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Cold-water coral communities in the Central Mediterranean: aspects on megafauna diversity, fishery resources and conservation perspectives

Francesca Capezzuto¹ · Francesco Ancona¹ · Roberto Carlucci¹ · Angela Carluccio¹ · Laura Cornacchia¹ · Porzia Maiorano¹ · Pasquale Ricci¹ · Letizia Sion¹ · Angelo Tursi¹ · Gianfranco D'Onghia¹

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Abstract

In the last two decades, many new living cold-water coral (CWC) sites throughout the Mediterranean basin have been discovered and investigated. As part of oceanographic cruises, using ROVs and towed cameras, and trawl and longline surveys as well as records from fishermen, a belt of CWC communities has been identified along the Apulian continental margin (Central Mediterranean). The most investigated CWC communities are those of the Santa Maria di Leuca (SML) CWC province (northern Ionian Sea) and Bari Canyon (BC) (southern Adriatic Sea). These communities are mainly structured by the habitat-former species *Madrepora oculata* and, to a lesser extent, by *Lophelia pertusa* together with *Dendrophyllia cornigera*, solitary species, such as *Desmophyllum dianthus*, black coral, such as *Leiopathes glaberrima*, sponges (e.g., *Pachastrella monilifera*, *Poecillastra compressa*), serpulids, boring clams and colonies of bryozoans. CWC sites are biodiversity hot-spots, that act as “Essential Fish Habitats” for commercial species and through the spill-over effect might contribute to the renewal of stocks in neighbouring fishing grounds, providing ecosystems’ goods and services. Despite their particular features, CWC areas along the Apulian slope are impacted by different anthropogenic activities. Fishermen operate close and around these areas with the aim of obtaining greater catches and sizes of commercial species. Although there are many conservation proposals for CWC habitats and a Fisheries Restricted Area established for Santa Maria di Leuca CWC province, human pressure is still very strong, due to the lack of adequate conservation measures. An effective system of monitoring, control and surveillance will be fundamental to meet the conservation objectives and to reach the Good Environmental Status as part of the Marine Strategy Framework Directive.

Keywords CWC communities · Central Mediterranean · Megafauna diversity · Fishery resources · Conservation perspectives

1 Introduction

In the last two decades, many new living cold-water coral (CWC) sites throughout the Mediterranean basin have been discovered and six CWC provinces have been recognized to date (e.g., Freiwald et al. 2009; Taviani et al. 2017). As part of oceanographic cruises with ROV and towed cameras, trawl and longline surveys as well as records by fishermen, a belt of CWC communities has been identified along the Apulian continental margin (Central Mediterranean) (Fig. 1) (Tursi et al. 2004; Freiwald et al. 2009; Taviani et al. 2011; Angeletti et al. 2014; D’Onghia et al. 2016; Taviani et al. 2016). These CWC communities are probably connected by the water masses that flow from the southern Adriatic to northern Ionian (Canals et al. 2009; Freiwald et al. 2009;

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✉ Francesca Capezzuto
francesca.capezzuto@uniba.it

¹ Department of Biology, Local Research Unit CoNISMa, University of Bari Aldo Moro, Via E. Orabona 4, 70125 Bari, Italy

