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Article

A Perspective for Best Governance of the Bari Canyon Deep-Sea Ecosystems

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Abstract: There is growing awareness of the impact of fishery activities on fragile and vulnerable deep-sea ecosystems, stimulating actions devoted to their protection and best management by national and international organizations. The Bari Canyon in the Adriatic Sea represents a good case study of this, since it hosts vulnerable ecosystems, threatened species, as well as valuable commercial species, but virtually lacks substantial management plans for the sustainable use of resources. This study documents the high level of biodiversity of the Bari Canyon and the impact of human activities by analyzing remotely operated vehicle surveys and benthic lander deployments. An integrated socio-economic study provides information on fishing pressure in the Bari Canyon and in the surrounding areas. Finally, measures of conservation, protection, and management are discussed and suggested for this remarkable site in the context of the deep Mediterranean Sea.

Keywords: canyon; VME; biodiversity; fisheries; conservation; management; Mediterranean

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1. Introduction

Among maritime human activities, fishing is one of the most impactful on the seafloor and on benthic communities, e.g., [1–3]. This is particularly true for the continental shelves whose fish stocks are overexploited and where the seafloor is severely damaged [4,5]. Due to the depletion of the shelf's resources and technical advances, fisheries have moved deeper to exploit new stocks [6,7]. As documented globally in the oceans, many fisheries are not sustainable [8–11]. Canyons and the surrounding areas offer refuge and provide nursery sites for marine fauna, thus providing goods and services to sustain human activities, especially exploitation of fish stocks [12,13]. Notoriously, fishing operations directly interacting with the seafloor (such as trawling) have a high impact on the environment, often negatively influencing biodiversity, habitat quality, and the integrity of the ecosystems' structure [14,15]. The Biodiversity Strategy for 2030 of the European Commission, together with the Marine Strategy Framework Directive, addresses the next 10 years for the protection and restoration of natural capital by preserving biodiversity and ecosystem services as critical steps for the sustainable management of marine resources [16]. In fact, biodiversity conservation and the sustainable use of resources have potential direct economic benefits [16]. This is also true for deep-sea ecosystems (>200 m) often represented by fragile organisms such as sponges and corals, which are strongly impacted by fishing operations. There is growing attention on the conservation and management of deep-sea vulnerable marine ecosystems (VME) with respect to the threats represented by fishery activities [17–19]. Deep-sea fisheries threaten a number of VMEs and endangered species as recognized also by international organizations [17]. Existing protection measures and/or current management programs for marine habitats and vulnerable ecosystems have so far failed to defend them from human pressure and overfishing [20,21].

The Adriatic Sea is known to be among the most productive basins in the Mediterranean Sea, hosting numerous fish stocks of commercial interest. The Italian fleet operating in the Southern Adriatic pertains to GSA18 (=geographical sub-area [22] established by the General Fisheries Commission for the Mediterranean (GFCM)) of the Mediterranean and Black Sea fishing region identified by FAO [23]. The GFCM defined a GSA as a useful tool for assessment and management of fishery activities (sustainable exploitation of living marine resources, stock assessments, and preservation of vulnerable ecosystems) [24]. The fleet is constituted by more than 1000 vessels [25], of which ca. 400 are mainly coastal trawlers, ca. 370 vessels are gillnetters, and only few operate below 200 m (see Table 1 of [26]). In general, trawlers operate on the shelf between 50 and 200 m and extend deeper on the continental slope (up to 600 m) when targeting big demersal species such as the European hake [26]. Fishing stocks in the southern Adriatic Sea, such as that of European hake (*Merluccius merluccius*), seem to be overexploited and not sustainable in the long term [26]. However, the possible collapse of fishing resources has not been assessed yet [27].

Table 1. Summary of the ROV metadata.

Station	Start Lat N—Long E (GG°mm.xx′)	End Lat N—Long E (GG°mm.xx′)	Start–End Depth (m)	Length (m)	Frames
A71	41°17.26′—17°16.61′	41°17.27′—17°16.63′	428–434	72	589
A77	41°14.66′—17°16.61′	41°12.01′—16°56.91′	422–449	55	149
A91	41°16.99′—17°17.55′	41°17.00′—17°17.53′	309–306	67	583
A207	41°17.27′—17°16.60′	41°17.18′—17°16,75′	460–330	1414	122
A208	41°14.24′—17°17.05′	41°17.15′—17°16.66′	412–382	654	418
A210	41°17.31′—17°17.12′	41°16.77′—17°15.94′	478–479	1075	478
MS15_20	41°17.71′—17°07.87′	41°17.58′—17°08.24′	284–205	2064	263
MS15_22	41°19.05′—17°05.02′	41°19.03′—17°04.96′	293–245	1092	149
MS15_24	41°16.92′—17°17.92′	41°16.76′—17°17.66′	284–222	1287	89
MS15_25	41°15.13′—17°19.55′	41°15.13′—17°19.14′	299–219	1133	87
MS17_II_140	41°17.32′—17°17.12′	41°17.27′—17°17.03′	490–385	860	508
MS17_II_141	41°22.69′—17°06.92′	41°22.97′—17°06.41′	274–201	1417	788
Total frames					4223

