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Editorial

Towards ecosystem based management and monitoring of the deep Mediterranean, North-East Atlantic and Beyond

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1. Introduction

The deep sea covers 65% of the earth's surface and 95% of the biosphere but only a very small fraction (less than 0.0001%) of this has been explored (Rogers et al., 2015; Taylor and Roterman, 2017). However, current knowledge indicates that the deep ocean is characterized by a high level of biodiversity and by the presence of important biological and non-renewable resources. As well as vast flat and muddy plains, the topography of the deep ocean contains a variety of complex and heterogeneous seafloor features, such as canyons, seamounts, cold seeps, hydrothermal vents and biogenic (deep-water coral) reefs and sponge bioherms that harbour an unquantified and diverse array of organisms. The deep sea, despite its remoteness, provides a variety of supporting, provisioning, regulating and cultural, ecosystem goods and services (Thurber et al., 2014). The recent push for 'Blue Growth', to unlock the potential of seas and oceans (European Commission, 2017) has increased the focus on the potential to exploit resources in the deep-sea and consequently the need for improved management (Thurber et al., 2014).

Ecosystem-based management (EBM) can be defined as an integrated approach to management that aims to maintain an ecosystem in a healthy, productive and resilient condition while providing the services that humans want and need (McLeod et al., 2005). While Cormier et al. (2016) argue that scientific impediments to EBM are no longer significant to prevent operational implementation, a lack of basic scientific knowledge still hinders its full realisation in the deep sea. Area-based management, particularly within a formal marine spatial planning framework, is now regarded as an essential component of EBM. In the European Union, the Maritime Spatial Planning Directive (MSP Directive 2014/89/EU) provides a means to integrate area-based management measures required under sectoral policy, such as the EU Habitats Directive, Marine Strategy Framework Directive and the Common Fisheries Policy. In international waters, the United Nations General Assembly adopted Resolution 69/292 to develop an international legally binding instrument under the United Nations Convention on the Law of the Sea (UNCLOS) on the conservation and sustainable use of marine biological diversity in areas beyond national jurisdiction, also known as the UN BBNJ process. The preparatory phase concluded with a fourth and final meeting of the UN BBNJ Preparatory Committee in June 2017. They recommended that the negotiation of the new BBNJ regulation include area-based management as one of the priority strands (Earth Negotiations Bulletin 2017). This builds on previous UN resolutions such as the UNGA Resolution 61/105, agreed to in 2006, that calls upon fisheries management organisations worldwide to: i) assess the impact of bottom fishing on vulnerable marine ecosystems (*sensu* FAO 2009); ii) identify/map vulnerable ecosystems through improved scientific research/data collection; iii) close such areas to bottom fishing unless conservation and management measures are established to prevent their degradation.

This special issue reports on research undertaken in Europe as part of the European Union Framework Project 'CoralFISH' (2008-2013; www.eu-fp7-coralfish.net) to improve the scientific basis for ecosystem-based resource management and monitoring in the deep waters of the Mediterranean and the North Atlantic in addition to addressing the need for tools and data to support implementation of UNGA 61/105. By focusing on the interactions between coral, fish and fisheries, the outputs from the CoralFISH project, equally address current issues relating to implementation of area based management particularly the adequacy of conservation measures in the deep sea. CoralFISH brought together a unique consortium of deep-sea fisheries biologists, ecosystem researchers/modellers, marine geologists, oceanographers, economists and a fishing industry partner, from 11 countries, who collaborated to collect data from all of the key European marine eco-regions (ICES, 2004) where cold-water corals are found (Fig. 1).

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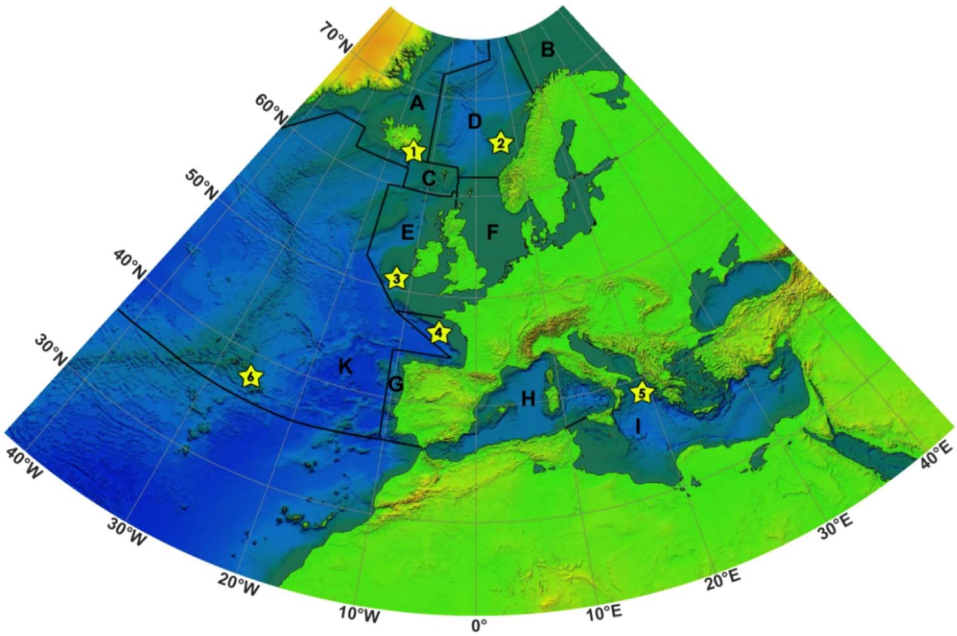

