002.
216. Stampar S.N., Broe M.B., Macrander J. et al., 2019: *Linear Mitochondrial Genome in Anthozoa (Cnidaria): A Case Study in Ceriantharia*. Sci Rep 9, 6094 (2019). DOI: 10.1038/s41598-019-42621-z.

217. Tamir R., Eyal G., Kramer N., Laverick J. H. et Loya, Y., 2019: *Light environment drives the shallow-to-mesophotic coral community transition*. Ecosphere 10, e02839. DOI: 10.1002/ecs2.2839.
218. Tapanila L., 2004: *The earliest Helicosalpinx from Canada and the global expansion of commensalism in late Ordovician sarcinulid corals (Tabulata)*. Palaeog. Paleoeclimat. Palaeoecol. 215, 99-110. DOI: 10.1016/j.palaeo.2004.08.006.
219. Teague J., Allen M. J., et Scott T.B., 2018: *The potential of low-cost ROV for use in deep-sea mineral, ore prospecting and monitoring,* Ocean Engineering, Volume 147, Pages 333-339, ISSN 0029-8018, DOI: 10.1016/j.oceaneng.2017.10.046.
220. Teixidó N., Caroselli E., Alliouane S., Ceccarelli C., Comeau S., Gattuso J. P., et al., 2020: *Ocean acidification causes variable trait-shifts in a coral species.* Global Change Biol. 26 (12), 6813–6830. DOI: 10.1111/gcb.15372.
221. Teixidó N., Casas E., Cebrián E., Linares C. et Garrabou J, 2013: *Impacts on Coralligenous Outcrop Biodiversity of a Dramatic Coastal Storm*. PLoS ONE 8(1): e53742. DOI: 10.1371/journal.pone.0053742.
222. Terzin M., Paletta M.G., Matterson K., Coppari M., Bavestrello G., Abbiati M., Bo M., Costantini F., 2021: *Population genomic structure of the black coral Antipathella subpinnata in Mediterranean Vulnerable Marine Ecosystems*. Coral Reefs. 40. 1-16. DOI: 10.1007/s00338-021-02078-x.
223. Thurman H. V. et Trujillo A. P., 2017: *Essentials of oceanography*. Pearson. ISBN: 978-0-134-07354-5.
224. Toma M., Bo M. et al., 2022: *Basin-scale occurrence and distribution of mesophotic and upper bathyal red coral forests along the Italian coasts*. Mediterranean Marine Science. 23. 484–498.
225. Trainito E., 2021: *Investigation of hard-bottom habitats (Anthozoa and their taxonomy) in Boka Kotorska Bay Final report.* DOI: 10.13140/RG.2.2.20367.61605.
226. Tsounis G., Rossi S., Grigg R., Santangelo G., Bramanti L., Gili J.M., 2010: *Precious coral exploitation.* Oceanogr. Mar. Biol. Ann Rev. 48. 161-212.
227. Tsounis G., Rossi S., Laudien J. et al., 2006: *Diet and seasonal prey capture rates in the Mediterranean red coral (Corallium rubrum L.).* Marine Biology 149, 313–325. DOI:10.1007/s00227-005-0220-1.
228. Valisano L., Notari F., Mori M. et Cerrano C., 2016: *Temporal variability of sedimentation rates and mobile fauna inside and outside a gorgonian garden.* Mar Ecol, 37: 1303-1314. DOI: 10.1111/maec.12328.
229. van de Water J., Coppari M., Enrichetti F., Ferrier-Pagès C., et Bo, M., 2020: *Local Conditions Influence the Prokaryotic Communities Associated With the Mesophotic Black Coral Antipathella subpinnata*. Frontiers in Microbiology. 11. DOI: 10.3389/fmicb.2020.537813.
230. Vermeij M.J.A., Marhaver K.L., Huijbers C.M., Nagelkerken I., Simpson S.D., 2010: *Coral Larvae Move toward Reef Sounds*. PLoS ONE 5(5): e10660. DOI: 10.1371/journal.pone.0010660.
231. Vertino A., Stolarski J., Bosellini F.R., Taviani M., 2014: *Mediterranean Corals Through Time: From Miocene to Present.* In: Goffredo, S., Dubinsky, Z. (eds) *The Mediterranean Sea*. Springer, Dordrecht. DOI: 10.1007/978-94-007-6704-1_14
232. Villechanoux J., Bierwirth J., Mantas T.P., et Cerrano C., 2022: *Testing Transplantation Techniques for the Red Coral Corallium rubrum*. Water 14, no. 7: 1071. DOI: 10.3390/w14071071.