This study documents and highlights the biological characteristics, anthropic impacts, and fishing pressure on the Bari Canyon (BC), located in the southern Adriatic Sea, and its surrounding shelf areas, providing suggestions for conservation and sustainable use of the resources of such an important deep-sea submarine canyon. As such, the BC represents a good example in the Mediterranean Sea [12,28–31] since it (i) hosts numerous endangered mega- and macro-benthic organisms such as cnidarians and sponges [32–38]; (ii) acts as a spawning area for blackbelly rosefish and blackspot seabream [37]; (iii) represents an essential fish habitat (EFH) for different commercial species such as European hake, greater forkbeard, European conger, blackbelly rosefish, blackspot seabream, and blackmouth catshark, among others, since reproductive specimens have been found [39]; and (iv) finally, nursery areas for the European hake and deep-water rose shrimp have been demonstrated to be permanent in the surrounding slope area [40–42].

Setting of the Area

The southwestern Adriatic margin is marked by an articulated morphology (Figure 1) [43], characterized by mass failures deposits [44,45], topographic highs [46], sedimentary bed-forms [47], and numerous incisions, among which the BC is the most developed [12].

The BC is located just off the Italian territorial waters at ca. 14 nautical miles from the coast (at 17°8′15′′ E, 41°20′24′′ N; depth range 200–1200 m) and at just 40 km from the city of Bari, in the Apulian Region (Italy). The BC is an erosional–depositional structure characterized by two branches, almost parallel, E-W oriented, and separated by a topographic high. The northern branch is markedly erosional between 200 and 750 m, whereas between 750 and 1100 m it becomes more sinuous and develops into a well-defined channel. Mud deposition characterizes this intermediate sector. Below 1100 m, mud draping progressively covers this channel. The southern branch is wider, about 4 km, and characterized by steep and sub-vertical flanks (>30 degrees and >600 m); gradient changes and deep scours mark its axis. Its morphological complexity results from tectonic control of the area [48]. The BC represents an efficient conduit conveying nutrients and sediments from the continental shelf down to the basin floor [49]. The Levantine Intermediate Water (LIW) and the a-periodical North Adriatic Dense Water (NAdDW) are the two main water masses bathing this margin. The LIW, saltier and forming in the Levantine Basin due to summer evaporation, enters the southern Adriatic through the Otranto Strait flowing SE-SW between 200 and 600 m [50–52], whereas the NAdDW originates in the northeastern Adriatic shelf during winter cooling associated with local wind forcing and moves southwest [53]. Finally, through cascading events in the BC, it is transferred to the basin [54]. Cascading events provide nutrients and oxygen that influences deep-water ecosystems, among which cold-water corals (CWC) are the most emblematic [35,38,55,56].

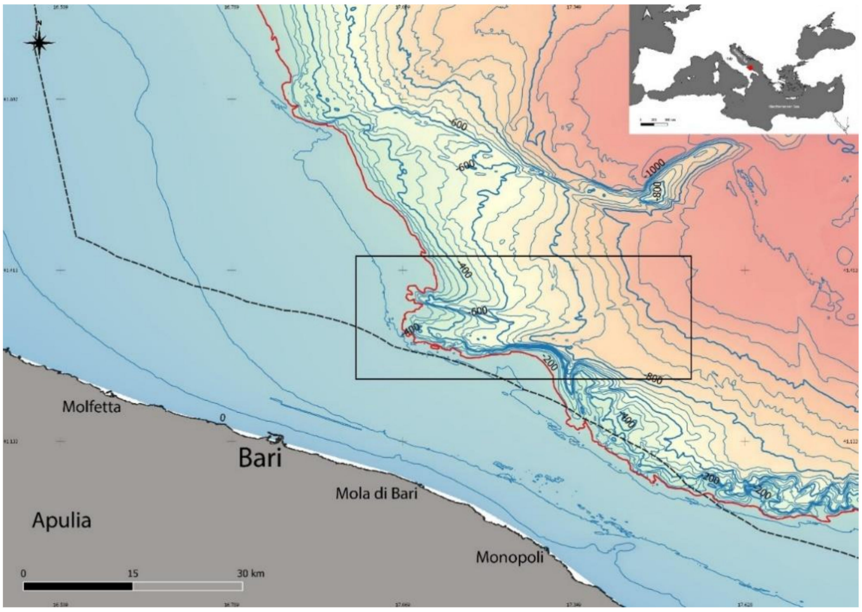

Figure 1. Location of the Bari Canyon (red circle in the inset) with the location of the main ports hosting fishing fleets operating in the area. Bathymetry from http://www.emodnet-bathymetry.eu/ (accessed on 16 April 2021). The black rectangle highlights the two branches oriented east-west of the Bari Canyon. The dashed black line indicates the limit of Italian territorial waters (12 nautical miles), the blue contour lines are spaced each 50 m, and the red line shows the bathymetric limit of 200 m.