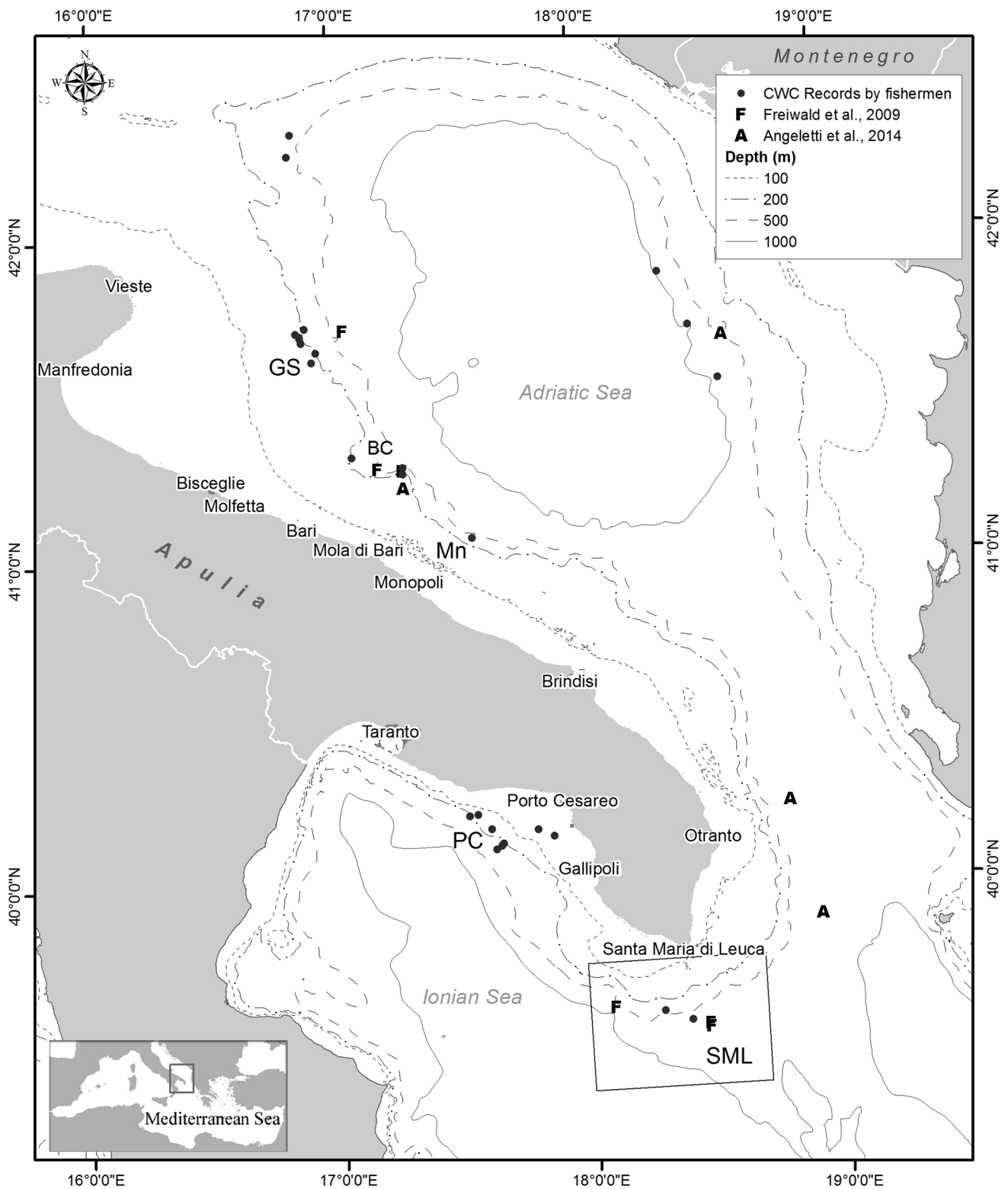


Fig. 1 Cold-water coral (CWC) communities investigated along the Apulian continental margin between the southwestern Adriatic Sea and northwestern Ionian Sea (Central Mediterranean). *GS* Gondola Slide, *BC* Bari Canyon, *Mn* off Monopoli, *SML* Santa Maria di Leuca CWC province, *PC* off Porto Cesareo. Solid dots indicate the records

of CWC provided by fishermen; **F** and **A** indicate the records by Freiwald et al. (2009) and Angeletti et al. (2014), respectively. The rectangle indicates the SML CWC province, with an extension of about 1000 km² (modified from D'Onghia et al. 2016)

Angeletti et al. 2014; D'Onghia et al. 2016; Taviani et al. 2016). From the Gondola Slide (southwestern Adriatic Sea) to Porto Cesareo (northwestern Ionian Sea), the most investigated CWC communities are those of the Bari Canyon (BC) (southern Adriatic Sea) and Santa Maria di Leuca (SML) CWC province (northern Ionian Sea). Most of these CWC communities are out of Territorial Waters (12 nautical miles) and, apart from SML, no conservation measures have yet been established for them. The BC and SML CWC provinces are both mainly structured by the habitat-former species *Madrepora oculata* and, to a lesser extent, by *Lophelia pertusa* together with *Desmophyllum dianthus* and *Dendrophyllia cornigera*, black coral, such as *Leiopathes glaberrima*, sponges, such as *Pachastrella monilifera* and *Poecillastra compressa*, serpulids, boring clams and colonies of bryozoans, which are also widespread in these communities (Tursi et al. 2004; Taviani et al. 2005; Mastrototaro et al. 2010; Bo et al. 2012; Sanfilippo et al. 2013; Angeletti et al. 2014; D'Onghia et al. 2015b).