233. Vincent A. C. J., Sadovy de Mitcheson Y. J., Fowler S. L. et Lieberman S., 2014: *The role of CITES in the conservation of marine fishes subject to international trade*. Fish. Fish. (Oxf). 15, 563–592. DOI:10.1111/faf.12035.
234. Waithaka J., Dudley N., Álvarez M. et al., 2021: *Impacts of COVID-19 on protected and conserved areas: A global overview and regional perspectives.* Parks. 27. 41-56. DOI: 10.2305/IUCN.CH.2021.PARKS-27-SIJW.en.
235. Weil E., 2019: *Disease problems.*In: Loya Y., Puglise K.A., Bridge T.C.L. (eds) *Mesophotic coral ecosystems*. Springer, New York, pp 777–800. DOI: 10.1007/978-3-319-92735-0.
236. Weiss K.R., 2017: *Can deep reefs rescue shallow ones?* Science 355(6328):903. DOI: 10.1126/science.355.6328.903.
237. White K. N., et al., 2013: *Typhoon damage on a shal-low mesophotic reef in Okinawa, Japan*. PeerJ 1:e151.
238. Williams A., Althaus F., Maguire K. et al., 2020: The Fate of Deep-Sea Coral Reefs on Seamounts in a Fishery-Seascape: What Are the Impacts, What Remains, and What Is Protected?. Frontiers in Marine Science. 7. 567002. 10.3389/fmars.2020.567002.
239. Williams G.C., 2011: *The Global Diversity of Sea Pens (Cnidaria: Octocorallia: Pennatulacea)*. PLoS ONE 6(7): e22747. DOI: 10.1371/journal. Pone.0022747.
240. Worm B., Barbier E. B., Beaumont N., Duffy J. E., Folke C., Halpern B. S. et al., 2006: *Impacts of biodiversity loss on ocean ecosystem services*. Science 314, p. 787–790. DOI:10.1126/science.1132294.
241. Zapata F., Goetz F. E., Smith S. A., Howison M., Siebert S., Church S. H., Sanders S. M., Ames C. L., McFadden C. S., France S. C., Daly M., Collins A. G., Haddock S. H., Dunn C. W., et Cartwright P., 2015: *Phylogenomic Analyses Support Traditional Relationships within Cnidaria*. PloS one, 10(10), e0139068. DOI: 10.1371/journal.pone.0139068.
242. Zavatarelli M., Raicich F., Bregant D., Russo A., Artegiani A., 1998: *Climatological biogeochemical characteristics of the Adriatic Sea*. Journal of Marine Systems 18: 227–263. DOI: 10.1016/S0924-7963(98)00014-1.
243. Zenetos A. et al., 2012: *Alien species in the Mediterranean Sea by 2012. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part 2. Introduction trends and pathways*. Mediterranean Marine Science. 13. 328-352. DOI: 10.12681/mms.327.

Online sources:

1. Aguilar , R. and Pastor, X., 2010: *The corals of the Mediterranean*. Edited by M. Madina. rep. Oceana, Fondazione Zegna. [acc. 2022.11.07]. Available at: https://europe.oceana.org/wp-content/uploads/sites/26/Corals_Mediterranean_eng.pdf
2. Anonymous, 2016: *NOAA's Coral Reef Conservation Program (CRCP) - coral facts*, *NOAA Coral Reef Conservation Program (CRCP) Home Page*. NOAA (online). [acc. 2022.11.08]. Available at: https://coralreef.noaa.gov/education/
3. CBD, 2010: *Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its tenth meeting.* Decision X/2. Strategic plan for biodiversity 2011–2020. Available at: https://www.cbd.int/doc/decisions/cop-10/cop-10-dec-02-en.pdf
4. CBD, 2023*: Background on the EBSA Process*. Ecologically or Biologically Significant Marine Areas (EBSAs).[acc. 2023.03.14]. Available at: https://www.cbd.int/ebsa/about#:~:text=EBSA%20Scientific%20Criteria,waters%20and%20deep%2Dsea%20habitats.

