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Do cold water corals provide an essential habitat for *Helicolenus dactylopterus* (Delaroche, 1809) in the Northwest Africa?

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Abstract :

Cold water corals (CWC) provide habitats for many organisms including demersal fish. Bottom trawl observations have indicated a co-occurrence of the fish Helicolenus dactylopterus with CWC reefs, but a detailed understanding of this relation is lacking. To better understand the nature of this relation we have analyzed 85 video-lines from ROV dives conducted at 25-1700m depth off Morocco, Mauritania, and Senegal in 2020 and 2021. We annotated abundance, size, and behavior of the 552 specimens observed (32% juveniles and 68% adults), of these 82% occurred in CWC habitats at 400-600m depth. Both juveniles and adults were observed standing on the seafloor. Our observations are discussed considering available knowledge on feeding ecology and life cycle of H. dactylopterus. Our findings show that CWC provides an essential habitat for this species at least during parts of its lifecycle, however, more behavioral studies are needed for an in-depth understanding of this association.

Highlights

► Our study shows that both juveniles and adults of *H. dactylopterus* are present within CWC habitats in the region. ► TCWC habitats plays an important role by protecting *H. dactylopterus* females and juveniles against predation and currents. ► This study increases our understanding of CWC reefs as habitat for *H. dactylopterus* and the need for reef protection.

Keywords : Helicolenus dactylopterus, Cold water corals, Northwest Africa, Essential habitat, behavior

1. Introduction

The blackbelly rosefish *Helicolenus dactylopterus* (Delaroche, 1809) is a deep water fish belonging to the Scorpaenidae family which is widely distributed in the Atlantic (including the Mediterranean) and South Western Indian Ocean at depths between 50 and 1100 m (Froese, R. and D. Pauly. Editors, 2024). In the Atlantic Ocean, this species is composed of 4 populations: (1) Northeastern Atlantic and Mediterranean, (2) Gulf of Guinea, (3) South Africa, and (4) Northwestern Atlantic from Venezuela to Nova Scotia (Eschmeyer, 1969; Poss, 2016) This species is a characteristic and abundant component of the Northwest African slope fish community at depths between 250 and 600 meters and from 17°00’N to 21°20'N latitude (Hoffmann, 1982).

In Morocco, Mauritania and Senegal, *H. dactylopterus* is not a target species of commercial fishers but it constitutes an important part of the hake (*Merluccius polli* and *M. senegalensis*) bycatch in Mauritania and Senegal (Fall M et al., 2016; Cervantes et al., 2017). Fisheries statistics in Morocco show that from 2020 to 2022 bycatch of this species resulted around 131 tons per year comprising both the Atlantic and Mediterranean fishing zones (Office National des Pêches “ONP”, 2022). According to Fernandez-Peralta & González (2017) the blackbelly rosefish was the dominant species in biomass (15% of total catch) during four scientific surveys conducted in Mauritania between 2007 and 2010 and the second most abundant species after *Synagrops microlepis* in the trawl catches in the depth range 80–1860 m.

H. dactylopterus is characterized by 1) slow growth rates, 2) late maturity (Heessen, 1996; Massutí et al., 2000; White et al., 1998), and 3) long life expectations (30 years old) with numerous age classes in the population (Massutí et al., 2000). It takes approximately 12 years for this species to reach a length of about 30 cm (Heessen, 1996). The reproductive mode is a zygoparous form of oviparity, and the age at maturity ranges from 7 to 30 years (White et al. 1998). The female spawns multiple batches of embryos enclosed in a gelatinous matrix (Muñoz et al., 2010). Most probably, the slow life history traits characterizing *H. dactylopterus* renders this species highly vulnerable to overfishing.

The diet of this species is composed mainly of benthic crustaceans (Macpherson, 1985; Neves et al., 2012) and to a lesser degree of fish (Hoffmann, 1982). However, with increased size shrimps and fishes contribute more to its diet (Neves et al., 2012). In the Cape Blanc area (Mauritania), individuals of this species measuring 12–16 cm TL (the length from the tip of the snout to the tip of the tail) take relatively large prey, such as cuttlefish, Decapoda Anomura (*Munida*), and fishes, as well as small organisms like euphausiids, shrimps, and amphipods (Hoffmann, 1982). According to Macpherson (1985) *H. dactylopterus* is primarily a daytime predator feeding during a relatively short period, after which it remains inactive.

Several studies have shown the importance of cold-water corals (CWCs) as habitat for fish including commercial species (Buhl-Mortensen et al., 2010; Capezzuto et al., 2018; Costello et al., 2005; Henry & Roberts, 2017; Kutti et al., 2013; Milligan et al., 2016). The habitat heterogeneity and architectural complexity provided by deep-sea Scleractinia corals support a high diversity of other organisms including demersal fish (Buhl-Mortensen et al., 2010): however, the role of the CWC for fish remains unclear (Milligan et al., 2016). Several observations have indicated a co-occurrence between *H. dactylopterus* and cold-water corals based mainly on trawl and fishing with longline (Abecasis et al., 2006; Allain, 1999; Deval et al., 2018; Macpherson, 1985; Massutí et al., 2000; Mili et al., 2016; Muñoz et al., 2010; Neves et al., 2012; Pirrera et al., 2009; Sion et al., 2012; White et al., 1998), while direct observations of behaviour are sparse (Uiblein et al., 2003).

In 2020 and 2021, two seafloor habitat mapping surveys were conducted by the R/V *Dr. Fridtjof Nansen* off Morocco, Mauritania and Senegal using an ROV (Remotely Operated Vehicle) to document environment and fauna that included a total of 85 video transects covering a depth from 25 to 1700 m depth. Several cold-water coral reefs were targeted, and video records included many observations of *H. dactylopterus.* This material allowed for an in-depth study of how this species relates to the seafloor and the ecosystems present.

The main objective of our study is to answer the question: Do cold water corals (CWC) provide an essential habitat for *H. dactylopterus?* To test if there is a clear and positive relation between *H. dactylopterus* and the CWC habitats we have undertaken a detailed analysis of videos from the ROV dives that includes, abundance, size, and behavior of this species in a broad set of bottom habitats. As a background for the discussion of our findings we provide a review of the knowledge available regarding the distribution and ecology of *H. dactylopterus*.

