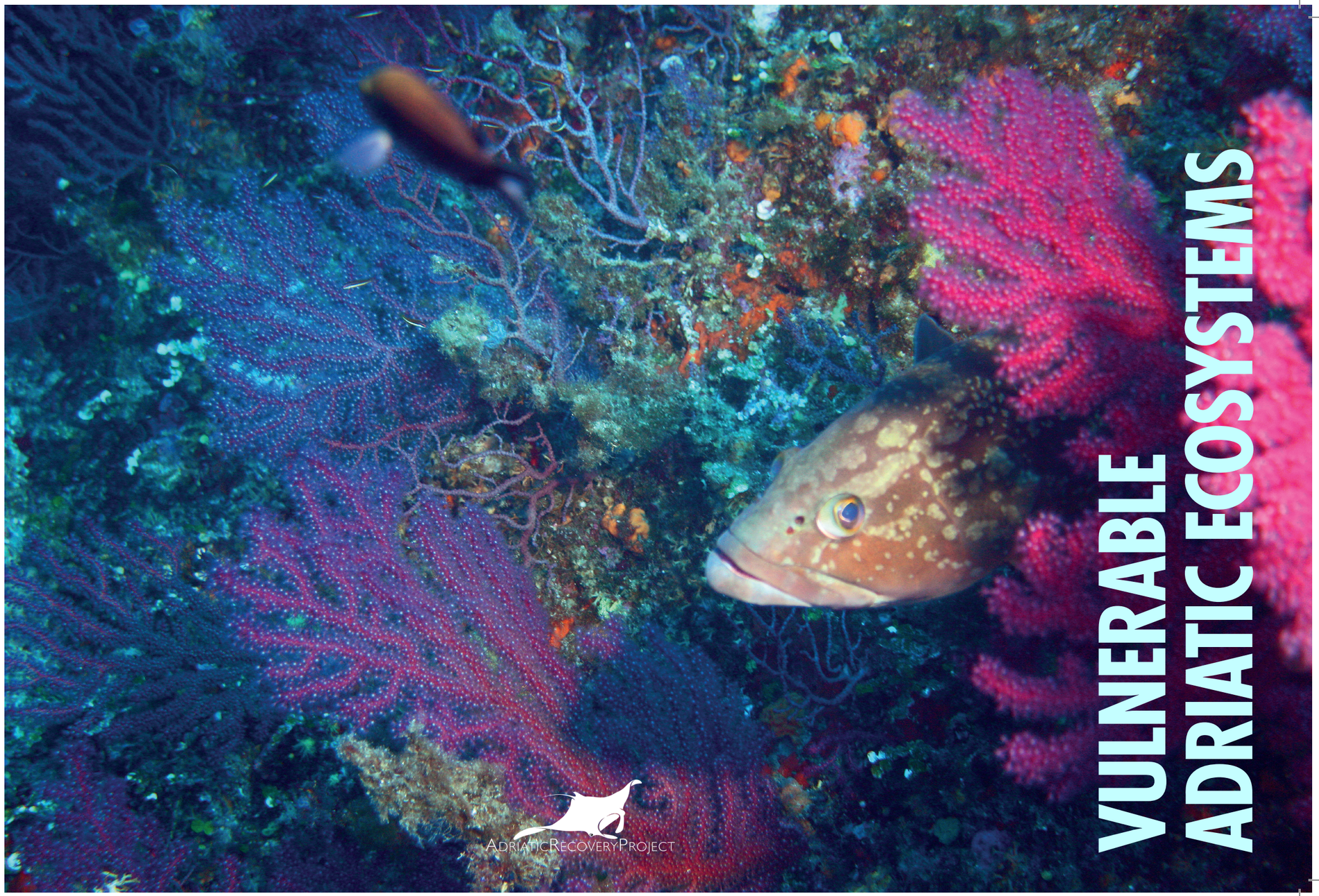
UNIVERSITÀ
POLITECNICA
DELLE MARCHE

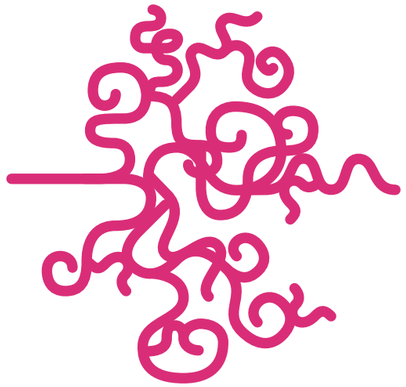
AdriaticRecoveryProject

MedReAct

www.medreact.org

@adriaticrecovery
@medreact.org





VULNERABLE ADRIATIC ECOSYSTEMS

2017

ADRIATICRECOVERYPROJECT

THE ADRIATIC RECOVERY PROJECT IS AN ALLIANCE OF CIVIL SOCIETY ORGANISATIONS AND SCIENTIFIC INSTITUTIONS ESTABLISHED TO PROTECT VULNERABLE MARINE ECO-SYSTEMS AND FISH ESSENTIAL HABITATS OF THE ADRIATIC SEA, FUNDED BY OCEANS5 AND SUPPORTED BY STANFORD'S WOODS INSTITUTE FOR THE ENVIRONMENT.

THE PROJECT IS COORDINATED BY MEDREACT IN PARTNERSHIP WITH LEGAMBIENTE, MAREVIVO, THE STANFORD UNIVERSITY AND THE MARCHE POLYTECHNIC UNIVERSITY.

photo credits:
Francesco Cabras, Gianfranco Rossi, Fabrizio Torsani

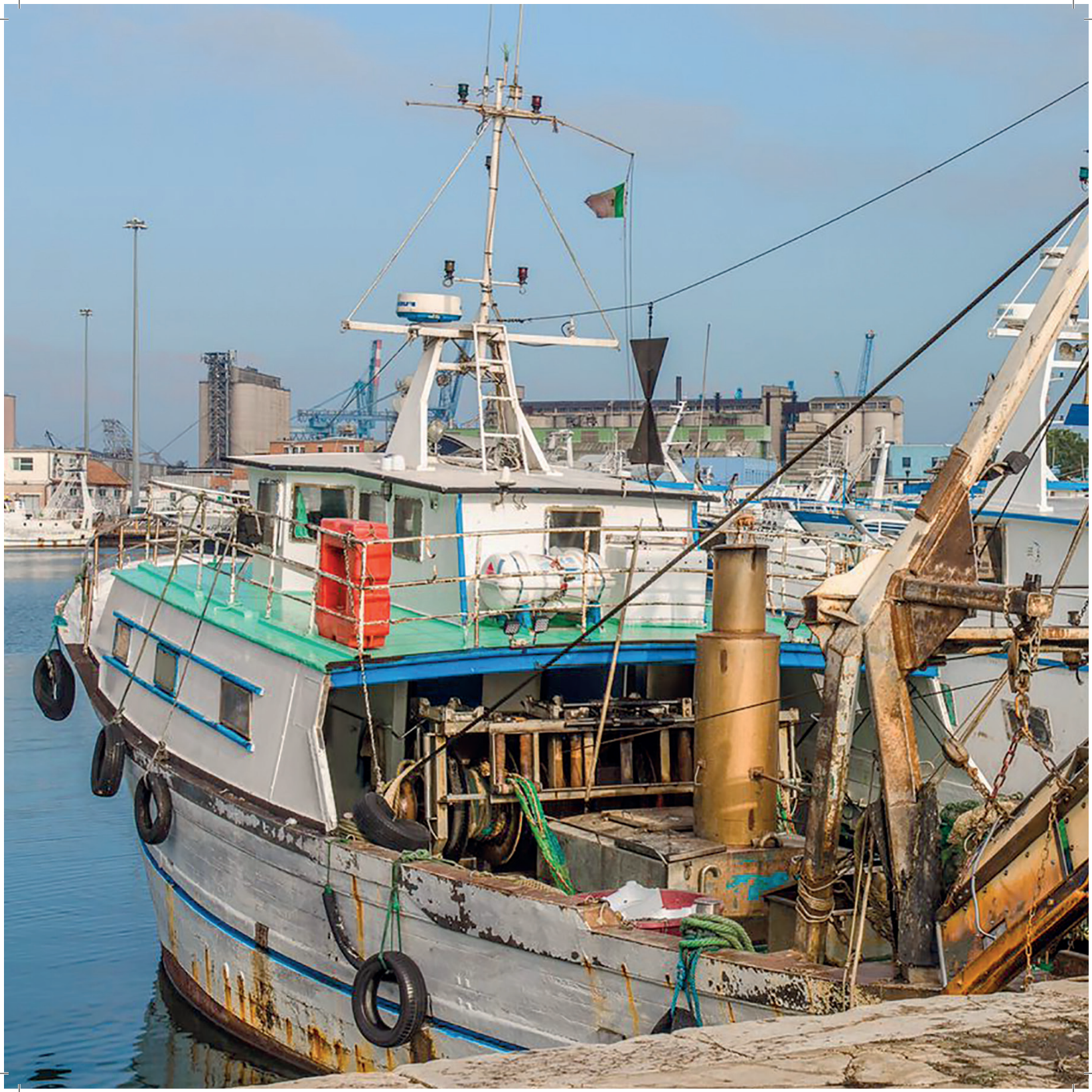
INTRODUCTION

The degradation of the marine environment is a growing concern in the Mediterranean, particularly in the Adriatic which alone sustains 50% of Italian fishery production (Coll et al., 2012; UNEP-MAP-RAC/SPA, 2015a) and is considered one of the areas of the Mediterranean that needs immediate protection. In fact the Adriatic, together with the Gulf of Gabès in Tunisia, is one of the areas of the Mediterranean where bottom trawling - a fishing technique that is particularly damaging to the seabed ecosystem - is practiced with greatest intensity. Nevertheless, the Adriatic hosts 49% of known marine species in the Mediterranean, many of which are endemic (Coll et al., 2012; Micheli et al., 2013).