2. Materials and Methods

2.1. Benthic and Demersal Fauna: Sampling and Visual Analysis

During the last two decades, at least 15 multidisciplinary cruises, funded by EU and national research and monitoring programs, have been carried out in the BC. Geophysical surveys (e.g., bathymetry acquisition, seafloor mapping) and equipment were described in [57]. Rock dredges, epibenthic hauls, and a large-volume (60 L) modified Van Veen grab were used to collect sediment samples in the area [35,38,58]. Remotely operated vehicle (ROV) dives surveyed the BC starting in 2006, when the Meteor 70/1 cruise [31] visually documented, for the first time, the occurrence of deep-water (between ca. 300–1000 m) megabenthic (>2 cm and easily recognizable in video and/or photographs) organisms. The *RR/VV Urania* and *Minerva Uno* cruises ARCADIA, MARINE STRATEGY15, SIRIAD16, and MSFD-II-17 surveyed the BC using the ROV Achille M4 (equipped with a low-resolution CCD camera) and the ROV Pollux III (equipped with a low-resolution CCD camera) for navigation, a digital camera (Nikon D80, 10 megapixels), and a high-resolution video camera (SonyHDR-HC7, with an image frame of 2304 × 1296 dpi). Three laser beams spaced 20 cm from each other provided a scale bar on the videos. ROV position and navigation were provided every 1 s by an underwater acoustic tracking system. Taxonomic identifications were made using high-resolution still-image analysis, whereas low-resolution images were analyzed for habitat mapping along the ROV track following the procedure reported in [59]. Megabenthic organisms were identified to the lowest taxonomic rank possible; taxa that could not be identified to species level from the images were identified only as morphological categories or morphospecies [60].

Several deployments of the MEMO (Marine Environment MOnitoring system) baited lander were carried out in the BC and in the nearby area in order to explore and monitor demersal fish populations. The lander is equipped with two high-resolution cameras (Sony ICX414) with two LED lights (12 V, 700 mA) for both wide and macro observations. A multiparametric CTD probe, a doppler current meter, an inclinometer, and an altimeter completed the equipment. During each deployment, the lander was baited with specimens of the Atlantic mackerel *Scomber scombrus* (see details in [36,61]). Experimental longline deployments were also carried out in the area using the sardine *Sardina pilchardus* as bait [30,36,37,39,62]. All video-recorded or caught fish specimens were measured, weighed, and identified to the lowest possible taxonomic rank. The maturity stage of the gonads were examined for the most abundant commercial species. The benthic and demersal taxonomic names conform to the World Register of Marine Species database [63].

2.2. Fishers, Fisheries, Fishing Pressures

To recognize the pressure on fishing stocks in the BC, trawlers and longliners from fleets based at the nearest ports were chosen (Bari, Molfetta, Monopoli, Mola di Bari) by analyzing data on volume of catches, specific composition, etc. from the Italian National Program on Data Collection on Halieutic Resources (CAMPBIOL DCF) [64,65]. Additional information on vessel activities was obtained from the AIS (Automatic Identification System) data, which consisted of an automated tracking system (compulsory for European fishing vessels of lengths above 15 m) that provides a unique identification, the position, the course (=navigation), and the speed of any ship to the competent authorities. AIS data are used for fishing fleet monitoring and control and are freely available from the Global Fishing Watch organization (https://globalfishingwatch.org/ accessed on 9 April 2021). The first step for the identification of fishing activity is to determine which part of the vessels' tracks can be considered fishing and which cannot. In fact, a specific speed footprint characterizes vessels that are using fishing gear (such as a trawl). Prior to any statistical analysis, AIS data were filtered following the procedure reported in [66] by excluding navigation. We calculated the fishing time following [67]. R software and the *mixtools* library (*NormalmixEMcomp2* script) were used for statistical analyses. In addition, the analysis of MEDITS data contributed to exploring the characteristics of the demersal population of the area [68–70]. Finally, a socio-economic survey on a target population of 174 vessels, following the FAO Guidelines [71], was carried out to localize eventual fishing grounds in the BC area. The survey focused on 80 vessels (representing ca. 46% of the target population) operating as trawlers, longliners, and gillnetters, located at Mola di Bari (n = 37), Monopoli (n = 25), and Molfetta (n = 18) ports [72].

3. Results

3.1. Biodiversity

The BC seascapes and surrounding slope, between 200 and 1000 m, are characterized by several habitats, which include CWC ecosystems and sponge grounds [32–38,55–57,61,73–77]. ROVs surveyed the BC and the surrounding areas (i.e., flanks, rims) 12 times (see Table 1). Steep slopes and vertical canyon flanks are inhabited by CWC, by far dominated by *Madrepora oculata*. Other cnidarians seldom occur, i.e., the colonial *Desmophyllum pertusum* (synonym of *Lophelia pertusa*: [78]) and *Dendrophyllia cornigera* and the solitary *Stenocy-*