2. Materials and Methods

With the main objective of mapping seafloor ecosystems in selected areas in the EEZs off Morocco, Mauritania and Senegal, two surveys were conducted in 2020 and 2021 with the R/V *Dr. Fridtjof Nansen* organized by the FAO/EAF-Nansen Programme. In the selected areas, visual documentation of the ecosystems was done using an ROV (Remotely Operated Vehicle) that is part of the Video Assisted Multi-Sampler (VAMS) developed by the Institute of Marine Research (IMR) and equipped with five hydraulic operated grabs with a sampling area of 0.1 m^2, each mounted below the ROV garage (Buhl-Mortensen et al., 2017). During dives the VAMS was tethered by the vessel at a speed of ~0.3 knots, and the ROV was remotely driven in front of VAMS. The ROV was equipped with two lasers mounded 5 cm apart providing a measuring scale. A total of 85 ROV dives were conducted during the two surveys along the coast of Northwest Africa from Morocco to Senegal (Fig. 1).

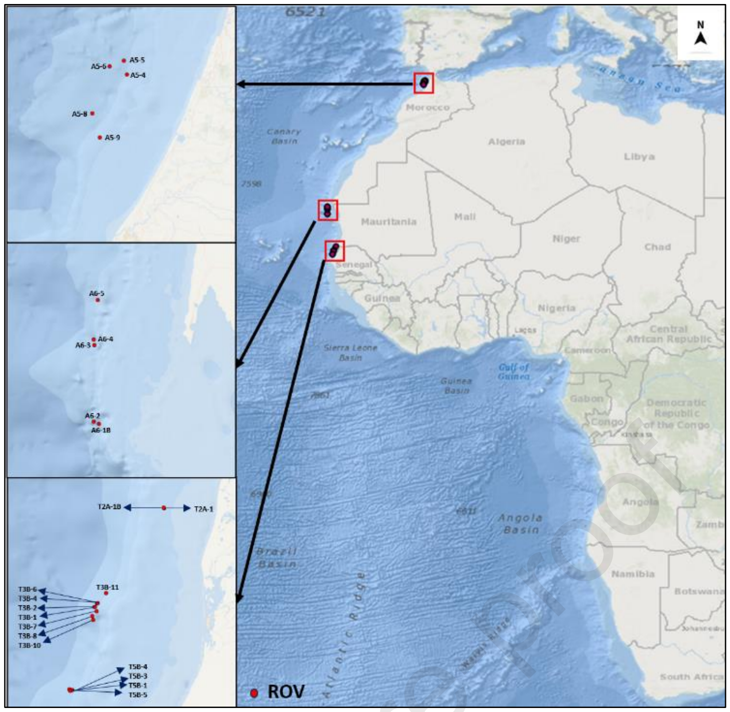

Fig. 1. The positions of the 24 ROV dives where *H. dactylopterus* was present. The ROV dives were conducted during two R/V *Dr. Fridtjof Nansen* surveys held in 2020 and 2021 (for details on ROV transects see Table 1).

Infield annotation of fauna, substratum type, trawl marks and litter were conducted using the CampodLogger program developed by IMR. Coral reefs were targeted on 24 of the ROV dives. The occurrence of coral skeleton (rubble and blocks) and live *Lophelia* colonies was together with bathymetry used to identify the presence of coral reefs. Video records including observations of *H. dactylopterus* were analyzed in detail using the software VideoNavigator developed by IMR. The output of this software provides information about date, time, geographical position, depths, species names, abundances, substrate type. Information on environment, depth, transect length and area covered by the transects is provided in Table 1. The surveyed area by each ROV transect was estimated by multiplying the transect length with the observation field of the ROV (1.5 m).

For the detailed statistical analysis of the association of *H. dactylopterus* to different bottom types and habitats a photo was grabbed from the videos for each observed specimen. In total 552 specimens were observed and habitat setting was documented based on 558 images. All together 58 images (10%) were excluded, 15 due to poor quality not allowing identification, and 43 images classified as undetermined Scorpaenidae. The photo analysis included the recording of habitat background (mud, sand, bedrock, boulder, and coral). The "coral" category was used when skeleton or live colonies were present. To study *H. dactylopterus* in detail within different coral reef habitats the co-occurrence with, coral rubble, coral block, live coral, was recorded together with three levels of rugosity; "low rugosity" exemplified by flat seafloor with mud and scattered coral rubble, "medium rugosity" somewhat uneven seafloor with a thick layer of rubble and some whole colonies present, and "high rugosity" high relief areas with many coral blocks consisting of coral skeleton or with live corals present (Fig. 2).

Cruise	ROV station	Latitude	Longitude	Depth (m)	Transect length (m)	Surveyed area (m^2)	Temp. (°C)	Oxygen ml L^{-1}
Survey no. 2020-401 29 January – 22 February 2020	A5-4	35°13'48"	- 6°35'58"	194-209	200	300	7.5-14.8	
	A5-5	35°18'50"	- 6°37'13"	357-381	400	600		
	A5-6	35°16'55"	- 6°42'26"	443-488	400	600		
	A5-8	35°0'5"	- 6°48'53"	575-660	400	600		4.01 - 4.09
	A5-9	34°51'20"	- 6°45'54"	169-245	400	600		4.67 - 4.71
	A6-1B	20°14'47"	- 17°40'12"	526-595	1200	1800	7.5-9.0	1.48 - 1.52
	A6-2	20°15'6"	- 17°42'20"	538-573	340	510		1.38 - 1.48
	A6-3	20°45'56"	- 17°42'8"	540-558	300	450		1.31 - 1.51
	A6-4	20°48'19"	- 17°42'17"	503-569	300	450		1.34 - 1.46
	A6-5	21°4'19"	- 17°40'42"	492-583	400	600		1.64 - 1.65
Survey no. 2021-401 22 October – 15 November 2021	T2BV1	16°31'12"	-16°41'14"	499-576	330	495	9 .1 – 10.1	1.3
	T2BV2	16°31'16"	-16°41'18"	501-564	430	645		1.3
	T3BV1	16°4'50"	-16°59'51"	530-566	220	330	7.0-11.6	
	T3BV2	16°4'45"	-16°59'56"	504-518	300	450		
	T3BV4	16°5'46"	-16°59'14"	520-603	260	390		
	T3BV6	16°5'52"	-16°59'8"	505-583	280	420		
	T3BV7	16°3'45"	-16°59'33"	582-644	530	795		
	T3BV8	16°2'13"	-17°0'35"	458-557	440	660		
	T3BV10	16°1'11"	-17°0'15"	431-557	530	795		
	T3BV11	16°8'20"	-16°57'6"	473-516	600	900		1.02-1.2
	T5BV1	15°42'32"	-17°6'39"	516-557	410	615	6.9-17.7	
	T5BV3	15°42'38"	-17°6'56"	495-596	510	765		
	T5BV4	15°42'15"	-17°5'53"	500-525	580	870		
	T5BV5	15°42'19"	-17°6'25"	477-480	450	675		

