

1 **An association between a cusk eel (*Bassozetus* sp.) and a black coral (*Schizopathes* sp.) in the deep western**  
2 **Indian Ocean**

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8 **Abstract**

9 Detailed observations in the deep sea can reveal previously unknown behaviour, species interactions and fine-  
10 scale habitat heterogeneity. Here, the first *in situ* images of the black coral *Schizopathes* sp. (Anthozoa:  
11 Antipatharia) in the deep western Indian Ocean have been obtained from remotely operated vehicle video  
12 footage and time-lapse photography. In these images there appears to be an association with the cusk eel  
13 *Bassozetus* (Family: Ophidiidae). In the primary observation, chance encounters revealed the fish interacted  
14 with the antipatharian on multiple occasions over several days. Subsequent time-lapse camera footage  
15 showed the fish remained underneath the antipatharian almost exclusively for the duration of a 30 hour  
16 deployment. Excursions from the cover of the antipatharian were for less than two minutes. The primary  
17 observation is supported by two similar encounters in the same region. Observed reduction in the tail-beat  
18 frequency of the fish under the antipatharian suggests reduced energy requirements for the ophidiid in this  
19 position. The observations demonstrate the role that even individual coral colonies play as a source of three  
20 dimensional structure, providing habitat heterogeneity in the deep sea.

21 **Key words**

22 Antipatharia; SERPENT Project; Energy conservation; Ophidiidae; Tail-beat frequency; Time-lapse photography

23

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## 31 **Introduction**

32 Little is known about the ecology of most deep-sea species and intraspecific interactions are particularly poorly  
33 studied because of a lack of detailed observations in such remote areas. Such data are required in order to  
34 improve understanding of deep-sea ecosystems. In this paper we report *in situ* observations from Remotely  
35 Operated Vehicle (ROV) video footage and time-lapse photography of an association between a black coral  
36 (Antipatharia) and a cusk eel (Ophidiidae) in deep water in the western Indian Ocean off Tanzania.

37 Many fish species have an innate propensity to seek contact with physical structures, demonstrated by the  
38 effectiveness of open-ocean fish aggregating devices (FADS) (Relini et al. 2000). There are a number of  
39 hypotheses as to why this may occur, and the species involved and local habitat conditions likely influence this  
40 behaviour. In deep water, complex structures such as reef-forming corals create habitat heterogeneity that  
41 supports many invertebrate species (Buhl-Mortensen and Mortensen 2004) and fishes (Du Preez and  
42 Tunnicliffe 2011). At a fine scale, associations such as juvenile ophidiids using echinothuriid urchins, are  
43 thought to protect from predators and provide shelter from currents (Moore and Auster 2009). The use of  
44 three-dimensional structure as an energetic refuge in a food-poor ecosystem, such as the deep sea, is probably  
45 advantageous. Furthermore, the complex biogenic structures may enhance feeding opportunities for  
46 associated species as the arborescent three-dimensional structure disrupts laminar bottom currents inducing  
47 local turbulence (Buhl-Mortensen et al. 2010) while corals themselves increase flow over their polyps through  
48 action of cilia (Shapiro et al. 2014).

49 Antipatharians (Hexacorallia) are commonly known as black corals because their proteinaceous axis is black or  
50 dark in colour. They are generally found at depths greater than 50 m (Cairns 2007) and are long-lived and slow  
51 growing. Antipatharians often provide habitat for other organisms such as crustaceans and polychaetes

52 (Wagner et al. 2012; Wicksten et al. 2014; Wicksten and Heathman 2015), and fishes at a range of water  
53 depths. Gobioid fish have been reported inhabiting *Cirripathes* sp. in shallow water in the tropical Pacific (Davis  
54 and Cohen 1968), and aggregations of antipatharians such as *Antipathella subpinnata* (150-230m) (Deidun et  
55 al. 2014) and *Leiopathes glaberrima* (250-400 m) form “coral gardens” that provide habitat to a variety fish  
56 species (de Matos et al. 2014). *Schizopathes* Brook, 1989 is a poorly studied genus of antipatharian with three  
57 known species, one of which, *S. amplispina* Opresko, 1997, was described from the western Indian Ocean  
58 (Opresko 1997).