In this paper, some characteristics of the megafauna diversity recorded in and around some cold-water coral habitats distributed along the Apulian continental slope (southern Adriatic and northern Ionian, central Mediterranean) are briefly reviewed, presenting the main deep-water fishery resources and the conservation perspectives of both habitats and resources.

2 Megafauna diversity and ecosystem services

To date, a total of 111 and 257 invertebrate and vertebrate species have been recorded from the BC and SML CWC provinces, respectively (Figs. 2, 3) (D'Onghia et al. 2015b).

Among the species recorded, some are endemic (e.g., *Eurypon topsenti*, *Hexadella pruvoti* and *Vermiliopsis monodiscus*), some others are of conservation importance (e.g., *Hexanchus griseus*, *Centrophorus granulosus* and *Merluccius merluccius*), many others are of interest to fishery (e.g., *Merluccius merluccius*, *Phycis blennoides*, *Pagellus bogaraveo* and *Helicolenus dactylopterus*), although of variable commercial values. The fish assemblages recorded in these CWC sites reflect the fish fauna previously collected on fishing grounds (e.g., Bello and Rizzi 1988; D'Onghia et al. 1998; Ungaro et al. 1998a, b; Relini et al. 2000, 2010). The presence of species at the top of the marine food web, such as *Centrophorus granulosus*, *Dalatias licha* and *Merluccius merluccius* has been recorded in the BC, SML CWC provinces and other CWC communities along the Apulian slope. The former is considered Critically Endangered (CR) and the latter two are Vulnerable (VU) on the International Union of Conservation of Nature (IUCN) European Red List of Marine Fishes (Nieto et al. 2015). It has been documented

in several geographic locations that CWC habitats act as shelter and life-history critical habitats for many commercial and non-commercial species (e.g., Brodeur 2001; Fosså et al. 2002; Reed 2002; Costello et al. 2005; Busby et al. 2006; Stone 2006; Etnoyer and Warrenchuk 2007; Sulak et al. 2007; Quattrini et al. 2009; Baillon et al. 2012; Miller et al. 2012; Henry et al. 2013; Ross et al. 2015). The remarkable abundance of juveniles both of the shark *Etmopterus spinax* and teleost fish *M. merluccius*, *Micromesistius poutassou*, *P. blennoides* and *H. dactylopterus* suggests that the SML CWC province acts as a nursery area for these deep-water species which find suitable environmental conditions and refuge from fishing (D'Onghia et al. 2010, 2016), due to its complex topography related to the presence of carbonate mounds (Savini et al. 2014). The presence of maturing and mature individuals, both females and males, as well as post-reproductive individuals of *Galeus melastomus*, *Conger conger*, *H. dactylopterus*, *M. merluccius*, *P. blennoides* and *P. bogaraveo*, although in different proportions, indicates that these CWC communities act as spawning areas, representing "sources" of new individuals which can spill-over into fishing areas (D'Onghia et al. 2016).

All the CWC communities provide ecosystems' goods and services as described in the Millennium Ecosystem Assessment (2005), that is supporting services, provisioning services, regulating services and cultural services. Supporting services are those that are necessary for the production of all other ecosystem services. Examples of supporting services are habitat, nutrient cycling, water circulation and exchange, primary production, and resilience. Provisioning services are the products used by humans that are obtained directly from habitats and ecosystems. Regulating services are the benefits obtained through the natural regulation of habitats and ecosystem processes, such as gas and climate regulation, natural carbon sequestration and storage, waste absorption and biological control. Cultural services are the often non-material benefits which people obtain from habitats and ecosystems through recreation, aesthetic enjoyment, inspiration and awe (Grehan et al. 2009; Armstrong et al. 2014). In particular, CWCs are indirect provider of supporting services, such as habitat and biodiversity. The habitat service is provided by the bioconstructor species which in the SML CWC province are mostly represented by the colonial scleractinians *M. oculata* and *L. pertusa*. The complexity of CWC habitats is enhanced by the abundant presence of massive poriferans (Longo et al. 2005; Mastrototaro et al. 2010). As these communities are unsuitable for trawl fishing and only partly suitable for longline and other gears, many benthic and benthopelagic organisms can spend part of their life cycle almost undisturbed there. Thus, these communities are an indirect provider of provisioning services in terms of food, represented by the commercial species that use this habitat for shelter, feeding, spawning and as nursery areas,