Table 1. Information on the 24 ROV dives where presence and behavior of *H. dactylopterus* was studied. For each dive, depth, transect length, surveyed area, measured temperature and oxygen at transect depth is listed. The observed area was estimated by multiplying the length of a video transect with 1.5 m that is the observation field recorded on video during the ROV dives.

To understand how *H. dactylopterus* relates to its habitat, behaviour was recorded as "hiding" (finding shelter by laying firmly on the bottom), "standing" (the body touching the bottom surface), or "swimming" not touching the bottom surface (Fig. 3). In addition, stage (juvenile or adult) was recorded based on a laser scale of 5 cm TL provided by the two laser spots mounted on the ROV (Fig. 4). Based on studies done on size at age distribution of *H. dactylopterus* (Table 2) we recorded individuals smaller than 20 cm TL as juveniles. For more information on size classes, we have divided the size of juveniles (<20 cm) into two categories, juveniles less than 10 cm TL and juveniles between 10 and 20 cm TL. The presence/absence of the black blotch on the dorsal fin was also recorded for each individual.

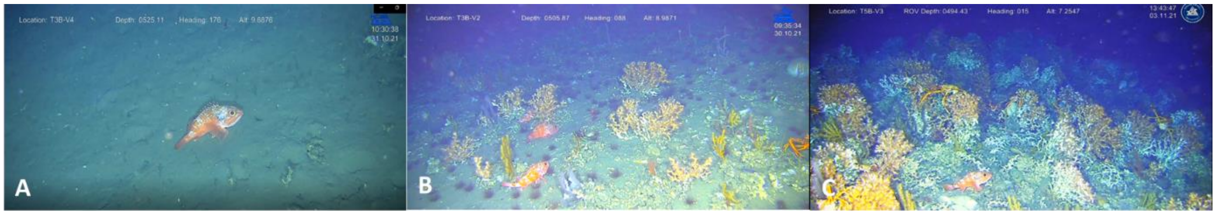

Fig. 2. Images illustrates how degree of rugosity is classified: A, low rugosity B, medium rugosity C, high rugosity.

Fig. 3. Representative images of different behavior: A, hiding B, standing C, swimming

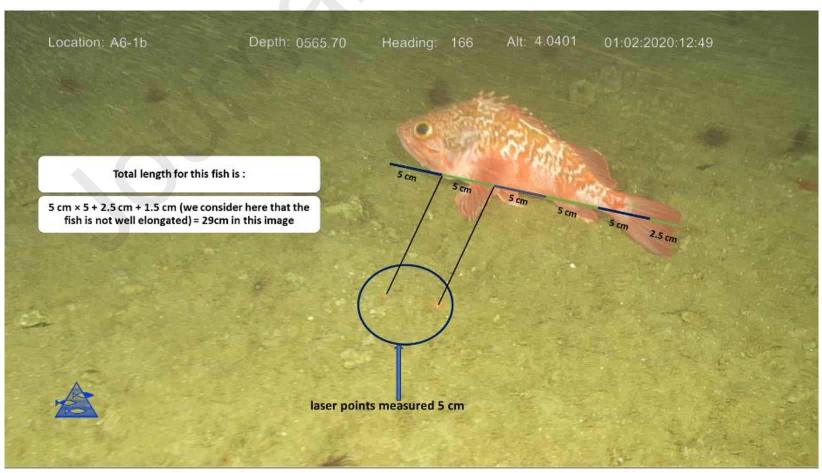

Fig. 4. Measuring size of a specimen of *H. dactylopterus* on image grabbed from a video. The distance between the two laser spots is 5 cm TL. This adult specimen is estimated to be 29 cm TL.

To assess the relationship between the occurrence of adults and juvenile specimens, and fish behavior (hiding, standing, swimming), and the different habitats (bottom type, coral habitats, and rugosity) a chi-square test was performed. The p-value of the tests carried out makes it possible to reject or accept the H_0 hypothesis of independence between variables.

Area	TL (cm)	Age (years)	Juveniles	Reference
Southern Tyrrhenian Sea (Central Mediterranean)	2-24	0-30	Recruits (age 0+) and juveniles (age up 4 years)	(Pirrera et al., 2009)
Western Mediterranean	2-36	0-30	2-18 cm	(Massutí et al., 2000)
Carolina, U.S.A.	16-41	7-30	No specimen in the age class 0-6 years were collected	(White et al., 1998)
Azores	3-49	0-32		(Abecasis et al., 2006)
Southern Tyrrhenian Sea (Central Mediterranean)	3-27	0-21	first age classes <12 cm	(Consoli et al., 2010)
Northern Tunisia (Central Mediterranean	8-30	0-9	1-4 years: 9-21 cm	(Mili et al., 2016)
Antalya Bay (Eastern Mediterranean)	4-36	0-27	0-4 years: <15 cm	(Deval et al., 2018)
Northeastern Atlantic Ocean	9-39	0-43	0-5 years: <17 cm	(Allain, 1999)

Table 2. Summary of the relation between the size, age, and stage for *H. dactylopterus* available in literature. Area of observation and reference to literature is provided.