59 Cusk eels (Ophidiidae) are found from the upper shelf to hadal depths. They reportedly feed on invertebrates  
60 and fishes (Nielsen and Merrett 2000) but much of their behaviour is unknown. There are thirteen described  
61 species of *Bassozetus* Gill, 1883 (members of this genus are commonly known as assfish). Six species are  
62 recorded from the western Indian Ocean off Kenya, Madagascar and Mozambique (*Bassozetus galathea*, *B.*  
63 *glutinosus*, *B. compressus*, *B. elongatus*, *B. levistomatus* and *B. robustus*). These were mostly collected during  
64 the voyages of the *Mabahiss* (1932-34), *Galathea II* (1952), *Vityaz* (1959-64) and *Anton Bruun* (1964) (Menzies  
65 et al. 1973). Since those pioneering expeditions there have been limited studies of the deep sea in the western  
66 Indian Ocean, particularly using modern techniques such as ROV survey. Through accessing industry ROVs in a  
67 collaborative project ([www.serpentproject.com](http://www.serpentproject.com)) at oil drilling locations off Tanzania we report novel  
68 observations of the ophidiid *Bassozetus* sp. apparently associated with an antipatharian at 1380-1780 m depth  
69 in the western Indian Ocean.

## 70 **Methods:**

71 The observations presented here were made in 2013 as part of the SERPENT Project (Jones 2009). Data were  
72 collected using a Deep Ocean HD video camera mounted on an Oceaneering International Millennium ROV  
73 deployed from the drill ship *Deepsea Metro 1* at three locations (Table 1). Mzia-2 and Mzia-3 were separated  
74 by 9 km and Pweza-3 was a further 160 km north of Mzia-3. The sites were dominated by soft sediment but  
75 Pweza-3 also had some areas of hard substratum. The names Mzia-2, Mzia-3 and Pweza-3 refer to the names  
76 of the drilling locations (Kiswahili names for marine organisms, barracuda and octopus).

## 77 **Primary Observation**

78 The primary observation of an ophidiiform sheltering under an antipatharian was first made at Mzia-3 on the  
79 4<sup>th</sup> November 2013 ([Supplementary Material: Video 2](#)). The same individual antipatharian with an associated  
80 fish was noted again on the 6<sup>th</sup> November 2013 ([Supplementary Material: Video 3](#)). After these two  
81 observations, a time-lapse camera was positioned 1 m north of the coral for 30 hours (9-10 November 2013).  
82 The time-lapse camera (Insight Pacific Scorpio Plus digital still camera and strobe light) was mounted on a  
83 bespoke frame designed for deployment with industrial ROVs through the SERPENT Project. The camera was  
84 located 100 m from source of drilling disturbance, outside of the obviously disturbed seabed (no drill cuttings  
85 visible) and beyond the expected extent of drilling disturbance (Gates and Jones 2012). Images were taken  
86 every 60 seconds (1829 frames in total). A time-lapse movie was created using the still images in Adobe  
87 Premier Pro to display the data collected ([Supplementary Material: Video 1](#)).

88 Each original frame from the time-lapse camera deployment, prior to cropping for Figure 1 and Supplementary  
89 Material Video 1, was examined and the presence of the fish, its alignment under the antipatharian, notable  
90 behaviour and presence of potential prey items were recorded. The area of seabed imaged and the length of  
91 the ophidiid and antipatharian individuals were estimated using the acceptance angles of the camera and  
92 height of the camera above the seabed, using a three dimensional rotational matrix (Morris et al. 2014), where  
93 pitch was set as the angle of the camera from the vertical and roll and heading were set at zero to obtain the  
94 co-ordinates of the image corners and thus allow area and scale to be determined. Using these methods the  
95 area of seabed imaged was estimated as 8.48 m<sup>2</sup>. Much of this area was distant and unrealistic to analyse.