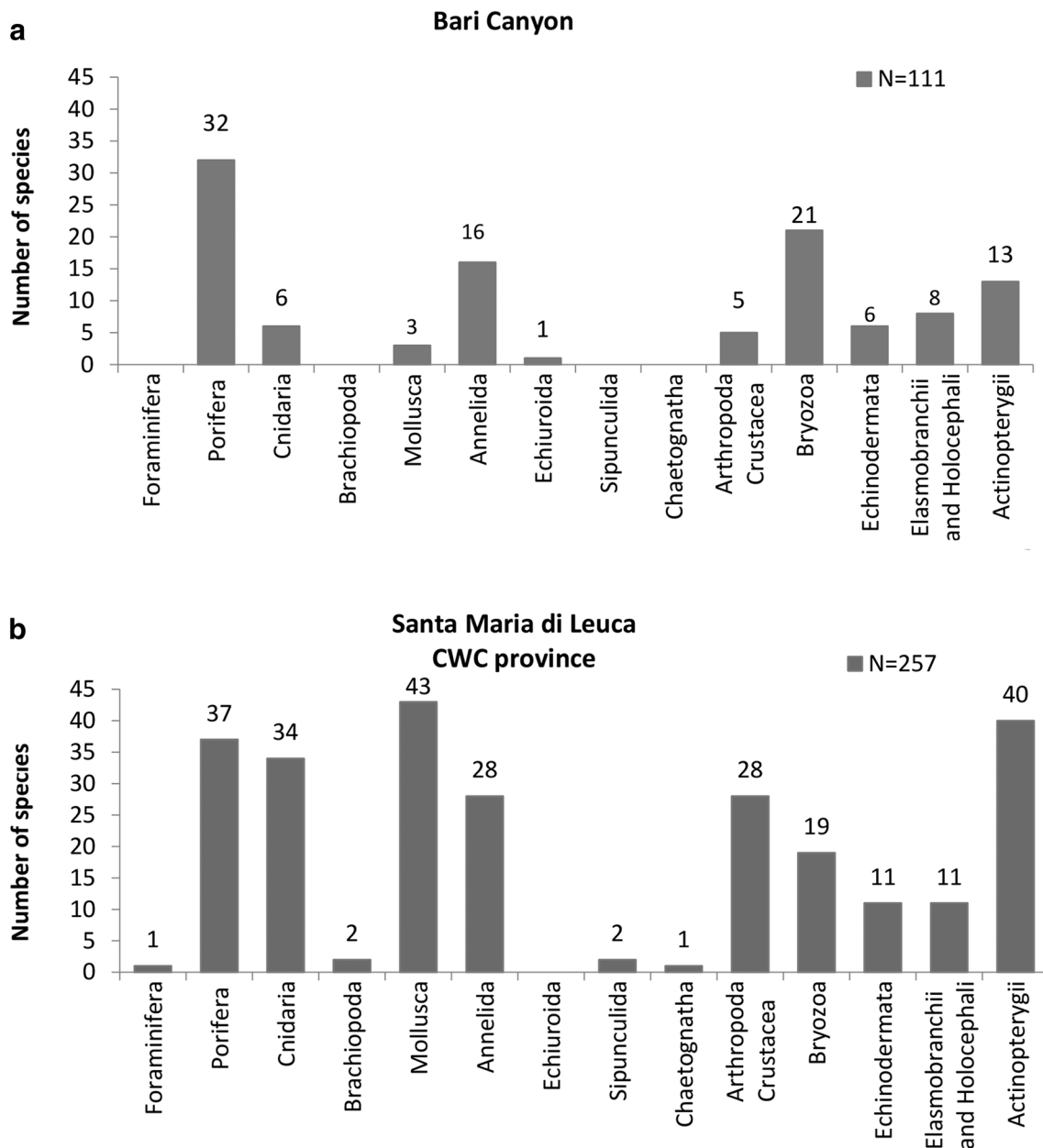


Fig. 2 Taxa composition in Bari Canyon and Santa Maria di Leuca CWC province (modified from D'Onghia et al. 2015b)

often reaching greater biomass and sizes than in exploited areas (e.g., D'Onghia et al. 2010, 2016, 2017). Other provisioning services include chemical compounds for industrial and pharmaceutical applications (Armstrong et al. 2014). Regulating services could be related to carbon sequestration due to CWC and resilience of the ecosystem with respect to environmental disturbance. However, no assessments have been carried out for the CWC communities studied in the Central Mediterranean. Canyons and CWCs do not offer recreational or tourism services due to their inaccessibility, but they can provide cultural services related to research in bio-prospecting and in climate change studies as well as

education and dissemination activities (Grehan et al. 2009; Armstrong et al. 2014).