athus vermiformis and *Desmophyllum dianthus*, often settling on *M. oculata* frameworks on deeper rocky outcrops [38]. The black coral *Leiopathes glaberrima* was recorded from the deepest area, in low abundance [36]. Polychaetes are abundant, often intimately associated with CWC; for instance, *Serpula vermicularis* contributes to biogenic frameworks and habitat complexity [34,73]. Other relevant polychaetes are *Vermiliopsis monodiscus* and *Hyalopomatus madreporae*, which are Mediterranean endemics and represent new records for the BC [36]. Porifera is another important group that contributes to the high grade of biodiversity in the BC and nearby area. The most common species are the large fan-shaped *Pachastrella monilifera* and *Poecillastra compressa*, which dominate the environment, forming sponge ground habitats in coral-free areas (e.g., shallower area at depths between 200 and 350 m). At least four Porifera species (*Biemna parthenopea*, *B. tenuisigma*, *Eurypon topsenti*, and *Hexadella pruvoti*) are considered endemic to the Mediterranean Sea and represent new records for the Adriatic Sea and, in particular, for the BC, as well as *Cerbaris curvispiculifer*, which is a new addition to the Italian spongofauna [36]. Several invertebrate, cartilaginous, and teleost species, even of commercial interest, have been recorded in the BC [26,27,34,36,37,61]. Among crustaceans, *Aristaeomorpha foliacea* (giant red shrimp), *Aristeus antennatus* (blue and red shrimp), *Nephros norvegicus* (Norwegian shrimp), *Parapenaeus longirostris* (deep-water rose shrimp), and *Paromola cuvieri* (Paromola shrimp), and among mollusks, *Eledone cirrhosa* (horned octopus), *Octopus vulgaris* (common octopus), and *Sepia officinalis* (cuttlefish) are the most common invertebrate catches of a certain economic value in the nearby continental slope. The most important teleost fishes in terms of biomass and commercial interest recorded in the BC are *Merluccius merluccius* (European hake), *Conger conger* (European conger), *Helicolenus dactylopterus* (blackbelly rosefish), *Phycis blennoides* (greater forkbeard), *Pagellus bogaraveo* (blackspot seabream), *Micromesistius poutassou* (blue whiting), *Chelidonichthys lucerna* (tub gurnard), and *Polyprion americanus* (Atlantic wreckfish). Among cartilaginous fishes, the most abundant records are *Galeus melastomus* (blackmouth catshark) and *Hexanchus griseus* (bluntnose sixgill). Common occurrences also include the critically endangered *Centrophorus granulosus*, the near-threatened *Chimaera monstruosa*, and the vulnerable *Dalatia licha*, according to the IUCN Red List for the Mediterranean [27,30,36,37,61,62,79] (Figures 2 and 3, Table 2).

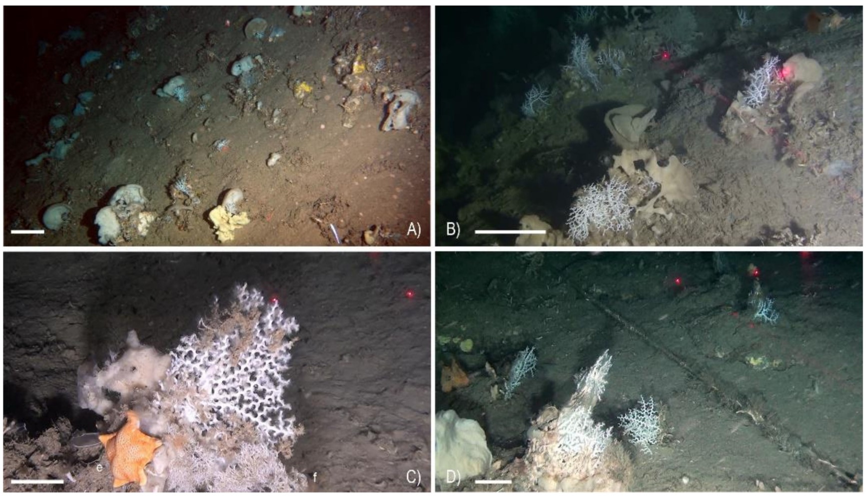

Figure 2. Examples of habitats and threatened benthic organisms recorded in the Bari Canyon. (**A**) Aggregation of deep-sea sponges (=sponge ground) dominated by the white large fan-shaped sponge *Pachastrella monilifera* (white) at ca. 486 m depth; scale bar = 20 cm. (**B**) Aggregation of deep-sea sponges and the scleractinian *Madrepora oculata* at ca. 250 m depth; scale bar = 20 cm. (**C**) *Madrepora oculata* settling on a rocky outcrop together with the echinoderm (**e**) *Peltaster placenta* and the colonial annelid (**f**) belonging to the *Filograna/Salmacina* complex at depth of ca. 230 m; scale bar = 10 cm. (**D**) Abandoned/lost longline in cold-water coral habitat, dominated by *Madrepora oculata* at ca. 280 m depth; scale bar = 20 cm.