#### 96 **Supporting observations**

97 The primary observation is supported by two similar examples acquired during previous field visits at the Mzia-  
98 2 and Pweza-3 locations. Both supporting observations were made with the HD camera on the ROV but no  
99 time-lapse deployments were carried out. As part of the wider project 12 km of video footage was collected  
100 over seven sites (1300-2600 m depth) but no further *Schizopathes* sp. specimens were encountered.

#### 101 **Estimating activity of the fish**

102 Tail beat frequency (TBF) was estimated from the HD video observations as an indication of fish activity (this  
103 was not possible from the time lapse footage because frames were not continuous). One tail beat was  
104 recorded as one complete oscillation of the tail (Ohlberger et al. 2007). This was carried out for the primary

105 observation and Supporting Observation 2 because the fish appeared to be of comparable size. Tail beat  
106 frequency was not estimated for Supporting Observation 1 because the size of the fishes was not comparable.  
107 As the video clips were short the tail oscillations were counted for discrete sections of footage. No statistics  
108 were carried out on these data because of their limited scope.

109 **Results:**

110 It was not possible to collect the antipatharian specimens, but the distinct triangular shape indicates that the  
111 three observations were *Schizopathes* sp., of which there are three described species in the genus. Based on  
112 external appearance, the observations appear to be *S. amplispina* but identification to species is only possible  
113 by examining a collected specimen (D Opresko personal communication). In the images the *Schizopathes*  
114 specimens were positioned with the holdfast up-current and with the apex and distal end of the pinnules in  
115 contact with the sediment.

116 **Primary observation (Mzia-3):**

117 The main observation of the association between *Bassozetus* sp. and *Schizopathes* sp., (termed primary  
118 observation) was observed on two separate occasions by ROV at the Mzia-3 site before the decision to deploy  
119 the time-lapse camera to record it in more detail. The *Schizopathes* sp. specimen is estimated to be 480 mm in  
120 length from the visible holdfast to the apex. The widest point (lower pinnules) was estimated at 630 mm.  
121 There was a circular impression on the sediment, with a small mound where the holdfast attaches, created as  
122 the pinnules sweep over the seabed as the colony moves in the current. The *Bassozetus* specimen observed  
123 under this antipatharian was approximately 400 mm in length. The first observation of this association (4<sup>th</sup>  
124 November 2013) showed *Schizopathes* sp. with *Bassozetus* sp. underneath (Supplementary material: Video 2).  
125 The video footage indicates gentle undulation of the *Bassozetus* specimen's body with tail beat frequency  
126 estimated at 25.38 min<sup>-1</sup> (Table 2). When the same specimens were encountered on 6<sup>th</sup> November 2013 the  
127 fish was again under the antipatharian (Supplementary Material: Video 3), with an initial tail beat frequency of  
128 28.13 min<sup>-1</sup>. A second estimate of the tail beat frequency, also under the antipatharian, on 6<sup>th</sup> November was  
129 considerably higher (40.00 min<sup>-1</sup>). There appears to be an effect of the ROV on the fish in this instance  
130 resulting in the higher tail beat frequency. As the ROV departed the fish left the cover of the coral swimming  
131 away rapidly (TBF: 57.27 min<sup>-1</sup>). The fish was not observed to return to the antipatharian at this time.

132 On return to the primary observation location on 9<sup>th</sup> November 2013 a *Bassozetus* sp. specimen was observed  
133 under the antipatharian again. The time-lapse camera was deployed to monitor the fish behaviour at this time.  
134 On this occasion the fish was not visibly disturbed by the presence of the ROV or time-lapse camera. During  
135 the course of the deployment the antipatharian turned approximately 180° in the current, sweeping a circular  
136 pattern over the seabed. The effects of the current were visible in the images as movement of items over the  
137 sediment and the streaming of what appears to be a worm tube. The current was sufficiently strong to move  
138 an item of terrestrial or shallow water plant material into the field of view, which then settled in a depression  
139 in the sediment. In 96% of the time-lapse frames the fish was under the antipatharian with its head orientated  
140 toward the holdfast and tail at the colony apex, demonstrating positive rheotaxis. In 3.7% of the frames  
141 *Bassozetus* was aligned in the opposite direction or perpendicular to the coral holdfast, on one occasion with  
142 its mouth open. On two occasions the fish left the shelter of the antipatharian, but returned in the subsequent  
143 image. Potential prey items (suprabenthic crustaceans) were present in 26 images. Occasionally other fishes  
144 such as halosaurs and ophidiiforms were observed in the time-lapse images including small individuals that  
145 could potentially be a food source for the *Bassozetus* specimen.