Fig. 1. Schematic representation of the 6 regional study areas of the CoralFISH project (cf. Davies et al., 2017). The 6 study areas are located; (1) offshore south Iceland (biogeographic region A); (2) offshore Norway (biogeographic region D); (3) offshore western Ireland (Porcupine Bank and Seabight, and Rockall Trough, within biogeographic region E); (4) offshore western France (Bay of Biscay, biogeographic region G); (5) offshore Italy and Greece in the Eastern Mediterranean sea (Northern Ionian sea, biogeographic region I) and (6) in the Azores archipelago (biogeographic region K).

The main objectives of the CoralFISH project were:

- Development of essential methodologies and indicators for baseline and subsequent monitoring of closed areas,
- Better understanding of coral habitat fish-carrying capacity through the integration of fish data into coral ecosystem models,
- The evaluation of the distribution of deep-water bottom fishing effort to identify areas of potential interaction and impact upon coral habitat,
- The use of genetic fingerprinting to assess the potential erosion of genetic fitness of corals due to long-term exposure to fishing impacts,
- The construction of bio-economic models to assess the impact on fisheries of various management measures adopted to protect coral habitat,
- The production of habitat suitability maps to identify areas likely to contain vulnerable marine habitat.

2. Key outputs from the CoralFISH project

2.1. Determining the importance of cold-water corals as fish habitat

2.1.1. Cold-water coral reefs and fish

One of the key objectives of the CoralFISH project was to determine the importance of coral habitat for fish. The project employed a variety of standardised methodologies involving on reef/off reef comparisons using fisheries acoustics, longlining and video transects. In Norway, Kutti et al. (2014, 2015) examined the relationship between demersal fish distributions and benthic habitats in: i) the Træna Deep marine protected area and adjacent areas of the Norwegian continental shelf using standardised longlining surveys, and in ii) the Trænadjupet marine protected area using a towed video system. Results from the longline surveys showed positive correlations between catch rates of tusk, *Brosme brosme*, the blackmouth catshark, *Galeus melastomus* and the rabbit fish, *Chimaera monstrosa* and density of small cold-water coral (CWC) mounds (Kutti et al., 2014). The authors noted, however, that differences in catch rates between coral and non-coral areas were quite low and that for most species the fish–habitat relationships varied temporarily and with the spatial scale used to delineate the habitat. Results from the towed video surveys indicate that the redfish, *Sebastes viviparus* and *B. brosme*, were twice as abundant in areas with coral habitats than in unstructured flat seabed at spatial scales from < 3 m to 2 km (Kutti et al., 2015). None of the fish species examined in Trænadjupet were confined exclusively to a single habitat; the authors thus concluded that fish are facultative users of coral habitat.

In the Santa Maria di Leuca (SML) CWC province (Mediterranean Sea), D'Onghia et al. (2012) compared deep-sea fish fauna in coral and non-coral mega-habitats using experimental longline surveys. They found some species specific differences in density and biomass between coral and non-coral mega-habitats. The blackspot seabream, *Pagellus bogaraveo* was exclusively collected in the coral mega-habitat, whereas the European conger, *Conger conger*, the blackbelly rosefish, *Helicolenus dactylopterus* and the wreckfish, *Polyprion americanus* were found with greater abundance in coral than in non-coral mega-habitat. The benthopelagic fauna of this Mediterranean cold-water coral province was further investigated using a baited lander in 2010 and 2011. The occurrence of *P. bogaraveo* exclusively in coral habitat was confirmed. The crustacean *Paromola cuvieri* and *C. conger* and *H. dactylopterus* were the most abundant species in coral habitat (Maiorano et al., 2013). The occurrence and behaviour of *P. cuvieri* and sharks: gulper (*Centrophorus granulosus)*, kitefin (*Dalatias licha)*, velvet belly lantern (*Etmopterus spinax)* and bluntnose sixgill (*Hexanchus griseus*), in coral areas of the SML CWC province were also recorded (Capezzuto et al., 2012; Sion et al., 2013).

Understanding the temporal interaction of fish with coral reefs requires novel technological solutions. Autonomous photographic landers provide a low-impact survey method that can be used in and around reefs (Linley et al., 2017). Lavaleye et al. (2017) describe testing of a new baited camera system deployed on a carbonate mound, off the west coast of Ireland. They provide a detailed description of their system and describe some of the technical challenges they faced in the field. A variety of fish and scavenging invertebrates were observed with varied frequency although no seasonal patterns were detected. Linley et al. (2017) describe the deployment of autonomous landers in the Arctic (Northern Norway), NE Atlantic (Belgica Mound Province and Bay of Biscay) and the Mediterranean (Santa Maria di Leuca CWC province). Observations were standardised between the

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