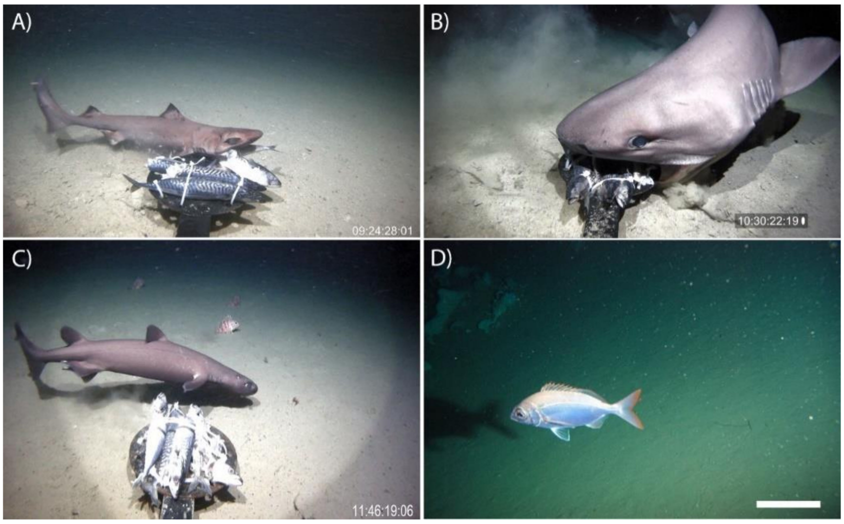

Figure 3. Examples of vulnerable cartilaginous and teleost fishes recorded in the Bari Canyon. (**A**) The critically endangered *Centrophorus granulosus*, (**B**) the bluntnose sixgill (*Hexanchus griseus*), which represents one of the most common sharks in the area and whose vulnerability is under minor consideration, and (**C**) the vulnerable *Dalatia licha* and in the background the blackbelly rosefish (*Helicolenus dactylopterus*), which represents one of the targeted deep-water species. The baited plat (diameter of 25 cm) is used for scale. (**D**) The common blackspot seabream (*Pagellus bogaraveo*) is one of the GFCM priority species, in the background, left side, note the *Pachastrella monilifera* ground. Scale bar = 15 cm.

Table 2. List of organisms of conservation interest identified in the BC and the surrounding areas. Asterisks mark local and/or Mediterranean endemism; their threatened status is indicated when possible, as well the legal instruments under which the species are protected.

Taxon	Status	Legal Instrument
Porifera		
Biemna parthenopea *		
Biemna tenuisigma *		
Eurypon topsenti *		
Hexadella pruvoti *		
Poecillastra compressa		VME indicator taxa
Pachastrella monilifera		VME indicator taxa
Cnidaria		
Dendrophyllia cornigera	Endangered	IUCN, Annex II of SPA/BD, VME indicator taxa
Desmophyllum dianthus	Endangered	IUCN, Annex II of SPA/BD, VME indicator taxa
Desmophyllum pertusum	Endangered	IUCN, Annex II of SPA/BD, VME indicator taxa
Leiopathes glaberrima	Endangered	IUCN, Annex II of SPA/BD, VME indicator taxa
Madrepora oculata	Endangered	IUCN, Annex II of SPA/BD, VME indicator taxa
Polychaeta		
Hyalopomatus madreporae *		
Vermiliopsis monodiscus *		
Chondrichthyes		
Centrophorus granulosus	Critically endangered	IUCN
Chimaera monstrosa	Near threatened	IUCN
Dalatias licha	Vulnerable	IUCN
Hexanchus griseus	Least concern	IUCN
Actinopterygii		
Helicolenus dactylopterus	Least concern	IUCN
Merluccius merluccius	Vulnerable	IUCN, GFCM Species priority
Polyprion americanus	Data deficient	IUCN
Phycis phycis	Least concern	IUCN
Pagellus bogaraveo	Least concern	IUCN, GFCM species priority

3.2. Anthropic Impact

Evidence of abandoned or lost fishing gear (LFG) and other marine litter is scant [31,34]. The analysis of 3745 still frames of both low resolution and high resolution from 12 ROV surveys (Tables 1 and 3) in different areas of the canyon showed the presence of LFG and litter in 56 frames (ca. 1.5% of the total). Longlines represented the most frequently recorded LFG, accounting for 41 (ca. 75% of the total marine litter), often entangling the bedrock. Plastic bags (n = 5) and other plastic items (n = 3) represented ca. 16% of the total litter and could be attributable to material lost from ships or transported from the shelf areas by downcurrents. Glass bottles (n = 2) and aluminum barrels/cans (n = 3) were the remaining marine litter recorded in the canyon (ca. 9% of the total recorded litter).

Table 3. Number of litter items identified through ROV analysis.

Station	Longlines	Plastic Net	Plastic Bag	Plastic Can	Plastic Tube	Aluminum Barrel/Can	Glass	Total
A71			1					1
A77				1				1
A91								0
A208	2						1	3
A207	1						1	2
A210	2		1					3
MS15_20	2							2
MS15_22	25			2	1	2		30
MS15_24								0
MS15_25								0
MS17_II_140	1	1	2			1		5
MS17_II_141	8		1					9
Total	41	1	5	3	1	3	2	56