#### 146 **Supporting Observation 1 (Mzia-2):**

147 At Mzia-2 (1622 m depth) another *Schizopathes* antipatharian was observed. (Figure 2a, [Supplementary](#)  
148 [Material: Video 4](#)). The 62 s clip shows a smaller antipatharian with a small unidentified fish (probably a  
149 juvenile ophidiid) in similar orientation to the primary observation.

#### 150 **Supporting Observation 2 (Pweza-3):**

151 The third example (1380 m depth) was another similar ophidiid swimming in close proximity, but at no point  
152 underneath a *Schizopathes* sp. antipatharian (Figure 2 b, [Supplementary Material: Video 5](#). Some crustaceans  
153 were also visible beneath the antipatharian (shown by arrows in Figure 2). The ophidiid was initially at greater  
154 distance from the antipatharian but gradually moved in towards the coral and remained in close proximity for  
155 the remainder of the clip. In two video clips of the fish holding station TBF was 36.23 and 34.96 min<sup>-1</sup>. In  
156 another short clip of the fish it was actively swimming away from the ROV (TBF: 56.00 min<sup>-1</sup>).

#### 157 **Discussion**

158 To our knowledge the *in situ* images presented here are the first of what is most likely *Schizopathes amplispina*  
159 (D. Opresko personal communication). *S. amplispina* was originally described from trawled specimens  
160 collected in 1964 at 1500-1600 m depth in the western Indian Ocean, east of Madagascar during the  
161 International Indian Ocean Expedition (Opresko 1997). The estimated length of the specimen in the primary  
162 observation (480 mm) is larger than the 420 mm quoted by Opresko (1997) for the type specimen of *S.*  
163 *amplispina*. These three observations and the locality and depth of the type specimen suggest the continental  
164 slope in the western Indian Ocean is of interest in the future study of *Schizopathes*. The appearance of the  
165 antipatharian, with the apex of the colony and the pinnules, sweeping over the seabed, leaving a circular  
166 impression in the sediment resembles the “unidentified fern-like attached organisms” described from early  
167 deep-sea photography in the Bellingshausen Sea, Southern Ocean (Hollister and Heezen 1967).

168 Six *Bassozetus* species are known from the deep western Indian Ocean. The specimen in the primary  
169 observation was estimated to be 400 mm in length, within the size range of members of the genus (maximum  
170 standard length of *Bassozetus* species ranges from 221-663 mm) (Nielsen and Merrett 2000). The reason for its  
171 presence under the antipatharian is not clear from the footage but at least two examples of this behaviour and  
172 the fact that the fish departed and returned to the antipatharian on several occasions in the primary  
173 observation suggest it is beneficial.

174 Returning to the antipatharian indicates it is useful to the fish as a geospatial marker, at least on the time-scale  
175 studied here. Nothing is known of the range of *Bassozetus* and whether the genus utilizes a territory or home  
176 range. Knowledge of the range of deep-water fishes is generally poor. Pop-up Satellite Archival Tagging studies  
177 are limited to the gulper shark *Centrophorus squamosus*, which reportedly travel long distances, likely within a  
178 relatively narrow depth range (Rodríguez-Cabello and Sánchez 2014) and information on other species inferred  
179 from stable isotope analysis (Trueman et al. 2012), for example ontogenetic changes in range (Longmore et al.  
180 2014).