3. Results

3.1 Depth distribution

A total of 552 individuals of *H. dactylopterus* were observed of which 176 specimens were juveniles (33%) and 376 adults (67%). Almost all observations (91.5%) were from the continental slope between 400-600m depth, and no individuals were found shallower than 190 m (Table 3). For juveniles, 96% of the observations were from 400 to 600 m and the corresponding number for adults was 89% (Fig.5) which agrees with the depth zone known for cold water coral reefs in this region (Buhl-Mortensen et al., 2023).

The number of individuals of *H. dactylopterus* observed per surveyed area (m^2) shows that the lower continental slope at 400-600m is the most inhabited depth zone both for juveniles and adults with an observed number of individuals per area of 40 individuals/1000m^2. This is followed by the upper slope depth zone 200-400m with 17 individuals /1000m^2 (Table 3).

3.2 Observed behavior

For the behavioral analysis, the relation of the observed *H. dactylopterus* to the seafloor was quantified using the categories: standing, hiding, and swimming (for definition see Fig. 3). The vast majority of the individuals were standing on their fins on the substratum (93% of the adults and 94% of the juveniles) and in most cases completely inactive (Fig. 6). Thirty-two individuals (6%) showed hiding behavior and only 4 individuals (1%) were swimming.

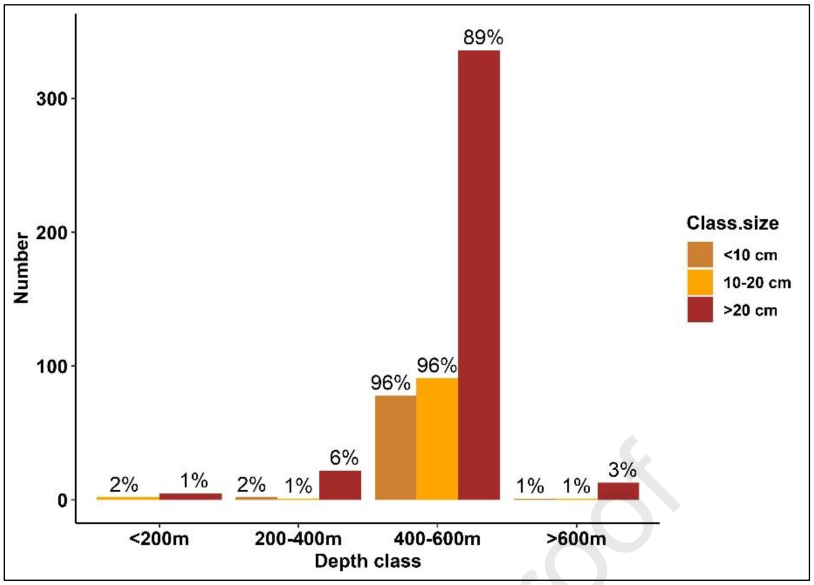

Fig. 5. Depth distribution of *H. dactylopterus* provided for two size groups (< 10 cm and 10-20 cm) of juveniles and adults (> 20 cm). The percentage of size class total is listed on top of the bar.

Depth zones (m)	No. Videos	Surveyed area (m^2)	No. Ind.	No ind./ 1000 m^2
<50	5	2655		
50-100	37	19792		
100-200	11	4785.5	7	1.5
200-400	3	1500	25	16.7
400-600	21	10803	505	46.8
>600	9	3993	15	3.8

Table 3. Observations of *H. dactylopterus* at different depth zones provided as total number and numbers per area. The number of videos transects, and area recorded are listed.

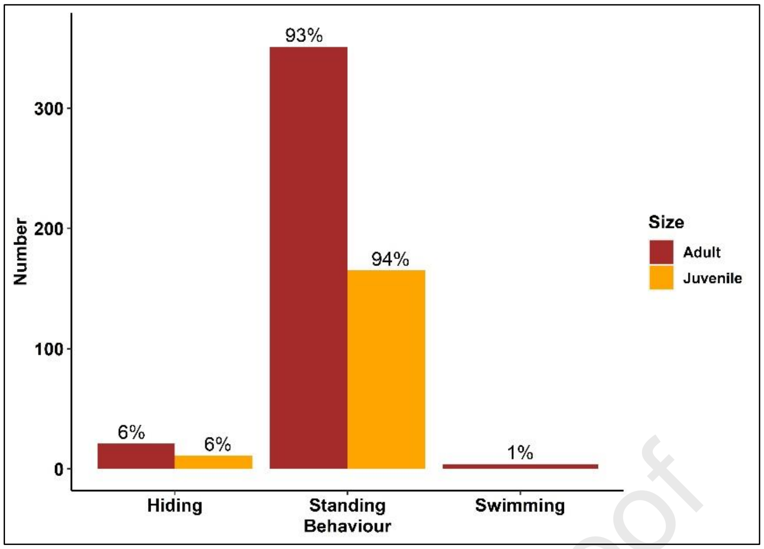

Fig. 6. Behavior of juvenile size groups (< 20 cm) and adults (>20 cm) of *H. dactylopterus* provided in the three categories, standing, hiding, and swimming (for definition see Fig. 3).

3.3 Association with coral habitats

The analysis of the environment surrounding the observed specimens showed the majority (82%) occurred in a coral reef habitat while 18% occurred without presence of coral, i.e., sandy mud, bedrock, and mud (Fig. 7). The analysis of the distribution between coral reef sub-habitat (coral ruble, coral blocks, live coral) revealed that most individuals were observed in relation to coral rubble (62%) followed by live coral (35%) and coral blocks (3%) (Fig. 8). Juveniles (< 20 cm TL) were most common in the coral rubble zone of reefs while adults had a more even distribution between the coral rubble and live coral zone.

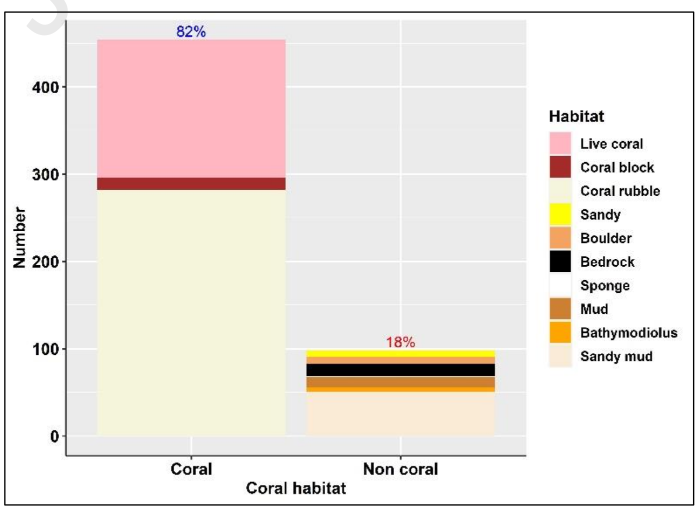

Fig. 7. Number of observed *H. dactylopterus* specimens in different seabed habitats divided into coral reef and non-coral environments, percentage of total observation is provided on top of the bares.