3.3. Fishers, Fisheries, Fishing Pressures

Several fisheries operate along the Apulian margin, with 15 base ports in which 989 vessels are registered [25]. The greatest number of (small) vessels operate with different fishing techniques, such as gill and trammel nets, longlines, and dredges, whereas the greatest fishing effort, engine power, and gross tonnage vessels are trawlers [26,80–82]. However, considering the expenses (such as fuel costs and navigation time), fleets harbored too far from the BC (out of Italian territorial waters, ca. 14 nautical miles from the nearest port) were excluded from analysis. Thus, 37% of the trawlers (152 out of 413) and 38% of longliners (92 out of the 241) were considered candidates to operate in the BC area, all from Bari, Mola di Bari, Molfetta, and Monopoli ports [72]. AIS analysis for the year 2019 shows that the fishing effort in the BC area is low. In fact, there are eight trawlers that operate in the area for a total amount of ca. 60 h/year (on average), yet there are no AIS data for longliners in the BC (they operate with small vessels, >15 m, where the use of AIS is not mandatory). Based on fishery data collected and ROV video analysis, it seems that the BC is not a regular fishing ground for longliners, whereas trawlers seem to occasionally work in areas bordering the canyon's rims (Figure 4).

The results of the fisher interviews show that the number of days at sea, on average, are 143 per year with a mean of 91 fishing trips per vessel. Longliners achieved 117 days at sea with 38 fishing trips per vessel, whereas trawlers attained 157 days at sea and 117 fishing trips per vessel, with the duration of each fishing trip differing between 3 days and 1 day, respectively. Overall, the target population spent ca. 26,000 days at sea and took 18,580 fishing trips. The number of days at sea correlates with fuel consumption, thus evidencing higher costs for larger vessels (LOA > 18 m). The fishers interviewed to collect information on fishing trips and localization of the fishing grounds indicated that the most visited areas are located on the continental shelf at depths between 50 and 200 m, just bordering the upper zone of the BC [72].

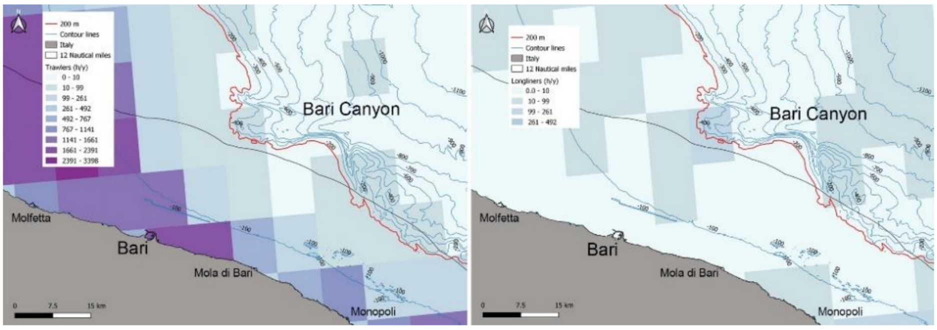

Figure 4. Fishing effort (trawlers on the left side and longliners on the right) on the shelf and slope in the area near the Bari Canyon. Effort (h/year) is indicated on a logarithmic scale. Contour lines are spaced 100 m apart; the red line marks the contour line of 200 m. The black line indicates Italian territorial waters (12 nautical miles).

Considering the volume of catches, as evidenced by baited lander deployments, experimental MEDITS surveys, and experimental longline surveys, *M. merluccius*, *C. conger*, *H. dactylopterus*, *P. bogaraveo*, *P. blennoides*, and *G. melastomus* are, by far, the most abundant species in the BC area [36,37,62]. The main catches in the surrounding slope and shelf areas are *M. merluccius*, *N. norvegicus*, *Mullus* spp. (red mullet), *E. cirrhosa*, *Lophius* spp. (black-bellied angler), *A. antennatus*, and *A. foliacea* [83]. Finally, by-catch is a major threat for several species in the BC, such as, for example, *G. melastomus*, which represents the most abundant by-caught deep-water shark in the area [34].

3.4. Vulnerable Ecosystems

The macro- and megabenthic (including demersal fish) diversity of the BC is high and includes more than 100 taxa [27,32,34–38,57,61,62]. Porifera and Cnidaria represent the dominant component of the community, acting as habitat formers. In fact, ROV images and bottom samples documented the presence of (i) cold-water coral reefs, (ii) deep-sea sponge aggregations (=deep-sea sponge grounds) and hard-bottom sponge gardens (=hard-bottom sponge grounds), and (iii) other dense emergent fauna (e.g., serpulids), categorized as VME indicator taxa by GFCM [84]. The presence of these three categories lend support to the BC and adjacent slopes as a site hosting relevant VMEs for the Mediterranean Sea. Furthermore, such habitat categories, included also in the EUNIS classification system [85], are all under consideration for protection by several international organizations (e.g., FAO, Barcelona Convention, Habitats Directive). The five most common cnidarian species and most of the cartilaginous and teleost fishes recorded in the BC are under protection through several international legal instruments (Table 2). Moreover, more than 21 fish species are recorded to date from the BC, of which many are of commercial value [36,61]. The presence of several nursery sites [40–42] in the BC and surrounding areas, for example, *M. merluccius* (European hake), emphasize the role of this area as a refuge from fishing activity [27,37]. Indications that the BC may act as a spawning area were provided by the presence of reproductive individuals of *P. bogaraveo* and *H. dactylopterus*. Mature/reproductive individuals of *M. merluccius*, *C. conger*, *H. dactylopterus*, *P. bogaraveo*, *P. blennoides*, and *G. melastomus* have also been collected in the BC [30,37,39,62]. The abundances of the latter and other species compared to the most abundant demersal species (*M. merluccius*) of the Mediterranean Sea seems to correlate with the distribution of adult specimens in the BC. Therefore, the megabenthic habitat-forming species (CWCs and sponges) contribute to the renewal of fish populations by acting as an essential fish habitat (EFH) and as spawning sites, and might potentially represent a renewal network among other Adriatic and Mediterranean sites [27,30,37,39,62]. Recently, it has been observed that the BC also plays an important role as a feeding habitat for *H. dactylopterus* and *P. bogaraveo*. These two species have a higher trophic level in the BC (and in other coral habitats) than on the surrounding muddy bottoms [86,87].