The centuries-old use by humans of the Adriatic's abundant marine resources has, especially in recent decades, caused a profound alteration of marine habitats and a drastic reduction in fish stocks. According to the General Fisheries Commission for the Mediterranean (GFCM), the regional body that governs the management and conservation of marine biological resources, commercial stocks such as those of anchovy, sardine, hake, Norway lobster and shrimps of the Adriatic Sea are all exploited well above sustainable levels (GFCM, 2016). In addition to the damages to fish stocks, more generally there is a loss of biodiversity, with many species now at risk.

In the past 50 years, large predators, especially sharks and rays, have diminished by 94% and some species, such as the angel shark (*Squatina squatina*) or the great white shark (*Carcharodon carcharias*), once common throughout the Adriatic, have practically disappeared (Ferretti et al., 2013; Fortibuoni et al., 2016). The same negative trend has been observed for marine mammals - dolphins, seals, whales - and for sea turtles. Recent estimates have shown that during 2014 around 52,000 sea turtles were incidentally captured by the Italian fishing fleet; of these at least 10,000 died (Lucchetti et al., 2017).

Unfortunately, available information about the distribution and abundance of habitat-forming species in benthic habitats remains scarce, especially with regards to their historic trends. Animal forest species such as sponges, hydrozoans, sea pens, gorgonians and corals which populate the bottom of our seas, have only occasionally been taken into account in research programmes (Raichevic et al., 2004; Lotze et al., 2011; Bastari et al., 2017).



VULNERABLE MARINE ECOSYSTEMS AND ESSENTIAL FISH HABITATS

Sponge and coral gardens, sea pen and gorgonian forests, oyster beds, are considered essential habitats for the health of the sea. These habitats and species are progressively being added to the international lists that identify and define Vulnerable Marine Ecosystems (VMEs) because they are considered to be particularly sensitive to the impact of fishing activities which, being continuous and ubiquitous, make recovery practically impossible.

The identification of VMEs requires that the species and/or habitat in question play fundamental ecological roles by supporting the diversity, development and growth of commercial and non-commercial fish species (FAO, 2009). VMEs are often associated with particular topographical characteristics of the sea bottom such as seamounts, canyons, hydrothermal vents – all environments known for being biodiversity hotspots.

By 'Essential Fish Habitats' (EFHs) what is meant is the waters and substrates necessary for the reproduction, nutrition, or growth of fish, molluscs, crustaceans and all other marine animals with the exception of mammals and birds.

The Mediterranean possesses a number of environments that could host VMEs and EFHs, and only recently the GFCM has launched a process for their identification.

IDENTIFICATION OF VULNERABLE MARINE ECOSYSTEMS

The vulnerability of a marine habitat and the community that it hosts must be defined in relation to specific disturbances. Whereas many fragile species and habitats can suffer the effects of a number of different disturbances, their vulnerability varies greatly and significantly, for example in relation to the type of fishing gear used, to the level and type of impact that the species endures. FAO's international guidelines for the management of deep-sea fisheries in the high seas establish criteria for the identification of VMEs.

Uniqueness or rarity

Areas and ecosystems that include habitats with endemic or rare, threatened, or endangered species that live only in discrete areas; or habitats with nursery, or discrete feeding, breeding and spawning grounds.

Functional significance of the habitat

Areas or habitats necessary for the survival, function, reproduction or recovery of fish stocks, for particular phases of the life-cycle of a species, or for rare, threatened or endangered species.

Fragility

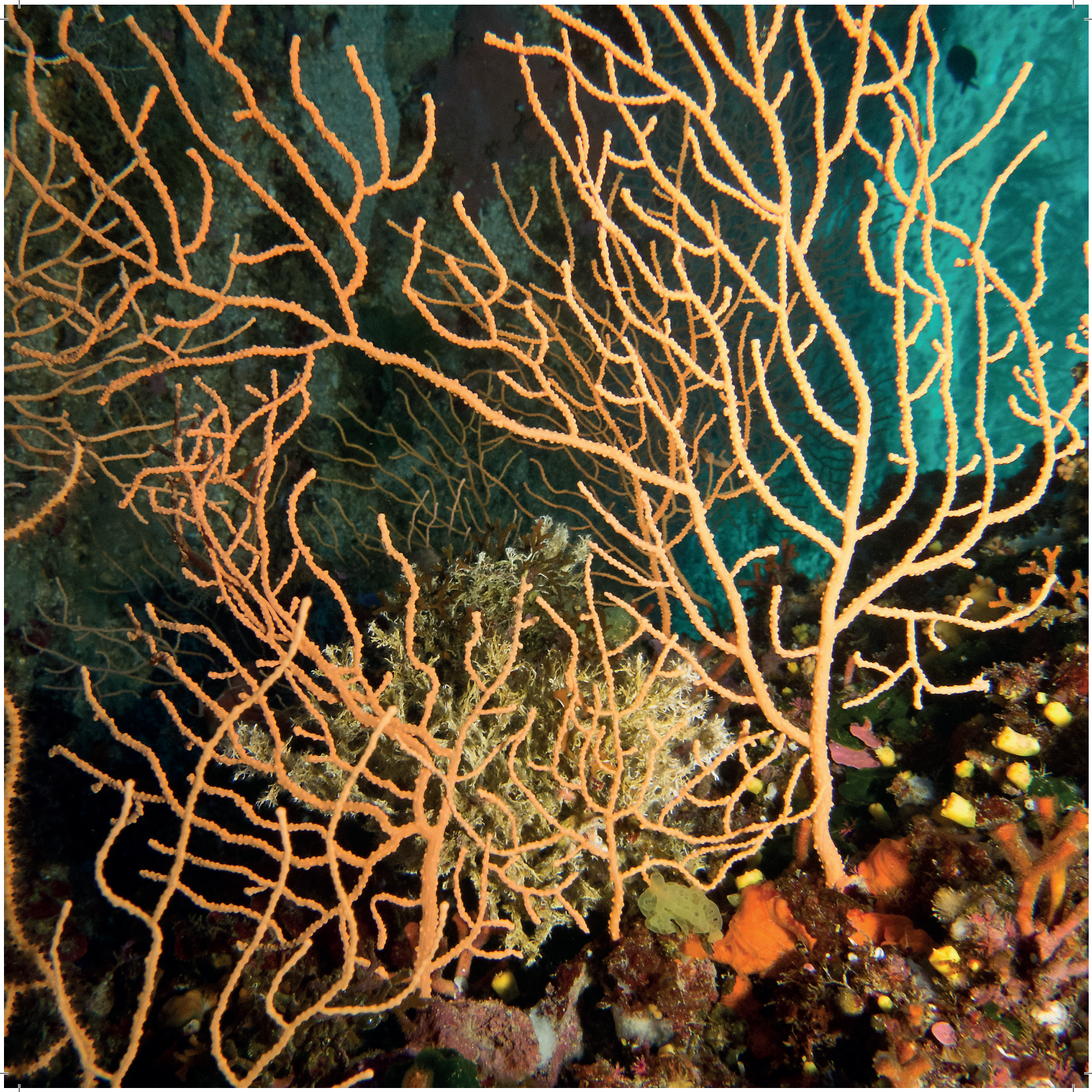
An ecosystem that is highly susceptible to degradation by anthropogenic activities.

Life-history traits of component species that make recovery difficult

That is, ecosystems that are made up of population or assemblages of organisms having one or more of the following characteristics: slow growth rate, late age of maturity, low or unpredictable recruitment, or long-lived species (decades, hundreds of years).

Structural complexity

An ecosystem that has a complex physical heterogeneity, created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are often strongly tied to these structural complexities, and in addition, they are often rich in biodiversity which depends on or changes in relation to the complexity of the habitat created by the structuring species of the ecosystem.



List of possible marine structures, habitat and taxa below 200m, classified as possible indicators of VMEs in the Mediterranean (GCFM, 2017)

VME indicator features
Seamounts and volcanic ridges
Canyons and trenches
Steep slopes
Submarine reliefs (slumped blocks, ridges, cobble fields, etc.)
Cold seeps (pockmarks, mud volcanoes, reducing sediment, anoxic pools, methanogenetic hard bottoms)
Hydrothermal vents

Mediterranean VME indicator habitats
Cold water coral reefs
Coral gardens:
Hard-bottom coral gardens
Soft-bottom coral gardens
Sea pen fields
Deep-sea sponge aggregations:
"Ostur" sponge aggregations
Hard-bottom sponge gardens
Glass sponge communities
Soft-bottom sponge gardens
Tube-dwelling anemone patches
Crinoid fields
Oyster reefs and other giant bivalves
Seep and vent communities
Other dense emergent fauna

Mediterranean VME indicator taxa		
Phylum	Class	Subclass (order)
Cnidaria	Anthozoa	Hexacorallia (Antipatharia, Scleractinia)
		Octocorallia (Alcyonacea, Pennatulacea)
		Ceriantharia
	Hydrozoa	Hydroidolina
Porifera (spugne)	Demospongiae	
	Hexactinellida	Amphidiscophora
		Hexasterophora
Bryozoa	Gymnolaemata	
	Stenolaemata	
Echinodermata	Crinoidea	Articulata
Mollusca	Bivalvia	Gryphaeidae (Neopycnodonte cochlear, N. zibrowii)
		Heterodonta*(Lucinoida) (e.g. Lucinoma kazani)
		Pteriomorphia*(Mytiloida) (e.g. Idas modiolaeformis)
Annelida*	Polychaeta	Sedentaria (Canalipalpata) (e.g. Lamellibrachia anaximandri, Siboglinum spp.)
Arthropoda*	Malacostraca	Eumalacostraca (Amphipoda) (e.g. Haploops spp.)