181 A coral structure may be a valuable reference point to indicate an area of higher current flow (Morris et al.  
182 2012) and possibly increased encounters with benthopelagic food sources. Evidence from the images  
183 demonstrates sufficient current to change the orientation of the antipatharian and to move material over the  
184 seabed. Association with a structure likely provides the benefit of shelter which would enable reduced energy

185 expenditure to achieve positive rheotaxis. The Tail Beat Frequency observations, although limited, do support  
186 reduced energy expenditure under the coral. The values recorded were comparable to unpublished TBF data  
187 ( $29.8 \text{ min}^{-1}$ ) of *Bassozetus (levistomatus?)* from the Kermadec trench (T.D. Linley *personal communication*). The  
188 distinct triangular shape of *Schizopathes* sp. seems particularly suitable as a shelter for a fish of the size  
189 demonstrated here. Several similar observations of fishes apparently using corals for shelter are shown in  
190 (Figure 3 a-c) with the cusk eel *Barathrites* sp. nestling close to a gorgonian, probably *Acanella* sp., of particular  
191 interest (Figure 3 b) (Hecker and Blechschmidt 1980).

192 At hadal depths *Bassozetus* sp. appears at baited camera experiments (Jamieson et al. 2009) suggesting the  
193 may scavenge or feed on other scavenging fauna, and ostracods have been reported from their gut contents  
194 (Angel 1973) as well as the remains of fish, polychaetes and crustaceans (Nielsen and Merrett 2000). Deep-sea  
195 video observations of other ophiidiids (e.g. *Bassogigas* sp. <http://archive.serpentproject.com/2188/> and  
196 *Acanthonus armatus* <http://archive.serpentproject.com/2186/>, A Gates personal observations) suggest they  
197 swim slowly, hovering in the benthic boundary layer. If they feed on benthopelagic prey items that they  
198 encounter in this way it is feasible that holding station, perhaps aided by the use of shelter, may increase  
199 encounters with their food source. The occurrence of 26 suprabenthic crustaceans in the time-lapse images  
200 supports this suggestion. The short excursions out of the shelter of the coral may be for the purpose of attacks  
201 on passing prey organisms. If such a strategy is employed the individual observed was using a feeding strategy  
202 similar to ambush predators of the deep-sea floor such as lizard fish (*Bathysaurus* sp.), instead of active  
203 foraging as other ophiidiids are thought to use (Gartner Jr et al. 1997). It is also possible that the coral itself  
204 attracts prey for the ophiidiid. There were two crustaceans under the antipatharian shown in Supporting  
205 Observation 2 (Figure 2), perhaps for protection from predators, as demonstrated by caridean shrimp  
206 *Bathypalaemonella serratipalma* inhabiting octocorals (Watling 2011). There are also various other  
207 documented crustacean associations with antipatharians (Wicksten et al. 2014; Wicksten and Heathman  
208 2015). It seems unlikely that the fish feeds on the coral itself, given the condition of the antipatharians in the  
209 images, although in shallow water fish have occasionally been reported feeding on antipatharians (Wagner et  
210 al. 2012).

211 Avoidance of predators has been suggested as a reason for ophiidiid association with other species. The closely  
212 related ophiidiid, *Barathrites* sp., make use of the venomous spines of Echinothuriid urchins for protection



213 from currents and predators (Moore and Auster 2009). The animals reported by Moore and Auster (2009)  
214 were juveniles and appear to be of similar size to the fish in Supporting Observation 2. It is feasible that the  
215 *Bassozetus* sp. here gains similar benefit by positioning itself under the complex structure of a larger coral  
216 colony which may camouflage the fish (non-visual crypsis, Ruxton, 2009), disrupting a predator seeking mobile  
217 fish prey, perhaps even benefitting from the presence of the spines or secondary metabolites of the  
218 antipatharian. Indeed, there are examples suggesting organisms use corals as a means of anti-predator  
219 defence, including the crab *Paromola* sp., which exhibits coral carrying behaviour (Braga-Henriques et al.  
220 2012). A variety of concealment strategies are reviewed by Guinot and Wickstein (2015), including those that  
221 utilise corals. At 400 mm in length the *Bassozetus* specimen in the Primary Observation is among the larger  
222 species encountered in the study area so predators seem limited. Potential predators at this depth include  
223 *Centrophorus* sp., which attended baited camera experiments at the same and nearby sites (A. Gates personal  
224 observations) and do feed on demersal fishes (Dunn et al. 2010) or large deep-diving epi-pelagic organisms.  
225 For example recent ROV observations from nearby include a Scalloped Hammerhead (*Sphyrna lewini*) at the  
226 seabed at over 1000 m depth (Moore and Gates 2015).