4. Discussion

4.1. Biodiversity, Anthropic Impact, and Fishing Pressure

The biological characteristics of the Bari Canyon CWC Province are emblematic of the Mediterranean CWC provinces. *Madrepora oculata* is the main frame builder, with less presence of other frame builders such *Desmophyllum pertusum* [34,35]. In terms of coral assemblages and structures, faunal data compare well with other Mediterranean sites such as the Nora Canyon [88], the Levante Canyon [89], the Cassidaigne Canyon [90] and the Cap de Creus Canyon [91]. The biodiversity richness (n = 111 species: [36]) is also well comparable with other Mediterranean coral-dominated situations such as Santa Maria di Leuca CWC Province (n = 222 species: [92]; n= 257 species: [36]), Dohrn Canyon (n = 64 species: [93]), Nora Canyon (n = 78 species: [88]), and Corsica Channel CWC Province (n = 58 species: [94]). Seldom represented in the Mediterranean literature, deep (>200 m) sponge grounds here are the dominant habitat in the coral-free area and compare well with the Santa Maria di Leuca sponge grounds [92,95] and, in term of biomass, seem to fit well with major Atlantic counterparts [33]. The high level of biodiversity of the Bari Canyon might be related to the canyon effect [96,97], which is the result of three main factors: (i) Trophic resources commonly increase in canyons with respect to surrounding areas, (ii) the presence of CWCs ecosystems (amongst others), and (iii) relatively low fishing pressure.

Different from other Mediterranean canyons [90,97,98], the anthropic impact in the Bari Canyon is limited and pertains mainly to lost fishing gear. Even if the hydrodynamism of canyons boosts marine litter (i.e., plastic) transportation from the continental shelf down to the basin [13,99,100], the few records of marine litter identified by frames analysis show that the sponge grounds and the CWC ecosystems of the Bari Canyon are still pristine. Here, coral colonies do not trap plastic material as evidenced in other Mediterranean situations such as the Cassidaigne [90], Nora, and Dohrn canyons [88,93], the Adriatic and Northern Ionian Tricase Canyon [101], and Santa Maria di Leuca CWC Province [20]. There are three hypotheses to explain this setting: (i) There is a low input of plastic marine litter along the Italian coast and consequently very few material floating and sinking in the water mass; (ii) the majority of plastic marine litter is fished by fishers on the shelf, preventing its sinking and transportation along the canyon to CWC sites; and (iii) the plastic input is carried by the downslope currents deeper with respect to the investigated areas (>600 m). Even if very limited, LFGs more commonly observed on ROV footage are all represented by longlines. The latter is in agreement with the results of fisher interviews that indicated that fishing activity in the canyon is rather scarce. In fact, the survey indicated that the fishing grounds exploited by the Monopoli, Mola di Bari, and Molfetta fisheries are located on the trawlable grounds of the continental shelf bordering the rim of the Bari Canyon. Longliners could, in principle, exploit the canyon, but the fleet able to reach the fishing grounds in the canyon (outside 14 nautical miles from the nearest port) is small, and the cost/earnings ratio is not favorable; therefore, only few longliners effectively fish in the canyon. The latter was confirmed also by AIS data that suggested that fishing trips in the Bari Canyon are occasional.

Although the anthropic impact in the Bari Canyon is still limited at present and is not causing as much damage as seen in other Mediterranean and Atlantic situations, actions for proper management and governance should be undertaken. The presence of vulnerable marine ecosystems, species with threatened to critically endangered status and/or that are endemic to the Mediterranean, and indications that the Bari Canyon represents an essential fish habitat and a sensitive habitat, call for a management plan and protection measures to preserve and restore the good environmental status of the canyon's ecosystems and services.