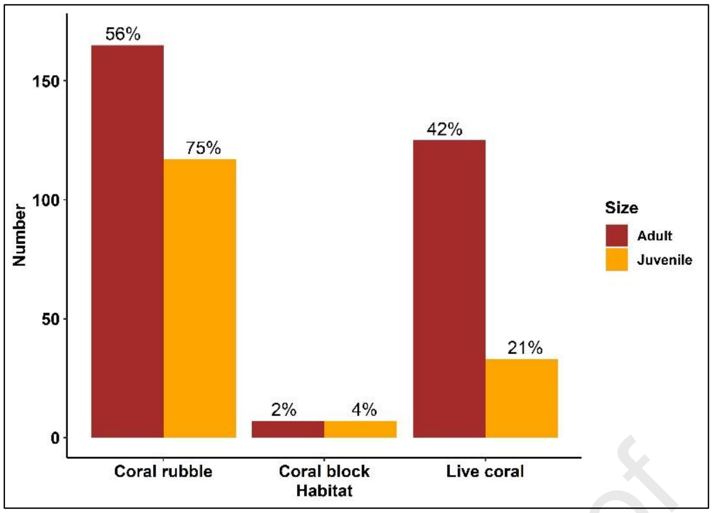

Fig. 8. Distribution of adult (> 20 cm) and juvenile (< 20 cm) specimens of *H. dactylopterus* in different coral reef sub-habitats.

3.4 Rugosity

Three types of rugosity (low rugosity, medium rugosity and high rugosity) were used to describe seafloor three dimensionality of the settings where *H. dactylopterus* was observed. Both juveniles and adults were more frequently observed in low rugosity settings, however, adults resulted more frequent at medium to high rugosity (in combination 39%) compared to juveniles (33%) (Fig. 9). Analyzes of *H. dactylopterus* videos and images showed specimens with different types of behaviors, sizes, and habitats, in figure 10 some representative images of its recorded behavior are provided.

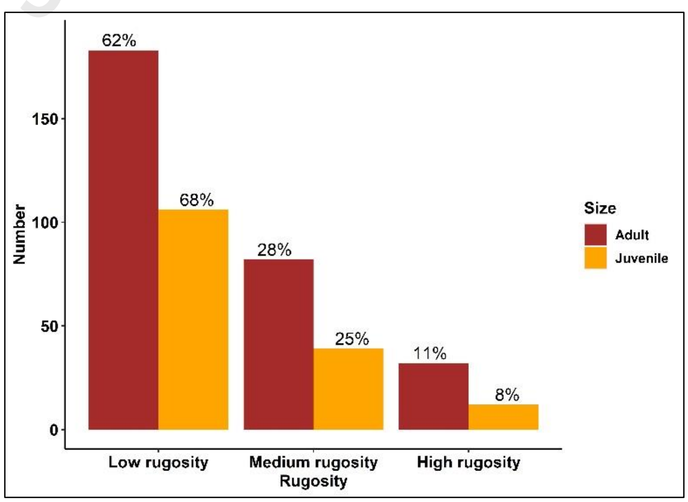

Fig. 9. Distribution of adult (> 20 cm) and juvenile (< 20 cm) specimens of *H. dactylopterus* in relation to rugosity levels. For definition of rugosity see Fig. 2.

3.5 Chi-square tests

The relation of fish and habitat: The results of the chi-square tests show that both adults and juveniles are associated with the presence of coral and mainly the coral habitats rubble and live coral (Table 4, see also Fig 7). There is no clear difference between adult and juvenile specimens in their relation to rugosity (p = 0.39, see also Fig. 8). Regarding behavior, there is no clear difference between adults and juveniles (p= 0.37, see also Fig. 6). In the different habitats the observed specimens are mainly standing on the seafloor and in a low to medium rugose environment (see also fig. 9).

Habitat	Adult	Juvenile	All	Adult expected	Juvenile expected	All expected	$\chi 2$	df	p-value
Coral	297	157	454	309.2	144.8	454.0	7.88	1	**<0.005**
Non coral	79	19	98	66.8	31.2	98.0			

Coral habitats	Adult	Juvenile	All	Adult expected	Juvenile expected	All Expected	$\chi 2$	df	p-value
Rubble	165	117	282	184.5	97.5	282.0	20.52	2	**<0.0001**
Live	125	33	158	103.4	54.6	158.0			
Block	7	7	14	9.2	4.8	14.0			

Rugosity	Adult	Juvenile	All	Adult expected	Juvenile expected	All Expected	$\chi 2$	df	p-value
Low	183	106	289	189.1	99.9	289.0	1.9	2	0.39
Medium	82	39	121	79.2	41.8	121.0			
High	32	12	44	28.8	15.2	44.0			

Behavior	Adult	Juvenile	All	Adult expected	Juvenile expected	All Expected	$\chi 2$	df	p-value
Standing	351	165	516	351.5	164.5	516.0	1.97	2	0.37
Hiding	21	11	32	21.8	10.2	32.0			
Swimming	4	0	4	2.7	1.3	4.0			

Habitat/Behavior	Hiding	Standing	Swimming	All	Hiding expected	Standing expected	Swimming expected	All Expected	$\chi 2$	df	p-value
Coral	23	431	0	454.0	26.3	424.4	3.3	454.0	21.47	2	**<0.0001**
No coral	9	85	4	98.0	5.7	91.6	0.7	98.0			

Rugosity/Behavior	Hiding	Standing	All	Hiding.expected	Standing. expected	AllExpected	$\chi 2$	df	p-value
High	1	43	44	2.2	41.8	44.0	11.11	2	**<0.005**
Low	9	280	289	14.6	274.4	289.0			
Medium	13	108	121	6.1	114.9	121.0			

Table 4. Results of chi-square test of the relationship between the occurrence of adults and juvenile specimen, and fish behavior (hiding, standing, swimming), and the different habitats (bottom type, coral habitats, and rugosity). Group size, expected value, $\chi 2$, df and p are listed. p values in bold indicates a significant relation.