227 While it is not possible to ascertain the reason for the association reported here, the observations do show a  
228 previously unreported opportunistic facultative commensalism between two poorly studied species. The  
229 observations demonstrate the role that even individual coral colonies play in providing habitat heterogeneity  
230 in the deep sea and provide an insight into behaviour of deep-sea fishes. Furthermore the observations  
231 highlight the lack of knowledge about the interactions between deep-sea species as indicated by a novel  
232 observation in a relatively short time observing an unexplored area.

233

#### 234 **Acknowledgements**

235

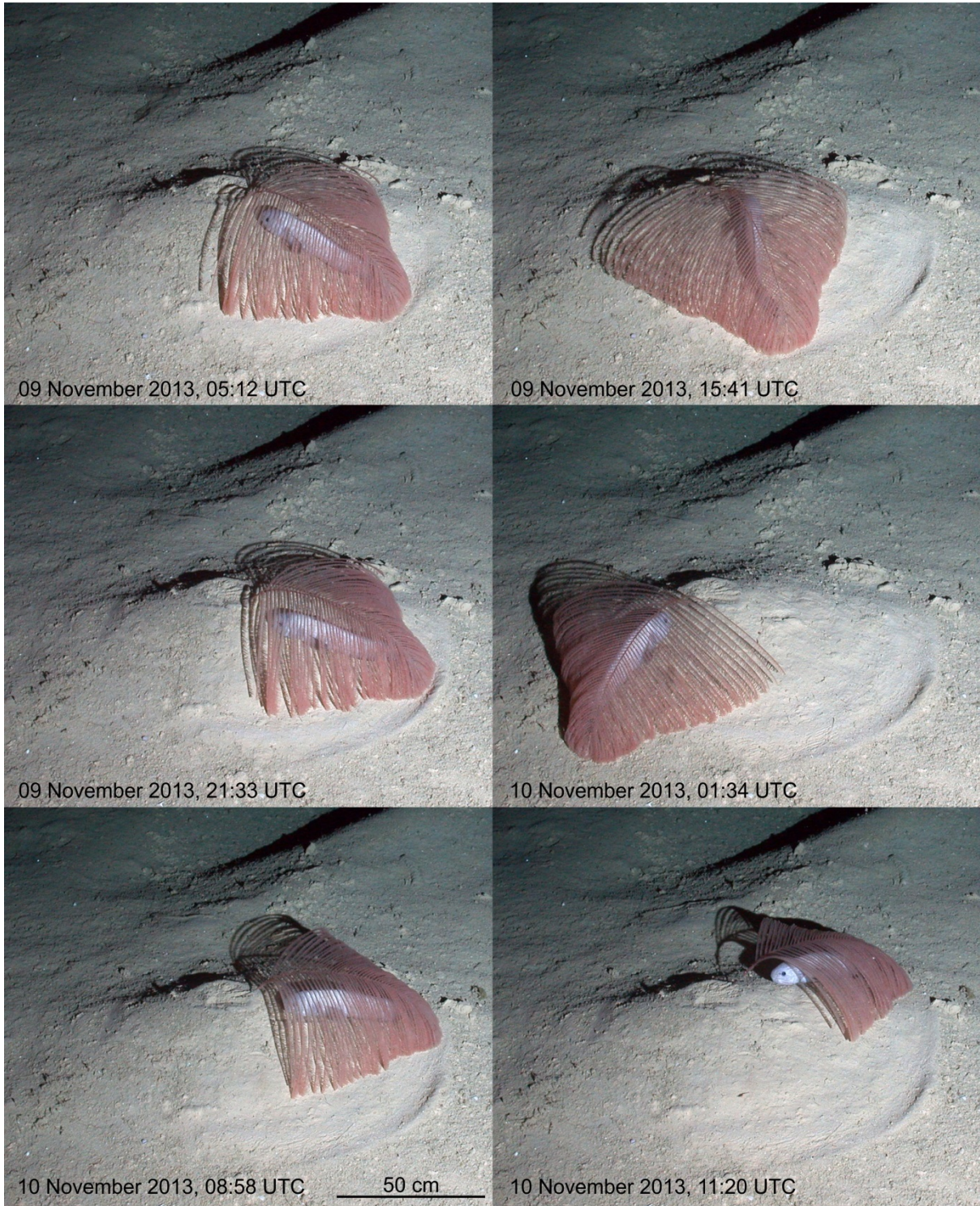
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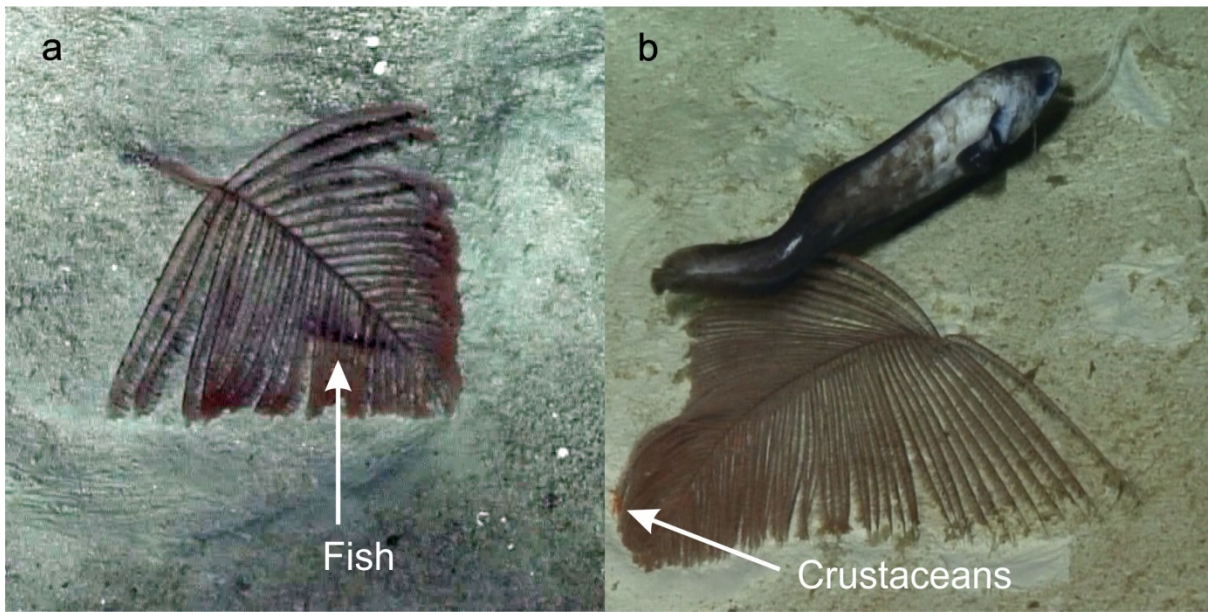
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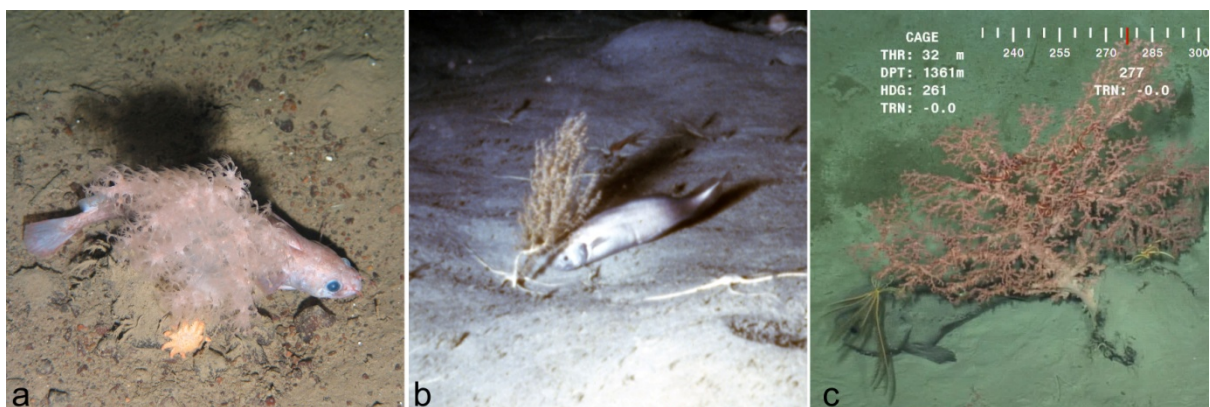