3 Fishery resources

CWC communities are impacted by anthropogenic activities (Hinz 2017). The major direct impacts are due to deep-water fishing activities which mainly include longlining and accidental trawling, discarded/lost gears, dumping and littering. Fishermen operate in these sites with the aim of obtaining greater catches and sizes of commercial species. This occurs

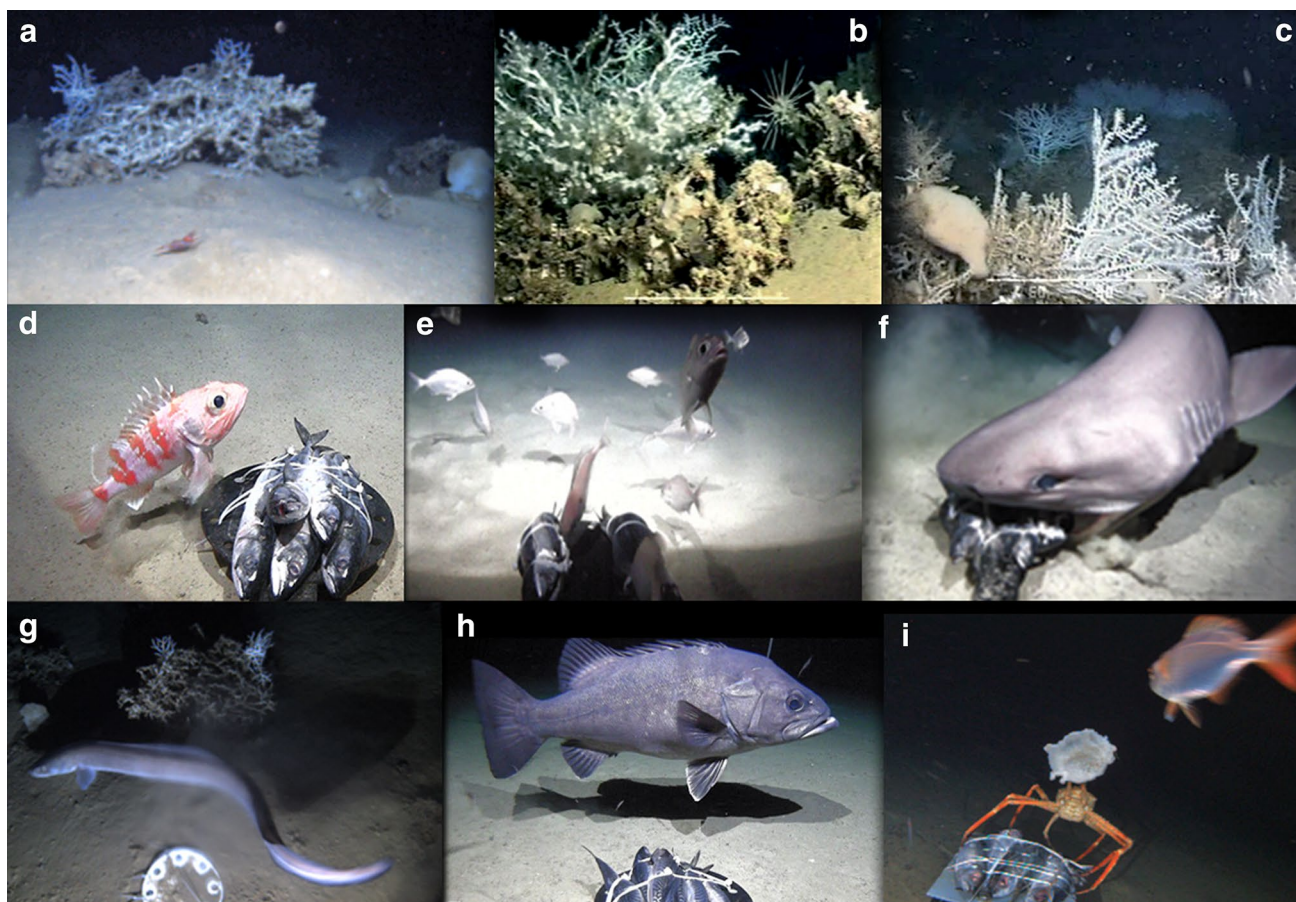


Fig. 3 Bari Canyon and Santa Maria di Leuca cold-water coral (CWC) communities. **a** SML CWC: *Plesionika martia* in coral habitat, **b** SML CWC: *Cidaris cidaris* in coral habitat; **c** SML CWC: *Madrepora oculata*; **d** Bari Canyon: *H. dactylopterus*; **e** Bari Canyon:

school of *P. bogaraveo*; **f** Bari Canyon: *Hexanchus griseus* on bait; **g** SML CWC: *Conger conger* in coral habitat; **h** Bari Canyon: *Polyprior americanus*; **i** SML CWC: *Paromola cuvieri* and *Pagellus bogaraveo*

also in the SML CWC province where a Fisheries Restricted Area (FRA) has been established (D'Onghia et al. 2017).

The largest marine fishery districts in the study area are Manfredonia, Molfetta, Bari (including Mola di Bari and Monopoli) and Gallipoli (Fig. 1). The fisheries belonging to the marine administrative district of Gallipoli operate to the northwestern of the SML CWC province, while the Adriatic fisheries often work close to the BC and other CWC sites. Among the deep-water fishery resources, the European hake (*M. merluccius*) is the most abundant demersal fish. This fish species is caught with trawl nets and longlines and bottom gill nets. It is a primary resource for Italian and in general for Mediterranean demersal commercial fishing, whose exploitation has been constantly monitored since the 1980s by national and EU research projects still in progress. An overfishing condition of the hake in all Italian seas has been detected (Relini et al. 2017).

In the northern Ionian, the deep-water shrimps *Aristeus antennatus* and *Aristaeomorpha foliacea*, represent the most valuable deep-water fishery resources (D'Onghia et al. 2005;

Sion et al. 2011; Tursi et al. 2011). Other important deep-water demersal resources, between the southern Adriatic and northern Ionian, are the crustaceans Norway lobster (*Nephrops norvegicus*) and the deep-water rose shrimp (*Parapenaeus longirostris*) (Lembo and Spedicato 2011a, b; Sion et al. 2011; Tursi et al. 2011). On the fishery grounds of the shelf edge and upper slope other fish species, such as the blue whiting (*M. poutassou*), greater forkbeard (*P. blennoides*), poor cod (*Trisopterus capelanus*), rockfish (*H. dactylopterus*), European conger (*C. conger*) and anglerfish (*Lophius piscatorius* and *Lophius budegassa*), provide a variable contribution to the capture of the trawls and longlines. Several species are captured as by-catch, among which the blackmouth catshark, *G. melastomus* is the most abundant. The hake (*M. merluccius*) is the primary target species also from offshore longline, followed by European conger (*C. conger*), gurnard (*Chelidonichthys lucerna*), rockfish (*H. dactylopterus*), greater forkbeard (*P. blennoides*) and blackspot seabream (*P. bogaraveo*) (Ungaro et al. 2005). Shark species, such as *H. griseus* and *G. melastomus*, are frequently

captured on deeper bottoms (Romanelli and Tarulli 2002). All these commercial species are captured on the fishing grounds and are also associated with CWC habitats.

4 Conservation perspectives

Fishing activity affects directly both fish stocks and CWC habitats; the reduction of these habitats will consequently negatively affects indirectly the fish stock. Hence, the destruction of these habitats, due to fishing, may have implications for service provision and a negative effect on the harvest as already documented in other areas (Armstrong and Falk-Petersen 2008; Armstrong et al. 2009).