5. *Coral's complex reproduction* (2021) *ImagenScience*. [acc. 2023.02.28]. Available at: https://imagenscience.com/
6. DUMAS J. , ADER D., MARAN V. , SITTLER A.-P., 2020: *Eunicella cavolini (Koch, 1887).* DORIS , [acc. 2023.02.10], Available at: https://doris.ffessm.fr/ref/specie/247
7. European Commission-DG MARE, 2013: *Costs and benefits arising from the establishment of maritime zones in the Mediterranean Sea.* Final Report.[acc. 2023.03.14]. Available at: https://ec.europa.eu/maritimeaffairs/sites/maritimeaffairs/files/docs/body/maritime-zones-mediterranean-report_en.pdf
8. GRID-Arendal, 2013: *Mediterranean Sea water masses: Vertical distribution.* [acc. 2023.03.30]. Available at: https://www.grida.no/resources/5885
9. Hand C.H., Gail F.D., 2023: *"cnidarian"*. Encyclopedia Britannica. [acc. 2022.11.03]. Available at: https://www.britannica.com/animal/cnidarian
10. IUCN, 2022: *IUCN rings alarm bells for corals in the Mediterranean.* acc. 2022.11.01] Available at: https://www.iucn.org/news/m%C3%A9diterran%C3%A9e/201705/iucn-rings-alarm-bells-corals-mediterranean
11. Lo V. and Jang N., 2022: *The Global Biodiversity Framework's "30X30" TARGET: Catchy slogan or effective conservation goal?*. International Institute for Sustainable Development. [acc. 2023.03.18]. Available at: https://www.iisd.org/articles/insight/global-biodiversity-framework-30x30-target
12. MAPAMED, the Mediterranean Marine Protected Areas Database. 2019 Edition. © 2020 by SPA/RAC and MedPAN. Licensed under CC BY-NC-SA 4.0. [acc. 2023.01.07]
13. Mediterranean Action Plan, 2017: *Tourism - Mediterranean 2017 Quality Status Report*, *Tourism | UNEPMAP QSR*. UNEP. [acc. 2022.11.23]. Available at: https://www.medqsr.org/tourism
14. MEDPAN & UNEP-MAP-SPA/RAC, 2017: *The 2016 status of marine protected areas in the Mediterranean.* Editors B. Meola and C. Webster. Tunis.[acc. 2023.03.14]. Available at: http://d2ouvy59p0dg6k.cloudfront.net/downloads/medpan_forum_mpa_2016___brochure_a4_en_web_1_.pdf
15. MedPAN and UNEP/MAP-SPA/RAC, 2021: *The System of Mediterranean Marine Protected Areas in 2020*. November 2021.[acc. 2023.03.14]. Available at: https://medpan.org/en/system-mediterranean-mpas-2020
16. *Mesophotic Coral Reef Ecosystems in Preserving Coastal Resources in American Samoa* (no date) *National Parks Service*. U.S. Department of the Interior. [acc. 2022.11.15] Available at: https://www.nps.gov/articles/000/c2-american-samoa.htm
17. Pannett, R., 2022: *Great Barrier Reef has most coral in decades. Global warming could reverse it.* The Washington Post (online). [acc. 2022.11.07]. Available at: https://www.washingtonpost.com/world/2022/08/04/great-barrier-reef-coral-recovery-climate-change/
18. Queensland Government, 2022: *About the Great Barrier Reef*. (online). [acc. 2022.11.07]. Available at: https://www.qld.gov.au/environment/coasts-waterways/reef/preserve-the-wonder/reef-protection
19. SPA/RAC, 2017*: Annexes: Regional Activity Centre for Specially Protected Areas*. [acc. 2023.03.14]. Available at: https://rac-spa.org/annexes
20. *Sustainable Development*, 2023: *United Nations*. United Nations. [acc. 2023.02.28]. Available at: https://sdgs.un.org/
21. U.S. National Park Service, 2021: *Mesophotic coral reef ecosystems in preserving coastal resources in American Samoa* [Webinar]. [Online]. U.S. National Park Service, released

03.03.2021. [acc. 2022.10.05]. Available at: https://www.nps.gov/media/video/view.htm?id=6E1F67ED-1A5B-4081-96B4-90EA63168ED1

22. *Un decade on restoration,* 2020: *UN Decade on Restoration*. [acc. 2023.02.28]. Available at: https://www.decadeonrestoration.org/
23. UNEPMAP, 2022: *Climate change in the Mediterranean*. [acc. 2023.03.05]. Available at: https://www.unep.org/unepmap/resources/factsheets/climate-change
24. US Department of Commerce, N.O.and A.A., 2009: *How much of the ocean have we explored?*, *NOAA's National Ocean Service*. [acc. 2022.11.13]. Available at: https://oceanservice.noaa.gov/facts/exploration.html
25. Willmer, G., 2020: *Understudied deeper water reefs could teach us how to better conserve corals*, *Horizon Magazine*. European Commission (online). [acc. 2022.11.08]. Available at: https://ec.europa.eu/research-and-innovation/en/horizon-magazine/understudied-deeper-water-reefs-could-teach-us-how-better-conserve-corals
26. WWF, 2021: *Scenarios to recover biodiversity and rebuild fish stocks in the Mediterranean Sea* .[Online].[acc. 2022.10.07] Available at: https://www.wwf.eu/?2248641%2FScenarios-to-recover-biodiversity-and-rebuild-fish-stocks-in-the-Mediterranean-Sea
27. Zeitvogel, K., 2011: *World's coral reefs could be gone by 2050: Study*, *Phys.org*. Phys.org. [acc. 2022.11.22]. Available at: https://phys.org/news/2011-02-world-coral-reefs.html