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245 Figure 1. Time-lapse footage of Ophidiid (*Bassozetus* sp.) and antipatharian (*Schizopathes* sp.). The images  
 246 show the changes in the antipatharian position relative position of the fish during a 30 hour time-lapse camera  
 247 deployment at Mzia-3 site in the western Indian Ocean  
 248  
 249



250  
 251 Figure 2: Supporting observations. a) Small fish, indicated by an arrow, under a *Schizopathes* sp. specimen at  
 252 the Mzia-2 site (1622 m), b) Ophidiid (*Bassozetus* sp.) close to a *Schizopathes* sp. specimen at the Pweza-3 site  
 253 1380 m depth (note crustaceans under the antipatharian near the apex of the colony, indicated by an arrow).  
 254



255  
 256 Figure 3: Examples of potential shelter or concealment by deep-sea fishes in close association with individual  
 257 coral colonies a) arctic rockling, *Gaidropsarus argentatus*, behind *Gersemia* sp. at 1085 m depth in the Faroe-  
 258 Shetland Channel, NE Atlantic <http://archive.serpentproject.com/2617/> b) ophidiid *Barathrites* sp. apparently

259 sheltering behind *Acanella* sp. at 2131 m depth at Hecker Circle off the east coast of the USA, c) Blobfish,  
260 *Psychrolutes* sp. behind a coral colony (likely *Paragorgia* sp.) in the western Indian Ocean at the Pweza-3 site  
261 (1380 m) (<http://archive.serpentproject.com/2530/>).

262 **Tables:**

263 Table 1: Location and depth of observations in the western Indian Ocean off Tanzania

Association	Date (2013)	Site Name	Latitude (S)	Longitude (E)	Depth (m)	Temperature (°C)
Primary	4 Nov*	Mzia-3	9° 49' 39"	40° 27' 30"	1788	3.2
Supporting 1	10 Apr	Mzia-2	9° 54' 05"	40° 29' 43"	1622	3.6
Supporting 2	16 Sep	Pweza-3	8° 23' 58"	40° 04' 46"	1380	4.5

264 \*First of multiple observations of this specimen

265

266 Table 2: Estimated tail beat frequency of *Bassozetus* sp. demonstrating different behaviours in video

267 observations

Site	Association	Position of fish	Behaviour of fish	Duration (s)	Tail beat frequency (min <sup>-1</sup> )
Mzia-3	Primary	under coral	Holding station	26	25.38
Mzia-3	Primary	under coral	Holding station	64	28.13
Mzia-3	Primary	under coral	Holding station*	45	40.00
Mzia-3	Primary	outside coral	Actively swimming forward	22	57.27
Pweza-3	Supporting 2	outside coral	Holding station	53	36.23
Pweza-3	Supporting 2	outside coral	Holding station	53	34.96
Pweza-3	Supporting 2	outside coral	Actively swimming forward	15	56.00

268 \*Fish may be experiencing effects of current induced by presence of ROV

269

270

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366 **Supplementary Material:**

367 **Supplementary videos are available to download here (they may take some time to download):**

368 Supplementary video:

369 <https://www.youtube.com/watch?v=YlJm3uxkCYI>

370 <https://link.springer.com/article/10.1007/s12526-016-0516-z>

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