**only chemosynthetic species that indicate the presence of hydrothermal vents are considered*

facing page: Example of structural complexity and habitat heterogeneity created by the gorgonian *Eunicella cavolini*

Taking into account the principal characteristics of demersal[1] resources and their distribution in the Adriatic basin, the most important and critical stages that need to be considered in order to define an EFH are those of spawning and recruitment[2] (STECF, 2006). Every species, based on its own biological cycle and ecological characteristics, will use specific areas for reproduction. The size of these areas and the abundance of species must be noted in order to develop adequate management measures. As far as pelagic species are concerned, environmental factors and the relative physical, chemical and biological properties of the water column (for example, temperature, salinity, and currents) and their temporal variability are the most important factors for determining a potential EFH.

The Adriatic Sea is one of the most studied areas in the world, even though some zones, particularly in the southern Adriatic, are not well known. Nevertheless, numerous research projects have allowed the collection of a good quantity of scientific data in support of the presence and distribution of ecosystems and sensitive areas in the basin.

Among the EFHs in the Adriatic are all those areas in which an elevated abundance and density of larvae or juveniles of commercial species can be found (for example the Jabuka/Pomo Pit). Examples of potential VMEs for demersal species present in the Adriatic Sea, on the other hand, are the Posidonia oceanica meadows, coralligenous habitats and maerl beds, fields of sea pens, submarine canyons. Here we will concentrate on the description of VMEs and EFHs present in the international waters of the Adriatic, leaving aside for now some habitats which, while fundamental for some commercial species and for the marine ecosystem in general, are located only in coastal areas (for example phanerogam beds).

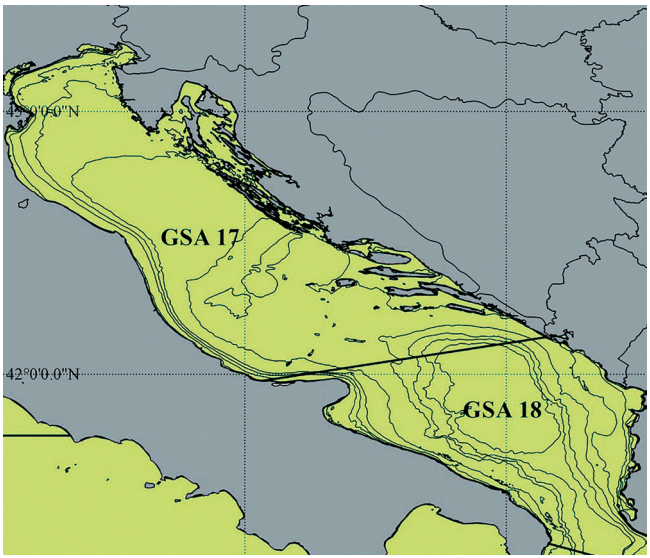
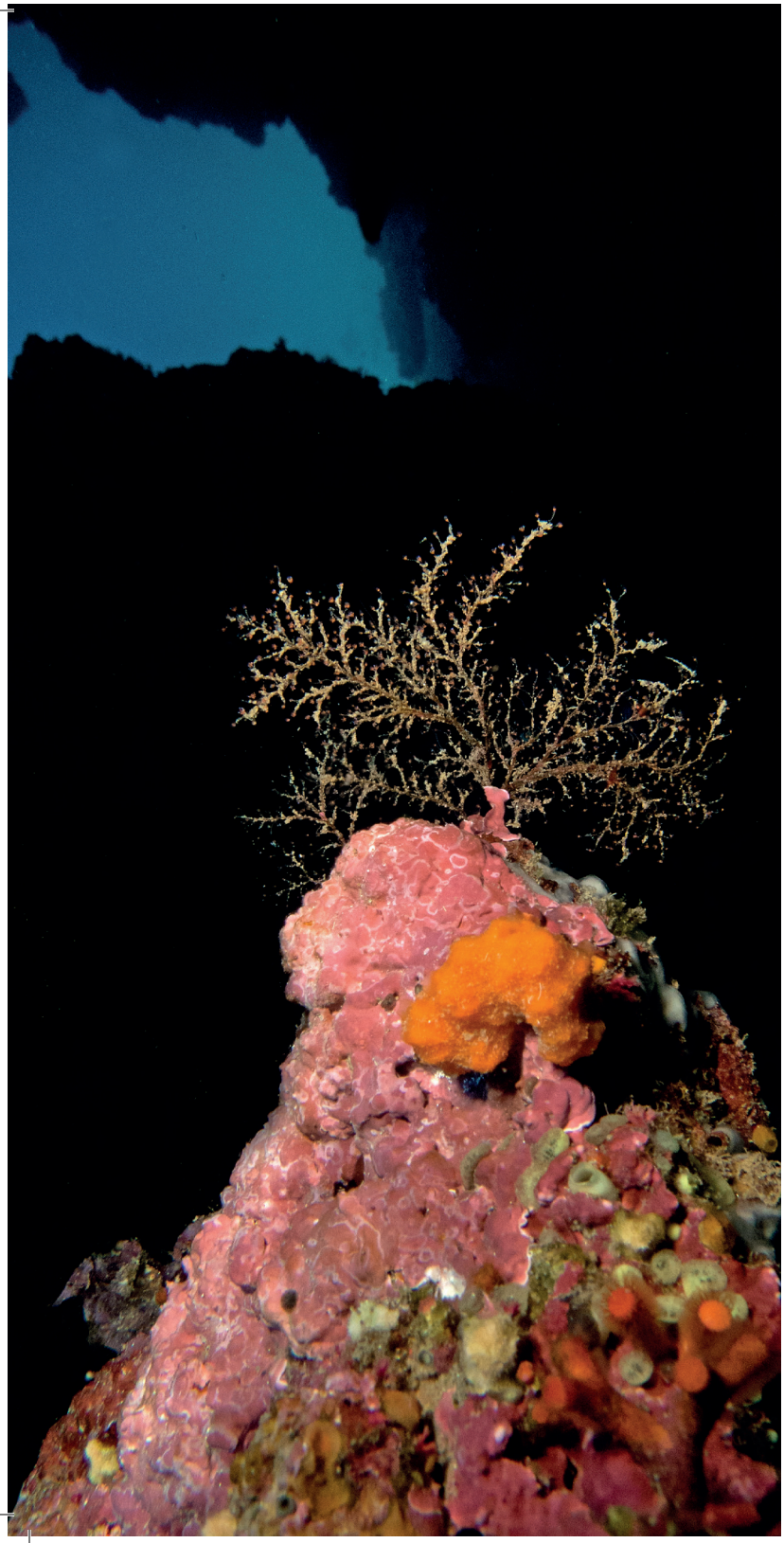


Fig.1 Subdivisions of the Adriatic Sea:
GSA 17 Northern Adriatic
GSA 18 Southern Adriatic (GFCM)

[1] Demersal resources, i.e. those marine animal species that swim actively but that live in close contact with the seabed (where, for example, they feed).

[2] Recruitment: increase in population numbers due to new births, or to the temporary migration of species (in particular fish) in areas where reproduction or growth takes place, or to the arrival of free-swimming larvae in a particular zone favourable to them.



FRAGILE ECOSYSTEMS OF THE NORTHERN AND CENTRAL ADRIATIC

The northern Adriatic, with an average depth of 35m, has the most extensive continental shelf in the entire Mediterranean. The depth increases gradually towards the central basin, ultimately reaching depths of 250-260m in the Jabuka/Pomo Pit. The shallowness and the prevalence of a sandy-muddy sea bottom have made the northern and central Adriatic (GSA 17) one of the most exploited and trawled areas of the Mediterranean. The centuries-old exploitation of Adriatic resources and the increase in industrial fisheries in recent decades have provoked a sharp decline in fish stocks and the depletion of the biodiversity of the entire Adriatic. In the last 50 years a dramatic reduction, at times to the limits of extinction, of large predators such as sharks and rays, marine mammals, birds, and sea turtles has been observed, as well as the reduction of habitat-forming species, such as oyster beds, or sponge and coral gardens, fundamental for the recovery of commercial species and more (Ferretti et al., 2013; Fortibuoni et al., 2010, 2017; Lotze et al., 2011; Bastari et al., 2017). The VME indicators present in the international waters of GSA 17 include:

Bioconstructions

Bioconstructions such as coralligenous assemblages or maerl beds are the typical submarine landscape of the Mediterranean Sea, which are born thanks to the calcareous formations produced by encrusting algae and/or animals creating hard structures that then become substrates for numerous other species, including perforating species.
In the international waters of GSA 17, coralligenous/maerl structures are scattered particularly in North-Eastern Adriatic and the Jabuka/Pomo Pit (Figure 2).
Among the bioconstructions there are also those originating from cemented sand resulting from gas emissions, in particular methane, successively covered by organisms. Recent structures, the formation of which is associated with methane emissions from the seabed, have been described in the GSA 17, particularly off-shore the Marche region (UNEP-MAP-RAC/SPA, 2015a) (Figure 2).
Bioconstructions are potential VMEs since they create a hard and heterogeneous substrate on a sandy expanse to which numerous organisms can attach themselves, grow, find food and shelter, and so create an area of high biodiversity.