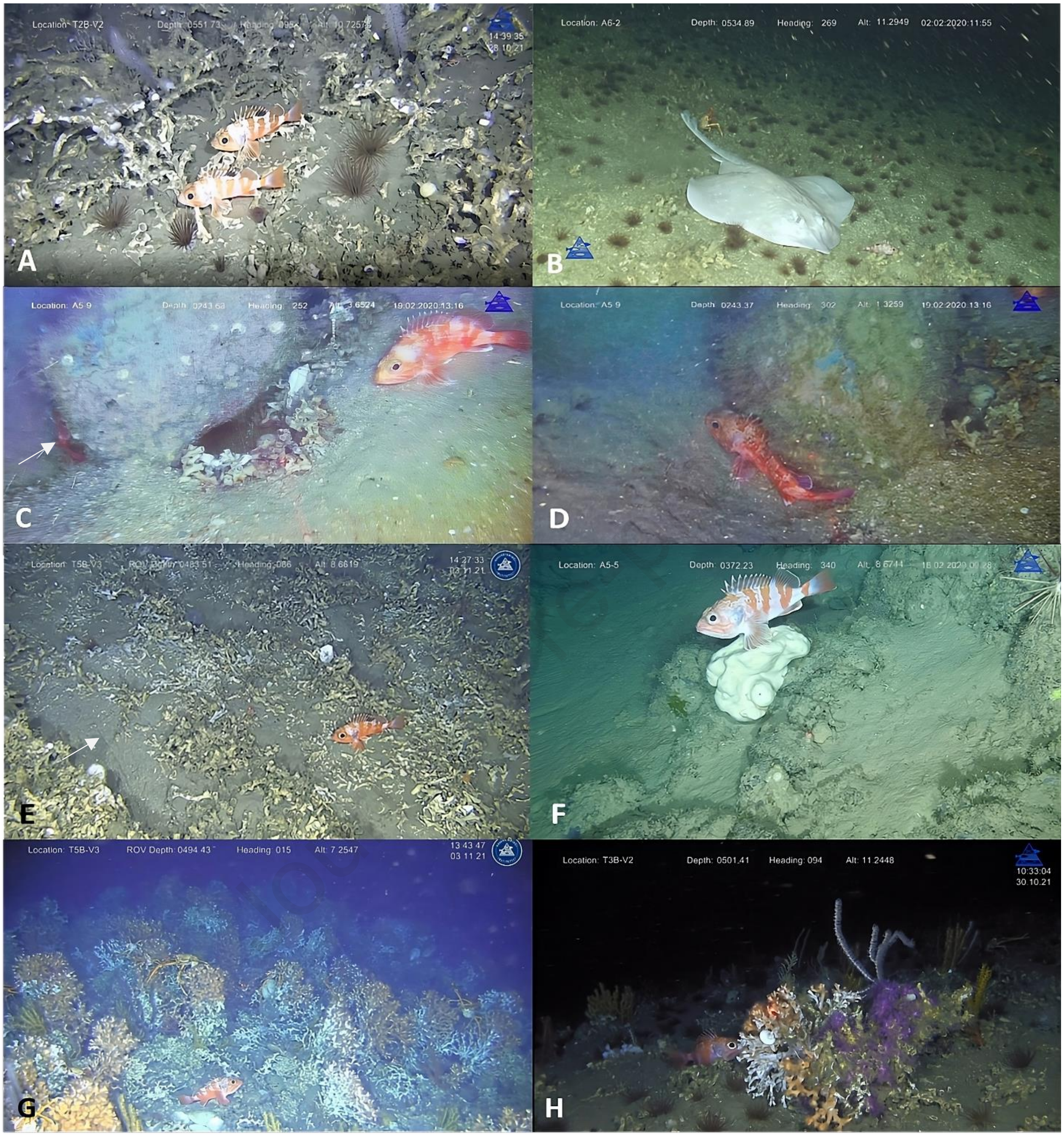

Fig. 10. Different images of *H. dactylopterus* in its habitat showing: A, juveniles (2 individuals, estimated size 12 cm TL) surrounded by a thick layer of coral rubble, anemones (Cerianthidae) and black corals (*Tanacetipathes* sp.); B, juvenile (estimated size 8 cm LT) with an adult male of white dappled skate *Leucoraja leucosticta* and numerous Cerianthids; C, male individual seeming to watching a nest and a female hiding behind the rock is indicated by the white arrow; D, the female behind the rock (also in C) looking very thin, presumably having spawned; E, juvenile individual surrounded by coral rubble near to a trawl mark (indicated with white arrow); F, adult individual standing on a *Geodia* sp. sponge; G, adult surrounded by live *Lophelia* colonies and the squat lobster *Eumunida bella;* H, coral block with live corals *Lophelia pertusa, Clavularia borealis, Acanthogorgia* sp, and the sea fan *Thesea talismani*.

4. Discussion

4.1 Methodology

This study was based on observations from visual seafloor mapping using an ROV and there are some inherent methodological problems related to this type of data. Because high resolution video recording cannot be achieved without strong lights this can affect the behavior of the target species. This is always a problem when studying organisms with eyes in the deep-sea, however, we found that *H. dactylopterus* showed almost no response to the ROV except for very small movements and in general stood still on the seafloor. This calm behavior related to ROV inspection has formerly been described by Uiblein et al. (2003), and we have no reason to believe that our results have been affected by a light aversive or concentrating behavior of *H. dactylopterus.*

Species identification was based on images and to secure a reliable identification a few photos with low quality were discarded. Furthermore, it was easy to discriminate between *H. dactylopterus* and the species that it could be confused with*, Trachyscorpia cristulata* and other Scorpaenidea. Size measuring was conducted based on two laser spots (5 cm apart), on the few images where they were not present other objects were used as an indication of scale. Because measurements could not be done with high precision (resolution +- 2 cm) we discriminate between three size groups <10 cm, 10-20 cm and < 20 cm. The length of 20 cm was used to discriminate between juvenile and adult specimens, but, without physical samples life stage of specimens could not be verified morphologically. It has been suggested that the presence and absence of a black blotch on the dorsal fin is characteristic for juveniles. To test this, we have compared the presence of the black blotch within the three size groups (Fig. 11). Results showed that the black blotch was present on 78% of the juveniles and on 4% of the adults, showing that it could be a useful indicator of life stage.