4.2. Governance and Protection

A number of requirements have been ascertained as key to identifying and improving management and protection actions for deep seas [17–19,84,102,103]. Ecological and biological traits of the species (distribution, reproduction, feeding, etc.), habitat mapping and modeling, the assessment (i.e., decline) of commercial stocks, and the presence of threatened/endangered/endemic organisms are used in protocols, as well as the criteria of uniqueness or rarity, vulnerability, biological productivity, and economical value, to address the identification of VMEs, EFHs, ecologically or biologically significant marine areas (EBSAs), sensitive habitats (SHs), and, finally, protected areas such as sites of community interest and marine protected areas [16,17,28,29,104–107]. Socio-economic information (i.e., fishing effort and impact) bearing on the target area is also of great importance and advances the understanding of the sensitivity of the ecosystem. All these requirements have been integrated in several directives, such as the European Union's Habitats Directive (92/43/EEC) and Marine Strategy Framework Directive (2008/56/EC), whose main goals are to preserve and maintain the good environmental status of the European marine (i.e., Mediterranean) habitats, using, among other tools, the implementation of the Natura 2000 network and establishing offshore nationally designated MPAs. These directives and protection measures need to also focus on deep-sea habitats, among which submarine canyons and CWC habitats are under major consideration. In fact, both submarine canyons and CWC habitats have been shown to have a fundamental role as sheltering, spawning, growing, and reproducing sites for fish and invertebrate species of commercial interest [13,30,108]. They contribute also to the spillover of large-size commercial species exploited in the surrounding fishing grounds, thus contributing to a "renewal network" of fishery resources [108]. Furthermore, canyons and CWC habitats may also serve as EFHs for exploited demersal species [9,109]. Taking into account the aforementioned reasons, submarine canyons and their habitats, including CWC habitats, need adequate protection and management.

Recommendations to enhance the protection of deep-sea ecosystems have been provided by international organizations, but their applications are still limited [31,103,105,106,110–116]. At present, few Mediterranean countries have enacted legislation aimed at preserving deep-water sites [31] and, in particular, canyons [13]. The best examples are the Gulf of Lion (France), were a network of three MPAs and a fisheries restricted area have existed since 2011 [90]), and the Seco de los Olivos Seamount (Spain), were a network of Natura 2000 sites was established in 2014 [117]. A long-term deep-sea protection plan exists for an Italian site, the Santa Maria di Leuca FRA, which was ratified in 2006 [118], but the monitoring, control, and surveillance plan is failing to preserve the area from fishing activities [20]. More recently, three FRAs have been ratified in Italian waters protecting EFHs (with the aim to preserve and manage, in particular, demersal stocks of *M. merluccius* and *P. longirostris*) in the Strait of Sicily (GFCM/42/2018/5). In the Adriatic Sea, the Pomo/Jabuka Pit FRA was established in 2018, aiming to protect demersal resources, among which *M. merluccius* and *N. norvegius* are the most important (GFCM/41/2017/3). The latter, however, regards shallow waters (<200 m). No more incisive protection plan exists thus far for the deep-water megabenthic and demersal habitats of the Italian margins.

The Bari Canyon is mostly located out of Italian territorial waters (12 nautical miles) at depths >200 m, and no management plan exists for the area thus far, excluding the Italian and European regulation for fishing activities (Council Regulation (EC) No. 1967/2006), despite evidence that the area includes several vulnerable megabenthic and demersal organisms [34–36].

The data presented here lend support to the vulnerability of the Bari Canyon and the need to implement protection measures. Considering the presence of VMEs (sponge grounds and CWCs) and their pristine status, to prevent the possibility that future fishing activities may significantly damage these fragile sessile fauna and given that the BC acts as an EFH (presence of mature/reproductive specimens of several demersal species of commercial interest), an area of regulation of fisheries and for the overall protection of its biodiversity should be contemplated. As a first step, the following suggestions should be considered:

(i) Fishing activities could be completely banned, at least for the most impactful gear such as trawls, or only allowed under strict regulations.
(ii) A no-take area could be useful for the protection of the densest CWCs and sponge grounds, as well as EFHs.
(iii) The institution of an offshore protection zone in the Bari Canyon through conservation and management measures will ensure sustainable management of its ecosystems. The establishment of no-take zones within it will protect CWC communities and assist in replenishing overfished stocks. Moreover, it will not strongly affect existing fishing activities in this area negatively, despite restrictions and limitations being defined, but will bring a positive effect to the surroundings and will enhance the goods and services (i.e., ecological and economical value) the canyon can provide. In fact, even if the economic value is difficult to estimate, taking into account other examples of protected areas [119], catches increase almost instantaneously after beginning the protection process [120,121].
(iv) The development of an offshore protection zone should balance short-term and long-term actions, as suggested by [9]. The long-term measures include the more sustainable use of the natural capital and sources for ecosystem services they provide (e.g., hydrodynamic processes of canyons enhancing nutrient supply to the deep-ocean ecosystem, carbon sequestration and storage, refuge sites for other marine life, rich source of genetic resources and chemical compounds, stock recovery, redistribution of commercial species in the nearby areas) by also increasing more sustainable fishing activity in surrounding areas.

5. Conclusions

The high biodiversity levels, the presence of several vulnerable organisms and ecosystems such as sponge grounds and cold-water corals, their abundance, their healthy appearance, their role as spawning and feeding grounds for many marketable fishery resources, and the importance that this area could have for the sustainment and renewal of resources in the Southern Adriatic and Ionian Sea, support the designation of the Bari Canyon as a protected site with area-based management measures.

Considering that human pressure (such as fishing activity) is expanding continuously in the deep seas, and that the vulnerable ecosystems of the Bari Canyon and the surrounding slope are by now under such a pressure, it is urgent to promote conservation actions for this key area of the Mediterranean Basin.

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