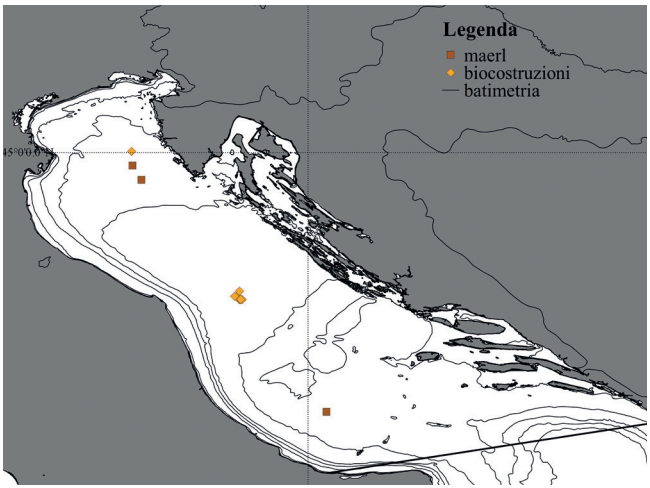


Fig. 2 Distribution of bioconstructions in GSA 17

Pockmarcks and mud volcanoes

Pockmarks are conical depressions in the sea floor caused by emissions of natural gas and interstitial water from bottom sediments. In the central Adriatic, pockmarks were observed in two distinct zones: one to the north near the decommissioned Bonaccia platform, the other more to the south, near the Jabuka/Pomo Pit (Figure 3a). Mud volcanoes, on the other hand, were observed in the area of the Jabuka/Pomo Pit (Figure 3b). These structures constitute potential VMEs, since they are areas with a unique diversity of endemic species.

Oyster beds and other structuring features

Beds of bivalves (mussels and oysters being among the most important) carry out and support fundamental ecosystem goods and services. Some bivalve species, in fact, can be present in very dense concentrations on the sea floor, forming actual beds and creating ample stretches of shells that create hard habitats and provide food, shelter and protection to various commercial and non-commercial species. In the past, oyster beds were observed offshore in the central Adriatic (Figure 4). Currently, the presence of these structures has been greatly reduced, if not completely eliminated, due to bottom trawling. Because of the important ecological role that bivalve beds play and because of their fragility, these habitats are included in the list of potential VMEs.
Other features that create a heterogeneous habitat, substrate and refuge for numerous commercial and non-commercial species, are represented by rocks spread on the sandy sea floor, remains of dead deep-sea corals, indicators of the existence of ancient communities of white corals which populated the basin in distant epochs and are now fossilised, the presence of which is noted in the Jabuka/Pomo Pit (Figure 4).

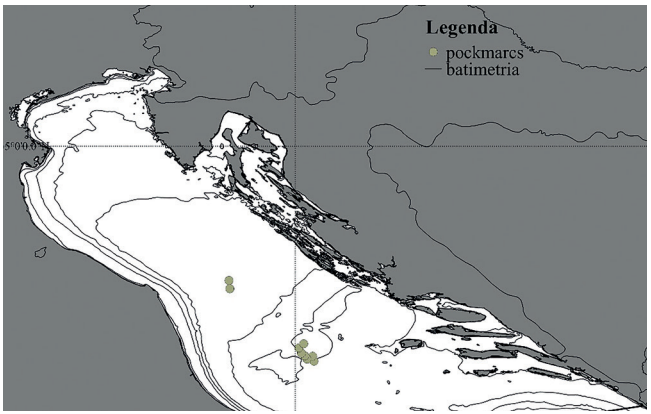


Fig. 3a Distribution of pockmarks in GSA 17

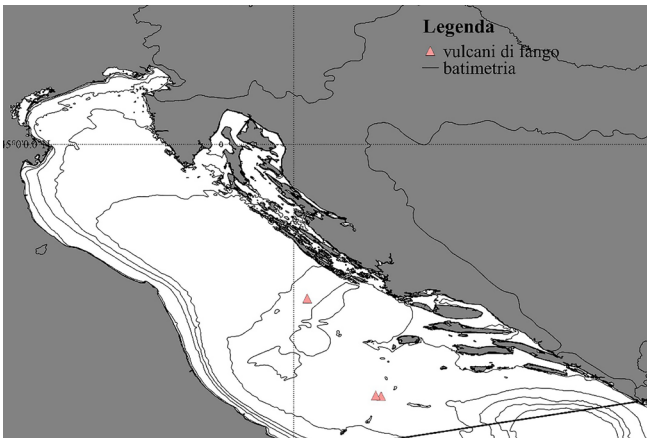


Fig. 3b Distribution of mud volcanoes in GSA 17

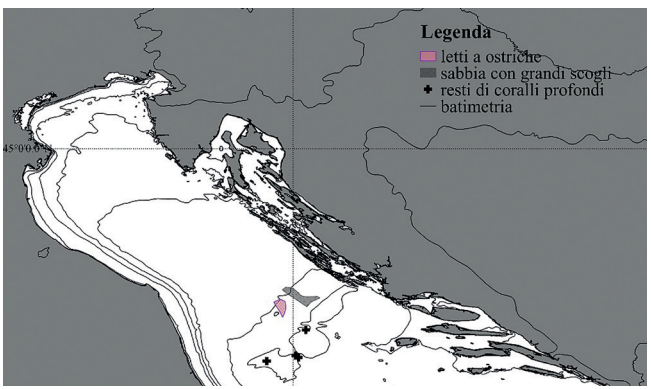
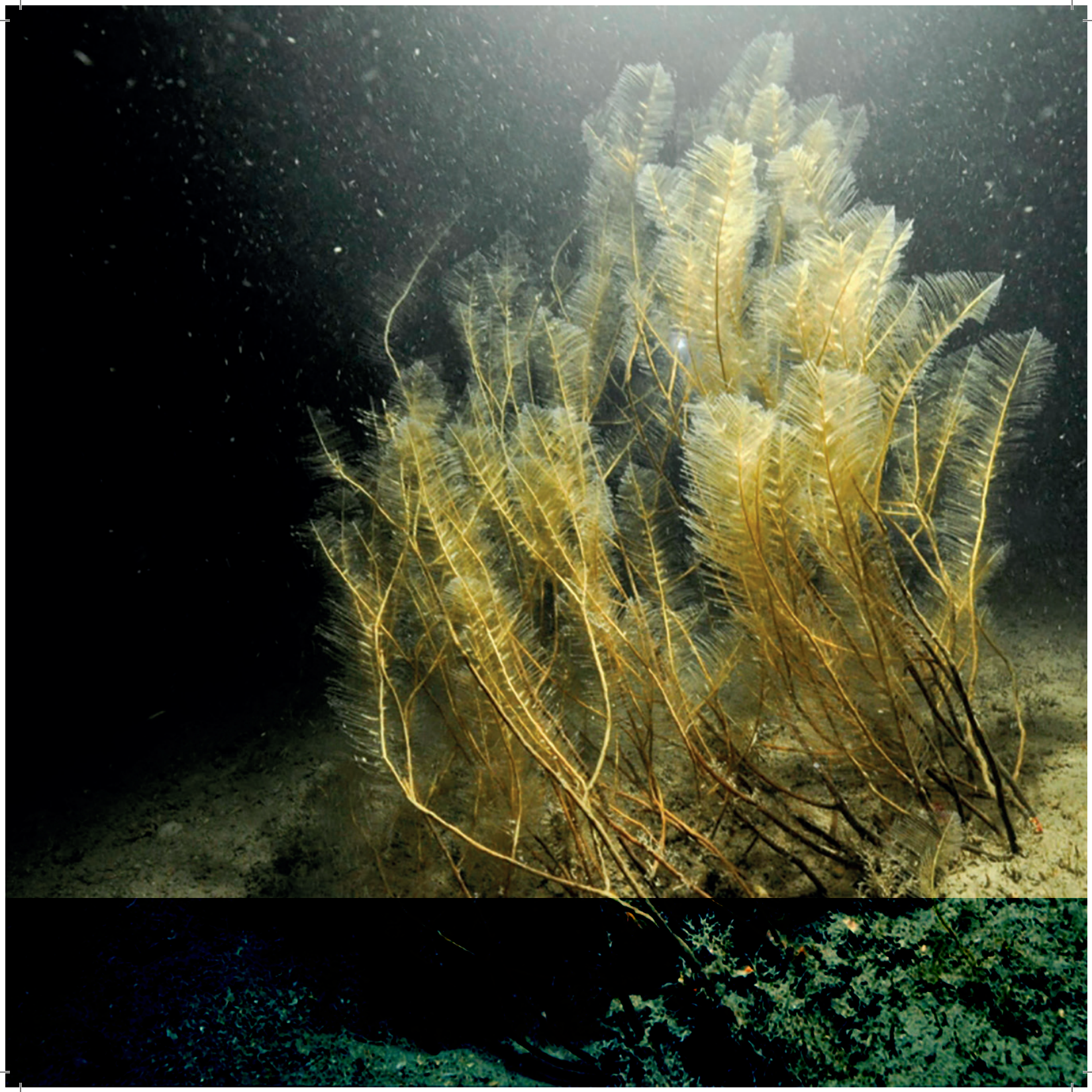


Fig. 4 Distribution of seabed structuring communities present in GSA 17



Sea pen fields, large hydrozoans and associations with Laminaria rodriguezii

Among the VME indicator species present in GSA 17, there are several species of sea pens (*Funiculina quadrangularis*, *Pennatula spp.*, *Virgularia mirabilis*, and *Pteroeides spinosum*), with a patchy distribution across the majority of soft seabeds of the Adriatic Sea, and large hydrozoans (*Lytocarpia myriophyllum*) observed predominantly near the Jabuka/Pomo Pit (Figure 5). These species, especially if present in high densities, can form true submarine forests which provide refuge for eggs, small fish and numerous other species. They are also important because they occupy the same habitats as species of high commercial interest, such as the Norway lobster (*Nephrops norvegicus*), in addition to being involved in other important ecological roles (for example, the biogeochemical cycles). Other fundamental habitats are those formed by the deep-water kelp *Laminaria rodriguezii*, once distributed in various zones of the Jabuka/Pomo Pit, and now reduced to few and scattered patches near the Croatian island of Palagruža (Figure 5). Once again, among the principal anthropogenic causes that have led to an extreme reduction and fragmentation of these habitats is bottom trawling.

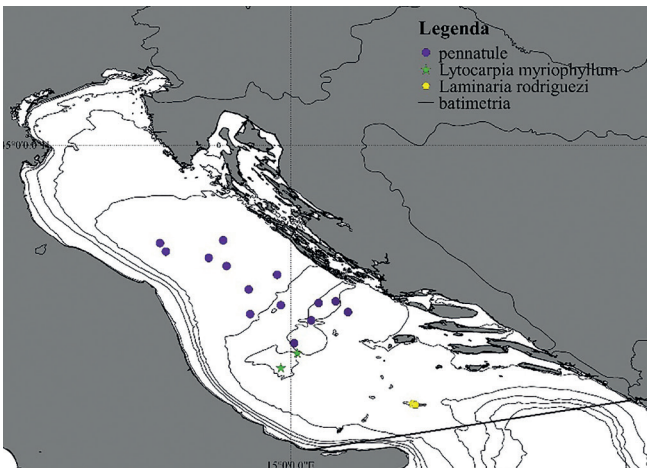
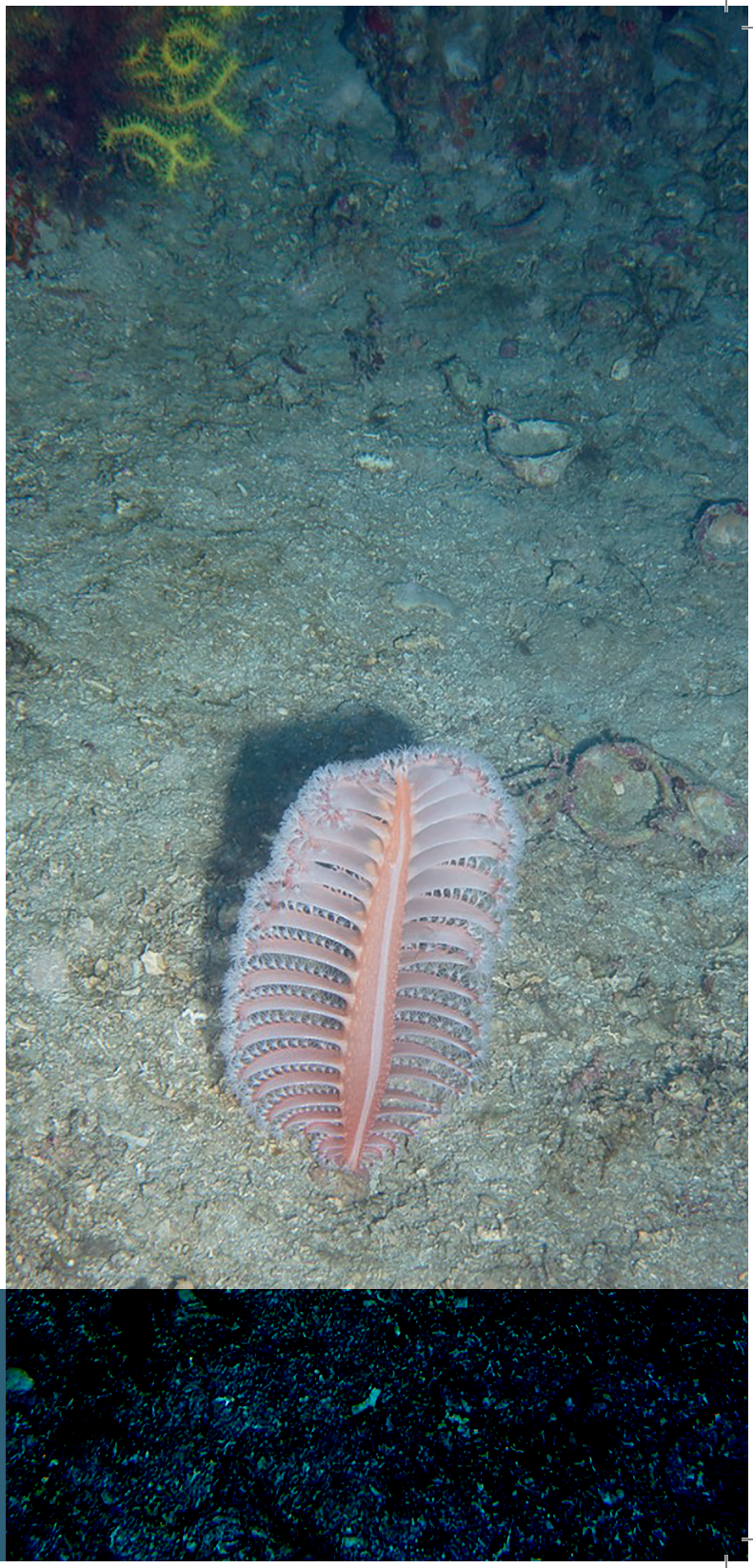
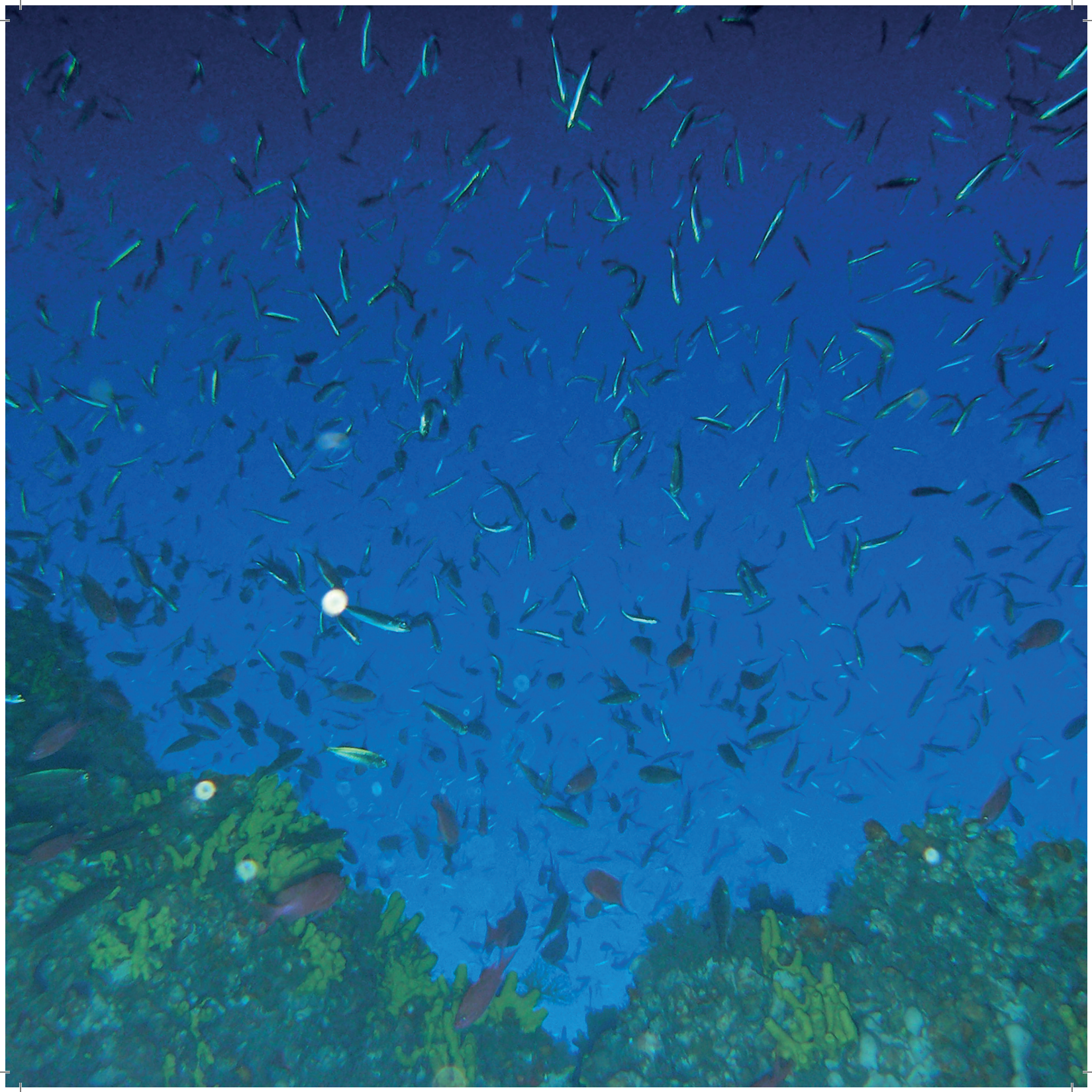


Fig. 5 Distribution of sea pens, hydrozoans and Laminaria rodriguezii in GSA 17

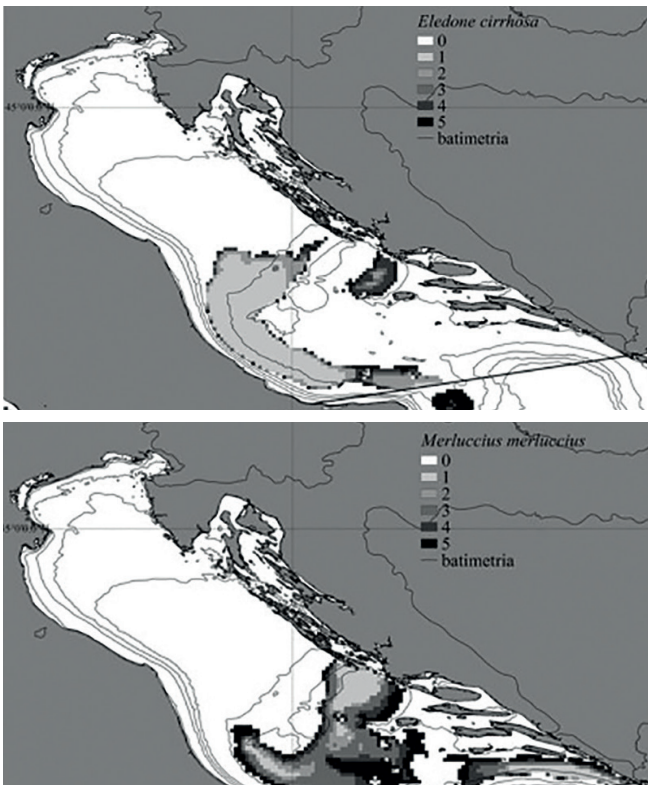


right: example of *Pennatula sp.* on the Adriatic seabed
facing page: Example of *Lytocarpia miriophyllum*



Nursery, foraging and migratory route areas

Lastly, GSA 17 contains nursery and spawning zones for a variety of commercially important species currently being overexploited. In particular, hake, Norway lobster, anchovies, sardines, and soles choose the waters of GSA 17 for their reproduction. In international waters, an extremely important nursery zone is the area of the Jabuka/Pomo Pit, that hosts the most important nursery, in the entire Adriatic, for Norway lobster (*Nephrops norvegicus*) and hake (*European hake*), as well as those for shortfin squid (Illex coindetti), horned octopus (*Eledone cirrhosa*), deep-water rose shrimp (*Parapeneus longirostris*) and black-bellied angler (*Lophius budegassa*) (Figure 6). The northern Adriatic, on the other hand, is very important for the reproduction of soles (*Solea solea*) (Grati et al., 2013). In addition to commercial fish species, GSA 17 hosts important spawning, foraging and migration areas for sea turtles (*Caretta caretta*), sharks (such as the porbeagle shark, Lamna nasus, classifed by IUCN as "critically endangered"), rays, dolphins and whales (UNEP-MAP-RAC/SPA, 2015b).



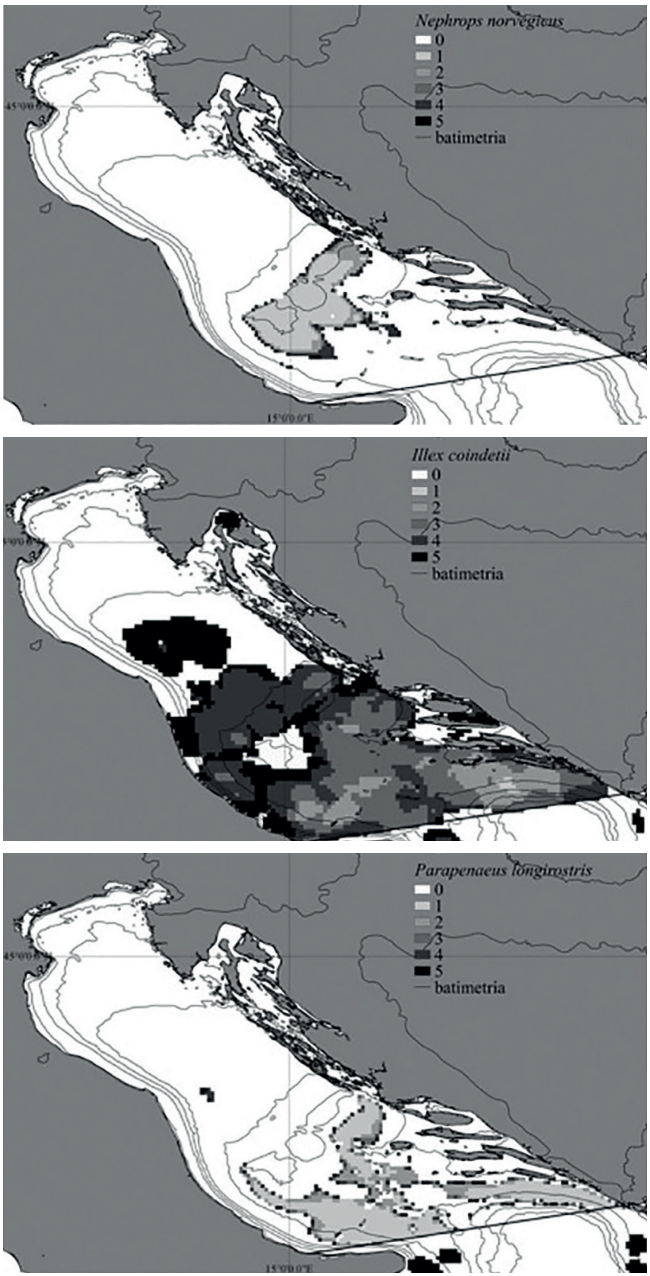


Fig. 6 Nursery areas of GSA 17. The scale (from 0 to 5) indicates the persistence index of nursery areas for commercial species, obtained from analysis of the MEDITS data (May-June 1994-2010; Colloca et al., 2015)

VULNERABLE AREAS IN THE SOUTHERN ADRIATIC

The southern Adriatic is characterised by a rapid increase in depth, culminating in the southern pit which reaches to more than 1200m. It is also home to the Strait of Otranto, the only point of exchange between the Adriatic and the rest of the Mediterranean. Available knowledge relevant to potential VMEs present in the southern pit is less than for the rest of the Adriatic, nevertheless, recent studies have highlighted the presence of some critical habitats in the high seas.

Canyons and seamounts

Submarine canyons, characterised by steep slopes and complex topographical structures, have been described as critical habitats for marine ecosystems (Vetter et al., 2010). The presence of canyons along the continental margins influences and modifies water circulation and provides very heterogeneous habitats, where hard bottoms faces alternate with scattered rocks in sandy bottoms. Furthermore, canyons represent the preferential route for the transportation of nutritional particles from the productive coastal areas to the more stable deep-sea environments (Fernandez-Arcaya et al., 2017).
The Bari canyon, located off the coast of Apulia, is a system formed by two deep incisions in the continental shelf of the southern Adriatic, that reach depths of up to 1000m (Figure 7). It is a biodiversity hotspot characterised by assemblages of megafauna, largely dominated by communities of cold water corals (CWC), in particular the *Madrepora oculata* and *Lophelia pertusa* corals, as well as sponges (*Pachastrella monilifera* and *Poecillastra compressa*) and numerous other benthic species. In addition, the canyon provides the ideal habitat for several commercial species, such as hake, as well as for species identified as vulnerable in the IUCN Red List, such as two shark species *Centrophosus granulosus* and *Hexanchus griseus* (WGVME, 2017).
A second canyon has been observed off the coast of Montenegro (Figure 7). Investigations using a ROV (Remotely Operated Vehicle), that is, a submarine vehicle piloted remotely which permits exploration of the deepest marine ecosystems, have brought to light that the communities that live within the Montenegro canyon are host to rich communities of megafauna. Among the principal groups of habitat-forming organisms, diverse species of cnidarians, such as scleratinia (*Madrepora oculata, Lophelia pertusa, Dendrophyllia cornigera*), antipatharia (Leiopathes glaberrima) and gorgonians (*Callogorgia verticillata*), dominate. A long side these are numerous other structuring organisms such as sponges and serpulids (Angeletti et al., 2014).
Among the seabed structures which potentially host VMEs, there are also seamounts such as the Dauno, off the coast of Bari (Figure 7). Along the western edge of the southern Adriatic pit a series of complex morphological structures have recently been described, characterised by submarine landslides, systems of anomalous activities (such as the Gondola Fault System) and a series of large-scale erosional and depositional features (Foglini, Campiani, Trincardi, 2016). Studies of the marine megafauna associated with these morphological structures highlight the presence of deep-sea corals and a rich associated fauna among which diverse species of sponges, gorgonians and fossil remains of bivalve beds (Taviani et al., 2016).

Bioconstructions

The communities of cold-water corals present in the Bari and Montenegro canyons represent the principal known bioconstructions in the southern Adriatic together with those observed off the coast of Otranto (Figure 7). The communities off the Otranto coast were observed at more than 700m, at the foot of steep slopes, with the communities characterised by small sea anemones, scleratinia (*L. pertusa* and *M. oculata*), as well as sponges, hydrozoans and serpulids.
The sandy sea floors, on the other hand, are characterised by the presence of bivalve communities (Angeletti et al., 2014). It has been hypothesised that these communities, in particular that off the coast of Otranto, could in some way represent a continuity, a connection with the much more well-known and protected deep-sea coral communities (white corals and yellow corals) of Santa Maria di Leuca.
A short distance from the city of Bar (Montenegro) at a depth of 450m, there is a spectacular field of "chimneys", that is, a group of columnar carbonate (mostly dolomite) structures reaching a height of up to 60cm and a diameter of 20cm, which currently provide substrate for a great variety of species, including white corals, yellow corals, and sponges (Angeletti et al., 2015). The Montenegran chimney field is one of the few known cases in the world in which the chimneys are still standing, emerging from the seabed, and the first of its kind ever recorded in the Mediterranean basin; it could represent another habitat to include as a potential VME of the southern Adriatic pit.

Sea pen fields

Available information concerning the distribution of sea pens in the southern Adriatic are very scarce and predominantly limited to the coastal zone. More extensive and detailed investigations of the sandy sea bottom of GSA 18 would be necessary to reduce the gap in knowledge about the distribution of this important organism.

Nursery, foraging and migratory route areas

The southern Adriatic hosts important spawning areas of various commercial species. In particular, in GSA 18, nursery zones for cephalopod molluscs (short-fin squid, horned octopus), crustaceans (deep-water rose shrimps, red shrimp, Norway lobster) and fish (hake) are to be noted.
The nursery areas of some cephalopods (*Eledone chirrosa, Illex condeitii*) are primarily situated along the western coast of the southern Adriatic. High densities of juveniles of red shrimp (*Aristaeomorpha foliacea*) have been found outside the area of the Gargano promontory and along the edge of the southern Adriatic pit, primarily at depths between 450-550m. The reproduction areas of the deep-sea rose shrimp (*Parapenaeus longirostris*) are predominantly located to the south of the Gulf of Manfredonia, in the waters between Monopoli and Brindisi and along the edges of the Strait of Otranto (Figure 8).
The Gulf of Manfredonia, the area offshore from the Gargano, and the Strait of Otranto are important nursery zones also for hake. In fact, the greatest concentration of juvenile hakes in the GSA 18 corresponds to these areas. On the other hand, zones with the highest density of adult female of Norway lobsters have been found only near to the Strait of Otranto, along the edge of the southern pit (Figure 8).
In addition, the southern Adriatic pit and the waters of GSA 18 constitute an ideal habitat for the sustenance of cetaceans, such as the various dolphin species which are commonly found there (*Stenella coeruleoalba, Ziphius cavirostris, Grampus griseus*), sea turtles, and other iconic species such as the devil ray (*Mobula mobular*) (UNEP-MAP-RAC/SPA, 2015b).

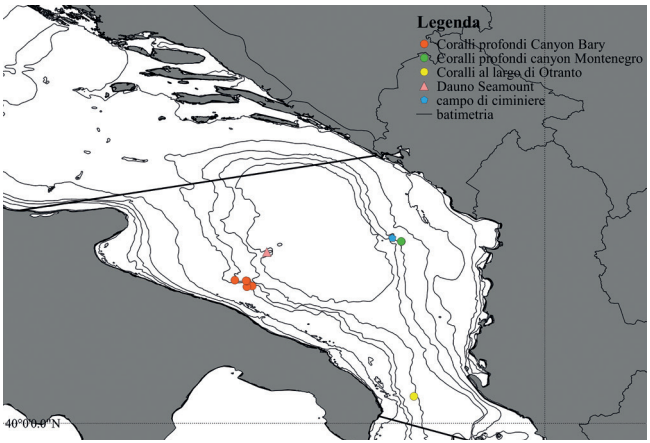


Fig. 7 Communities of deep-sea corals and particular topographic structures (canyons, seamounts, chimney fields) in GSA 18

facing page: Colonies of *Lophelia pertusa*, specimen in the DISVA didactic museum

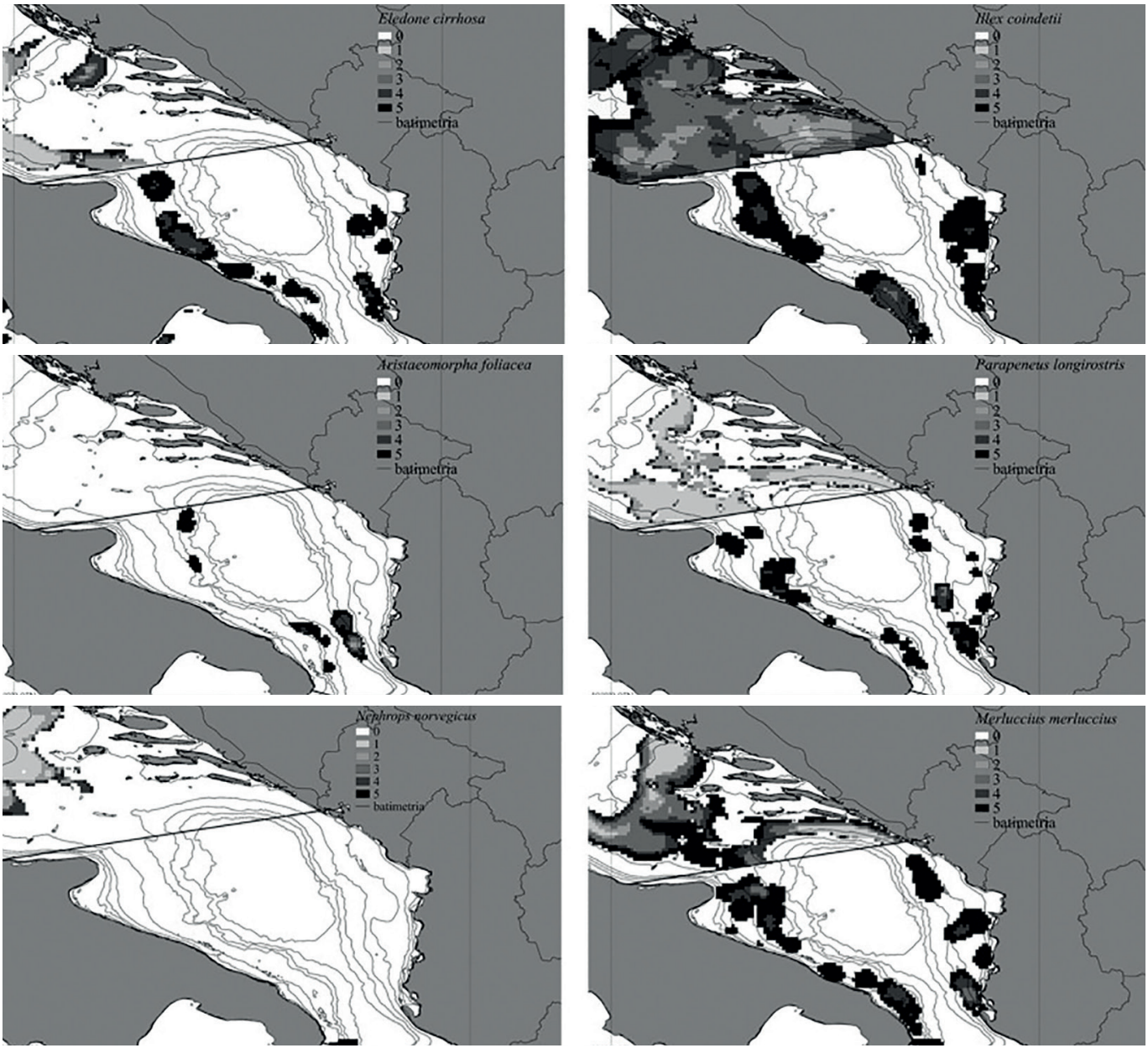


Fig. 8 Nursery areas of GSA 18. The scale (from 0 to 5) indicates the persistence index of nursery areas for commercial species, obtained from analysis of the MEDITS data (May-June 1994-2010; Colloca et al., 2015).

A SEA TO PROTECT

Over the years progress in European regulations has produced new instruments for the protection of ecosystems and sensitive marine species. In particular, the Natura 2000 network, the Marine Strategy Framework Directive and the new Common Fisheries Policy (CFP) allow interventions with spatial management measures to limit, if not prohibit, fishing activities that make the greatest impact.
In March 2017 the Mediterranean countries adopted the MedFish4Ever Declaration, which commits the signatories to create Fisheries Restricted Areas (FRA) in order to protect vulnerable species and essential habitats through the GFCM.
The GFCM produced in 2017 a list of species and habitats to consider as indicators of vulnerable marine ecosystems. Measures for their protection will therefore flank those already put in place by the GFCM with the establishment of FRAs which now include:

- Prohibition of bottom trawling below 1000m in the entire Mediterranean.
- Closure of bottom trawling for the protection of the white corals of Santa Maria di Leuca, of the Erathostenes Seamount near Cyprus, and the Nile Delta.
- Closure of bottom trawling in the eastern zone of the Adventure Bank, in the western zone of the Gela Basin and in the eastern zone of the Malta Bank (Strait of Sicily) for the protection of nurseries for hake and deep-sea rose shrimps.
- Limitation of fishing effort for bottom trawlers in the Gulf of Lion.

Currently, fishing management measures in the Adriatic are insufficient to guarantee the protection of vulnerable ecosystems. For example, the ban on bottom trawling below 1000m applies exclusively in the southern pit (Figure 9).
In February 2017 MedReAct, with the scientific support of the Marche Polytechnic University and Stanford University, therefore presented to the GFCM a proposal for the establishment of a new FRA in the Jabuka/Pomo Pit to protect important nursery grounds and VMEs present in the area (Figure 9).
The proposal stimulated a joint decision of Croatia and Italy for the closure of demersal fisheries as from 1 September 2017 in the central area of the Jabuka/Pomo Pit and for the reduction of fishing effort in two buffer areas (Figure 10).

In the coming years pressure from the European Union and the GFCM will be decisive in defining and introducing urgent conservation measures, such as the establishment of a network of Mediterranean FRAs , but equally important will be the collective commitment of civil society, stakeholders and the scientific community in supporting the recovery of our common sea.

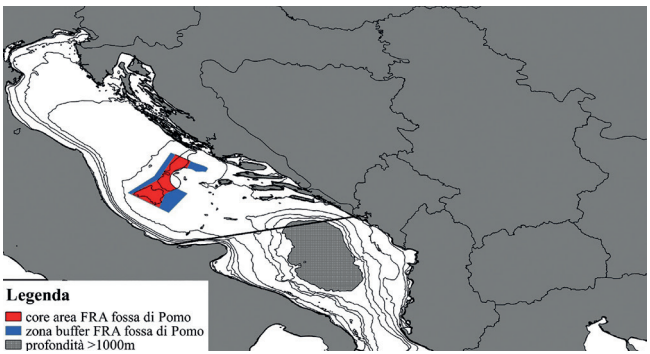


Fig.9 Current and proposed areas in the Adriatic for protection from bottom trawling

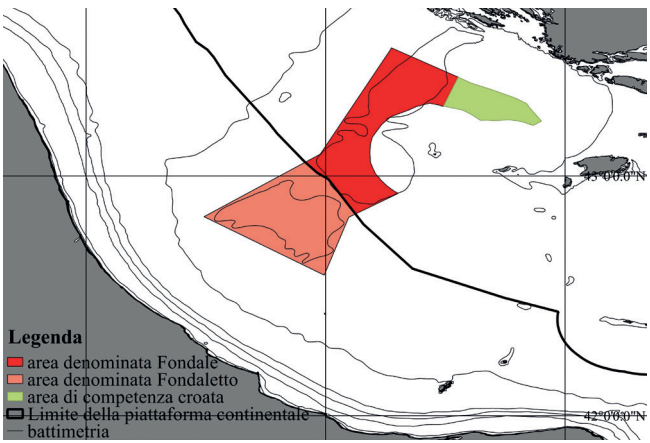


Fig.10 Areas subject to demersal fisheries restrictions established by Italy and Croatia in 2017

Bibliography

- Angeletti, L., Taviani, M., Canese, S., Foglini, F., Mastrototaro, F., Argnani, A., ... & Macic, V. (2014). New deep-water cnidarian sites in the southern Adriatic Sea. Mediterranean Marine Science, 15(2), 1-11.
- Angeletti, L., Canese, S., Franchi, F., Montagna, P., Reitner, J., Walliser, E. O., & Taviani, M. (2015). The "chimney forest" of the deep Montenegrin margin, south-eastern Adriatic Sea. Marine and Petroleum Geology, 66, 542-554.
- Bastari, A., Beccacece, J., Ferretti, F., Micheli, F., & Cerrano, C. (2017). Local ecological knowledge indicates temporal trends of benthic invertebrates species of the Adriatic Sea. Frontiers in Marine Science, 4, 157.
- Coll, M., Piroddi, C., Albouy, C., Ben Rais Lasram, F., Cheung, W. W., Christensen, V., ... & Palomares, M. L. (2012). The Mediterranean Sea under siege: spatial overlap between marine biodiversity, cumulative threats and marine reserves. Global Ecology and Biogeography, 21(4), 465-480.
- FAO (2009). International Guidelines for the Management of Deep-sea Fisheries in the High Seas. Directives internationales sur la gestion de la pêche profonde en haute mer. Directrices Internacionales para la Ordenación de las Pesquerías de Aguas Profundas en Alta Mar. Rome/ Roma, 73p.
- FAO (2016). Vulnerable Marine Ecosystems: Processes and Practices in the High Seas, by Anthony Thompson, Jessica Sanders, Merete Tandstad, Fabio Carocci and Jessica Fuller, eds. FAO Fisheries and Aquaculture Technical Paper No. 595. Rome, Italy.
- Fernandez-Arcaya, U., Ramirez-Llodra, E., Aguzzi, J., Allcock, A. L., Davies, J. S., Dissanayake, A., ... & Martín, J. (2017). Ecological role of submarine canyons and need for canyon conservation. Frontiers in Marine Science, 4, 00005.
- Ferretti, F., Osio, G. C., Jenkins, C. J., Rosenberg, A. A. and Lotze, H. K. (2013). Long-term change in a meso-predator community in response to prolonged and heterogeneous human impact Science Report, 3
- Foglini, F., Campiani, E., & Trincardi, F. (2016). The reshaping of the South West Adriatic Margin by cascading of dense shelf waters. Marine Geology, 375, 64-81.
- Fortibuoni, T., Borme, D., Franceschini, G., Giovanardi, O., & Raicevich, S. (2016). Common, rare or extirpated? Shifting baselines for common angelshark, Squatina squatina (Elasmobranchii: Squatinidae), in the Northern Adriatic Sea (Mediterranean Sea). Hydrobiologia, 772(1), 247-259.
- Grati, F., Scarcella, G., Polidori, P., Domenichetti, F., Bolognini, L., Gramolini, R., ... & Vrgo, N. (2013). Multi-annual investigation of the spatial distributions of juvenile and adult sole (Solea solea L.) in the Adriatic Sea (northern Mediterranean). Journal of sea research, 84, 122-132.
- Libralato, S., Coll, M., Tempesta, M., Santojanni, A., Spoto, M., Palomera, I., Arneri, E., Solidoro, C. (2010). Food-web traits of protected and exploited areas of the Adriatic Sea. Biological Conservation, 143(9), 2182-2194.
- Lotze, H. K., Coll, M., and Dunne, J. A. (2011). Historical changes in marine resources, food-web structure and ecosystem functioning in the Adriatic Sea, Mediterranean. Ecosystems 14, 198–222. doi: 10.1007/s10021-010-9404-8
- Lucchetti, A., Vasapollo, C., & Virgili, M. (2017). An interview-based approach to assess sea turtle bycatch in Italian waters. PeerJ, 5, e3151.
- Raicevich, S., Pranovi, F., Libralato, S., and Giovanardi, O. (2004). "The ecological role of potential scavengers in exploited ecosystems," in Poster Presentato al Simposio Internazionale "Quantitative Ecosystem Indicators for Fishery Management" (ambito UNESCO, SCOR, PICES)", Parigi.
- STECF. (2006). Report of the Mediterranean subgroup (sgmed 06-01) of the Scientific, Technical and Economic Committee for Fisheries (STECF). Sensitive and Essential Fish Habitats in the Mediterranean sea. Rome 6-10 march 2006.
- Taviani, M., Angeletti, L., Beuck, L., Campiani, E., Canese, S., Foglini, F., ... & Trincardi, F. (2016). Reprint of'On and off the beaten track: Megafaunal sessile life and Adriatic cascading processes'. Marine Geology 375, 146-160.
- UNEP-MAP-RAC/SPA. (2015a). Adriatic Sea: Important areas for conservation of cetaceans, sea turtles and giant devil rays. By Holcer, D ; Fortuna, C.M and Mackelworth, P.C. Edited by Cebrian, D.,& Requena, S., RAC/SPA, Tunis ; 69 pp.
- UNEP-MAP-RAC/SPA. (2015b). Adriatic Sea: Important areas for conservation of cetaceans, sea turtles and giant devil rays. By Holcer, D ; Fortuna, C.M and Mackelworth, P.C. Edited by Cebrian, D.,& Requena, S., RAC/SPA, Tunis ; 69 pp.
- Vetter, E. W., Smith, C. R., and De Leo, F. C. (2010). Hawaiian hotspots: enhanced megafaunal abundance and diversity in submarine canyons on the oceanic islands of Hawaii. Marine Ecology, 31, 183–199. doi: 10.1111/j.1439-0485.2009.00351.x
- WGVME, 2017. Report of the first meeting of the Working Group on Vulnerable Marine Ecosystems. Malaga, Spain, 3-5 April 2017.
- Micheli, F., Halpern, B. S., Walbridge, S., Ciriaco, S., Ferretti, F., Fraschetti, S., ... & Rosenberg, A. A. (2013). Cumulative human impacts on Mediterranean and Black Sea marine ecosystems: assessing current pressures and opportunities. PloS one, 8(12), e79889.
- Fortibuoni, T., Libralato, S., Raicevich, S., Giovanardi, O., & Solidoro, C. (2010). Coding early naturalists' accounts into long-term fish community changes in the Adriatic Sea (1800–2000). PloS one, 5(11), e15502.
- Colloca, F., Garofalo, G., Bitetto, I., Facchini, M. T., Grati, F., Martiradonna, A., ... & Tserpes, G. (2015). The seascape of demersal fish nursery areas in the North Mediterranean Sea, a first step towards the implementation of spatial planning for trawl fisheries. PloS one, 10(3), e0119590.