Our estimation of individuals per area seafloor were based on an average observation field obtained during the ROV dives, that changes with angle and distance to the seafloor, and 1.5 m was used as an average. This can affect the density estimates that should be viewed as minimum densities of *H. dactylopterus* (ind. per m^2) for the different depths.

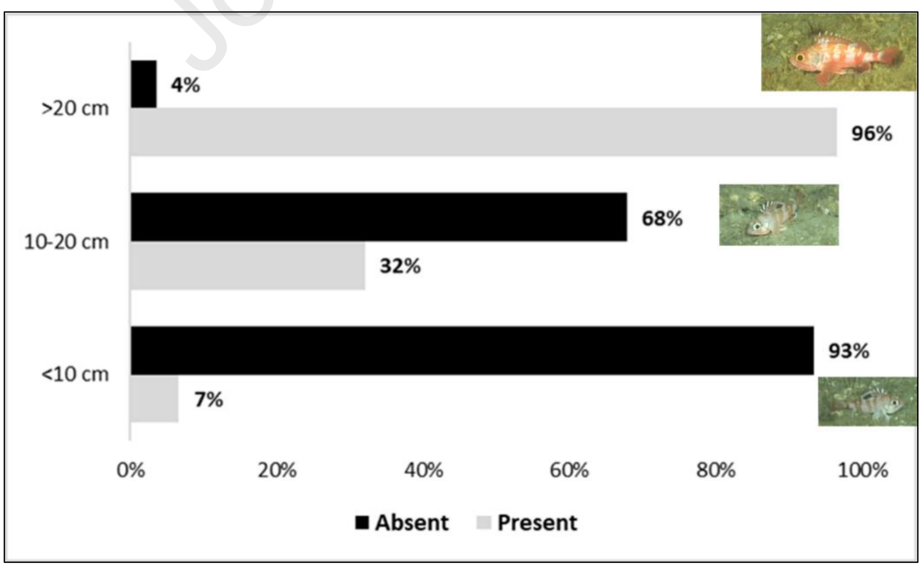

Fig. 11. The relation between body size and the presence/absence of the black blotch on the dorsal fin of *H. dactylopterus* specimens.

4.2 Depth distribution

We found that adults and juveniles of *H. dactylopterus* occur together at depths from 190 to 630 m (Fig. 5). Along the continental shelf and slope off the Iberian Mediterranean coast, Massutí et al. (2000) found the smaller size individuals concentrated at the shallowest depths and larger individuals appeared below certain depths and had a preference for rocky bottoms. In the Central Mediterranean Pirrera et al. (2009) reported juveniles from 150–300 m depth, whereas the adult specimens occurred from 200 m down to 1000 m. Our observations shows that off Morocco, Mauritania and Senegal juveniles occur at larger depths on the continental slope (400-600 m) together with adults.

4.3 Relation to coral reefs

Sion et al. (2012) compared the abundance and length distribution of *H. dactylopterus* between coral and non-coral habitats using longline inside the Santa Maria di Leuca coral province. They found that the length-frequency distribution was wider in the coral habitats. *H. dactylopterus* has been recorded as a characteristic species in sponges and Scleractinian habitats and its behavior and morphology appear to be adapted to a stay close to the seafloor (Alves, 2003).
We have demonstrated a clear association of *H. dactylopterus* with coral habitats that involves both juveniles and adult specimens (see table 4 and Fig 6). What makes this deep-sea coral habitat essential to *H. dactylopterus*? To try to answer this question we will look closely into the feeding ecology of this species and its unusual reproduction strategy. We hypothesize that the coral habitats both houses many of the organisms that constitute an important part of the diet of this species and in addition offers shelter for embryos and juveniles against predation.

<u>Relation to rugosity level</u>
The analyses of the level of rugosity including three categories (low rugosity, medium rugosity and high rugosity) to describe seafloor three dimensionality of the settings where *H. dactylopterus* was observed. The chi-square test (Table 4) showed that most juveniles and adults were sitting on a seafloor with low to medium rugosity and there was no life stage related difference. Because the well camouflaged small juveniles are relatively harder to observe in the a high rugosity environment the abundance values for juveniles are likely too low.

<u>Food and feeding</u>
H. dactylopterus has been characterize as a typical sit-and-wait predator that may attack its prey at rather short distances and close to the bottom (Uiblein et al. 2003). According to Macpherson (1985) *H. dactylopterus* is primary a daytime predator feeding during a relatively short period, after which it remains inactive. Its prey consists mainly of benthic crustaceans and fishes (Macpherson, 1985; Neves et al., 2012). Smaller fishes had a generalized diet, feeding mainly on mysidacea changing their diet to mainly natantia when getting larger than 20 cm. With increased size, shrimps and fishes contribute more to its diet (Neves et al., 2012). In the Cape Blanc area (Mauritania) individuals of 12-16 cm in length take large preys such as cuttlefish, *Munida* (Decapoda, Anomura), and fishes (Hoffmann, 1982). Larger individuals, >28 cm have a diet with pisces as dominant prey group (Neves et al. 2010). It is well known that cold water corals house a rich crustacean fauna because this habitat offers shelter and feeding place for crustacea (Buhl-Mortensen 2010). The increased presence of food offered in reef habitats could benefit both juvenile and mature *H. dactylopterus.*