The “deep-sea corals” habitat is reported on the list of priority habitats present in Italy (Relini and Tursi 2009) according to the SPA/BIO protocol (Barcelona Convention) and the SML CWC province is also included among the selected areas of conservation interest in the open sea, including deep sea (Specially Protected Areas of Mediterranean Importance) (SPAMIs) (UNEP-MAP-RAC/SPA 2009, 2010; de Juan et al. 2012). The criteria of rarity, importance for life-history stages of species, importance for threatened and endangered species/habitats, vulnerability, biological diversity and naturalness, make CWC ecosystem a Sensitive Habitat (SH) (de Juan and Leonart 2010). In this respect, the SML CWC province is included in the proposed conservation plan of “Vulnerable habitats” (de Juan and Leonart 2010). In addition, this Mediterranean CWC area is also among the proposed priority conservation areas according to several conservation initiatives (e.g., UNEP MAP EBSA; CIESM/Mediterranean Marine Peace Parks; Oceana/MedNet) (Oceana 2011; Micheli et al. 2013). CWC are included on the lists of Vulnerable Marine Ecosystems (VME) for which conservation constitutes a global priority (FAO 2009). Furthermore, since corals may provide Essential Fish Habitat (EFH) for commercial fish and invertebrates (e.g., Reed 2002; Roberts et al. 2009; Baillon et al. 2012; Henry et al. 2013; Fabri et al. 2014; Bo et al. 2015; D’Onghia et al. 2016; Huvenne et al. 2016; Cau et al. 2017), their protection could combine biodiversity conservation and fisheries management objectives according to the Ecosystem Approach to Fisheries (EAF) (Garcia et al. 2003). This implies sustainable management not only of the commercial stocks but also of the whole environmental system which supports their production, including the economic and social dimension (Spagnolo 2006; Tursi et al. 2015).

Considering the impact of trawling and, to a lesser extent, of other fishing gears, such as longline, on CWC communities, in January 2006 the General Fisheries Commission for the Mediterranean (GFCM) created the new legal category of “Fisheries Restricted Area” (FRA). The FRA covers a part of the SML CWC province. Towed dredges and bottom

trawl nets have been prohibited in the FRA. Members are required to call the attention of the appropriate authorities to protect this FRA from the impact of any other activity jeopardizing the conservation of the features that characterize the particular habitat (General Fisheries Commission for the Mediterranean—Regional Activity Centre for Specially Protected Areas, GFCM-RAC/SPA 2007).

Data on longlining and trawling activities from an observer program as well as through analysis of Vessel Monitoring System records, proved that trawlers still often fish inside the Fisheries Restricted Area (FRA) within the SML CWC province (D’Onghia et al. 2017). Moreover, using a camera system, impacts of longline fishing were evident through observations of lost gear, while otter board scars resulting from trawling impacts were also visible (D’Onghia et al. 2017). Observations by Savini et al. (2014) and D’Onghia et al. (2017) evidenced that plastic is the most abundant litter in the SML CWC province. The high abundance of plastic bags in coral-dominated habitats seems to be related to the ‘trapping effect’ of branching colonial corals located on geomorphological highs exposed to the strong currents that tend to gather plastic material (Savini et al. 2014).

A lack of monitoring, control and surveillance (MCS) has rendered the FRA ineffective and that strengthening of conservation and management initiatives is urgently required to prevent further overexploitation and habitat loss (D’Onghia et al. 2017; Grehan et al. 2017).

No protection measures exist for the Bari Canyon and other CWC communities along the Apulian margin, and in general for the Mediterranean CWC communities. However, the Bari Canyon is among the 30 “jewels” of the Mediterranean selected by Oceana (2011) with EBSA (Ecologically or Biologically Significant Marine Area) criteria four (vulnerability, fragility, sensitivity and slow recovery) and six (Biological diversity) (Marin and Aguilar, 2012). The recent studies carried out along the Apulian margin (Angeletti et al. 2014; D’Onghia et al. 2015a, b, D’Onghia et al. 2016; Taviani et al. 2016; Bargain et al. 2017) suggest that other EBSA criteria (e.g., one: uniqueness or rarity; three: importance for threatened, endangered or declining species and/or habitats; five: biological productivity; seven: naturalness) as well as the VME criteria (one: uniqueness or rarity; two: functional significance of the habitat; three: fragility; four: life-history traits that make recovery difficult; five: structural complexity) (FAO 2009) could also be assigned to the Bari Canyon and need to be taken into account for the planning of future marine protected areas (MPAs) and management measures to preserve its high biodiversity level in relation to the presence of CWC species.

The management requires both human and financial resources. Effort should be made to educate and persuade local people of the need to protect CWC communities.

Public awareness, stakeholder involvement and an effective system of MCS are fundamental to meet any conservation plans as well as to reach the Good Environmental Status as part of the Marine Strategy Framework Directive (MSFD). MCS of fisheries in deep sea will need approaches that involve fusion of data from a number of different sources including satellite-based remote sensing and other developed technologies (Rogers et al. 2015). In addition to the MCS, the establishment of a small network of FRAs in the region would favour a management approach according to an EAF.

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