Reproduction

Helicolenus dactylopterus is a zygoparous species that spawns multiple batches of embryos enclosed within a gelatinous matrix (Munoz et al. 2010). The females are internally inseminated between July and November and the females can retain the sperm inside the ovaries for a period that may reach 6 to 7 months (Mendonça et al. 2006). Spawning time has been suggested to take place in winter (Mendonça et al. 2006; Munoz et al., 2010) and the sex-ratio in catches that normally are close to equity are in winter dominated by males (Mendonça et al. 2006). White et al. (1998) reported that the overall population sex ratio male:female is 1:0.6 for most length intervals and that males are more abundant at lengths >25 cm. This is in line also with the observations by Mendonça et al. (2006) reporting that before the onset of first maturity more females are caught while after this point the sex proportion in the catches is inversed. We speculate that the complicated reproduction pattern of *H. dactylopterus,* involving repetitive spawning of batches of embryos enclosed in a gelatinous matrix, the female will need to stay close to the seafloor to protect herself and embryos against predation and currents. This hypothesis is supported by the increased catchability of males versus females during wintertime (the presumed spawning season) indicating that spawning females are less active and stay close to the seafloor. Our observations of what appears to be a nest (Fig. 10 C and D) shows a male in front of a rock with the burrow and fence made from coral skeleton and shells, behind the rock lies a female looking very thin (perhaps due to recent spawning). Where females chose to deposit the batches of juveniles are not known, but the complex reef environment could provide a safe site to avoid transport by currents. Later, when the juveniles are released, the reef offers many good hiding places and plenty of food. We hypothesize that the juveniles start their life in the deep coral reef habitat that offers protection from currents and predators and a rich food source of near bottom crustaceans and that they move into other habitats at a later stage in live. To know why *H. dactylopterus* is abundant in cold coral reef habitats more detailed studies will be needed in the future. We did see clear signs of trawling on some of the transects (Fig. 10 E) and damage to reef is clearly affecting an essential habitat for this species.

5. Conclusion

It's evident that cold water corals (CWC) play a crucial role in providing habitat and supporting a high diversity of marine organism, including deep sea demersal fishes. Numerous observations, based mainly on data from bottom trawl and longline fishing gears in different areas, have suggested a correlation between *H. dactylopterus* and CWC. Nonetheless, there are no studies that have investigated this correlation in detail and the role of CWC for this fish remains unclear. For the first time, a detailed analysis covering an extensive depth range (25-1700 m) through ROV dives (n. 85), was used to test the potential relation between *H. dactylopterus* and what makes this deep-sea coral habitat essential to this species.

Our study conclusively shows that both juveniles (less than 20 cm TL) and adults of *H. dactylopterus* are consistently present within CWC habitats in this region, particularly at depths ranging from 400 to 600 meters highlighting the significant role of cold-water corals, especially the scleractinian coral *Lophelia pertusa*, for this species.

In addition, our study confirms that available literature indicating small crustaceans as preferred prey of *H. dactylopterus*, is abundantly associated with these deep-sea Scleractinia corals and that possibly juveniles and adults of this species benefit from the increased presence of food offered by the CWC habitats.

At the same time, given the architectural complexity provided by the CWC habitats and considering the reproductive requirements of *H. dactylopterus* females, which need to stay close to the seafloor to secure their embryos, the CWC habitats apparently plays an important role for this species by protecting all life history stages against predation and currents.

In conclusion, the findings of this study contribute to our understanding of the correlation between *H. dactylopterus* and cold-water corals in Northwest Africa and highlight the importance of conserving and protecting CWC reefs as vital habitats for marine species such as *H. dactylopterus*, especially in the face of ongoing environmental challenges (e.g. oil and gas activities, deep sea fishing etc.). Nevertheless, while this study provides valuable insights into the habitat preferences of this species, it also emphasizes the need for more behavioral studies to fully elucidate its association with CWC reefs.

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Table 4. Results of chi-square test of the relationship between the occurrence of adults and juvenile specimen, and fish behavior (hiding, standing, swimming), and the different habitats (bottom type, coral habitats, and rugosity). Group size, expected value, $\chi2$, df and p are listed. p values in bold indicates a significant relation.

Habitat	Adult	Juvenile	All	Adult expected	Juvenile expected	All expected		$\chi2$	df	p-value
Coral	297	157	454	309.2	144.8	454.0		7.88	1	**<0.005**
Non coral	79	19	98	66.8	31.2	98.0				
Coral habitats	Adult	Juvenile	All	Adult expected	Juvenile expected	All Expected		$\chi2$	df	p-value
Rubble	165	117	282	184.5	97.5	282.0		20.52	2	**<0.0001**
Live	125	33	158	103.4	54.6	158.0				
Block	7	7	14	9.2	4.8	14.0				
Rugosity	Adult	Juvenile	All	Adult expected	Juvenile expected	All Expected		$\chi2$	df	p-value
Low	183	106	289	189.1	99.9	289.0		1.9	2	0.39
Medium	82	39	121	79.2	41.8	121.0				
High	32	12	44	28.8	15.2	44.0				
Behavior	Adult	Juvenile	All	Adult expected	Juvenile expected	All Expected		$\chi2$	df	p-value
Standing	351	165	516	351.5	164.5	516.0		1.97	2	0.37
Hiding	21	11	32	21.8	10.2	32.0				
Swimming	4	0	4	2.7	1.3	4.0				
Habitat/Behavior	Hiding	Standing	Swimming	All	Hiding expected	Standing expected	Swimming expected	All Expected	$\chi2$	df	p-value
Coral	23	431	0	454.0	26.3	424.4	3.3	454.0	21.47	2	**<0.0001**
No coral	9	85	4	98.0	5.7	91.6	0.7	98.0			
Rugosity/Behavior	Hiding	Standing	All	Hiding.expected	Standing. expected	AllExpected		$\chi2$	df	p-value

High	1	43	44	2.2	41.8	44.0	11.11	2	**<0.005**
Low	9	280	289	14.6	274.4	289.0			
Medium	13	108	121	6.1	114.9	121.0			

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Highlights

Our study shows that both juveniles and adults of *H. dactylopterus* are present within CWC habitats in the region.

The architectural complexity provided by the CWC habitats considering the reproductive requirements of *H. dactylopterus* females plays an important role by protecting all life history stages against predation and currents.

This study contributes to our understanding of the correlation between *H. dactylopterus* and cold-water corals in Northwest Africa and highlight the importance of conserving and protecting CWC reefs.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: