6-28-2016

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Gates, Andrew R.; Morris, Kirsty J.; Jones, Daniel O.; and Sulak, Kenneth J., "An association between a cusk eel (*Bassozetus* sp.) and a black coral (*Schizopathes* sp.) in the deep western Indian Ocean" (2016). *USGS Staff -- Published Research*. 1069.
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An association between a cusk eel (*Bassozetus* sp.) and a black coral (*Schizopathes* sp.) in the deep western Indian Ocean

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Received: 22 December 2015 / Revised: 16 May 2016 / Accepted: 23 May 2016 / Published online: 28 June 2016
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Abstract Detailed observations in the deep sea can reveal previously unknown behaviour, species interactions and fine-scale habitat heterogeneity. Here, the first in situ images of the black coral *Schizopathes* sp. (Anthozoa: Antipatharia) in the deep western Indian Ocean have been obtained from remotely operated vehicle video footage and time-lapse photography. In these images, there appears to be an association with the cusk eel *Bassozetus* (Family: Ophidiidae). In the primary observation, chance encounters revealed the fish interacted with the antipatharian on multiple occasions over several days. Subsequent time-lapse camera footage showed the fish remained almost exclusively underneath the antipatharian for the duration of a 30-h deployment. Excursions from the cover of the antipatharian were for less than 2 min. The primary observation is supported by two similar encounters in the same region. Observed reduction in the tail-beat frequency of the fish under the antipatharian suggests reduced energy requirements for the ophidiid in this position. The observations demonstrate the role that even individual coral colonies play as a source of three-dimensional structure, providing habitat heterogeneity in the deep sea.

Keywords Antipatharia · SERPENT Project · Energy conservation · Ophidiidae · Tail-beat frequency · Time-lapse photography

Introduction

Little is known about the ecology of most deep-sea species and intraspecific interactions are particularly poorly studied because of a lack of detailed observations in such remote areas. Such data are required in order to improve understanding of deep-sea ecosystems. In this paper, we report in situ observations from remotely operated vehicle (ROV) video footage and time-lapse photography of an association between a black coral *Schizopathes* sp. (Anthozoa: Antipatharia) and a cusk eel *Bassozetus* (Family: Ophidiidae) in deep water in the western Indian Ocean off Tanzania.

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

Communicated by R. Serrao Santos

Electronic supplementary material The online version of this article (doi:10.1007/s12526-016-0516-z) contains supplementary material, which is available to authorized users.

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et al. 2010), while corals themselves increase flow over their polyps through the action of cilia (Shapiro et al. 2014).

Antipatharians (Hexacorallia) are commonly known as black corals because their proteinaceous axis is black or dark in colour. They are generally found at depths greater than 50 m (Cairns 2007) and are long-lived and slow-growing. Antipatharians often provide habitat for other organisms such as crustaceans and polychaetes (Wagner et al. 2012; Wicksten et al. 2014; Wicksten and Heathman 2015), and fishes at a range of water depths. Gobiod fish have been reported inhabiting *Cirripathes* sp. in shallow water in the tropical Pacific (Davis and Cohen 1968), and aggregations of antipatharians such as *Antipathella subpinnata* (150–230 m) (Deidun et al. 2015) and *Leiopathes glaberrima* (250–400 m) form “coral gardens” that provide habitat for a variety fish species (de Matos et al. 2014). *Schizopathes* Brook, 1989 is a poorly studied genus of antipatharian with three known species, one of which, *S. amplispina* Opresko, 1997, was described from the western Indian Ocean (Opresko 1997).

Cusk eels (Ophidiidae) are found from the upper shelf to hadal depths. They reportedly feed on invertebrates and fishes (Nielsen and Merrett 2000), but much of their behaviour is unknown. There are 13 described species of *Bassozetus* Gill, 1883 (members of this genus are commonly known as assfish), of which 6 species are recorded from the western Indian Ocean off Kenya, Madagascar and Mozambique (*Bassozetus galathea*, *B. glutinosus*, *B. compressus*, *B. elongatus*, *B. levistomatus* and *B. robustus*). These were mostly collected during the voyages of the *Mabahiss* (1932–34), *Galathea II* (1952), *Vityaz* (1959–64) and *Anton Bruun* (1964) (Menzies et al. 1973). Since those pioneering expeditions, there have been limited studies of the deep sea in the western Indian Ocean, particularly using modern techniques such as ROV survey. Through accessing industry ROVs in a collaborative project (www.serpentproject.com) at oil drilling locations off Tanzania, we report novel observations of the ophidiid *Bassozetus* sp. apparently associated with an antipatharian at 1380–1780 m depth in the western Indian Ocean.

Methods

The observations presented here were made in 2013 as part of the SERPENT Project (Jones 2009). Data were collected using a Deep Ocean HD video camera mounted on an Oceaneering International Millennium ROV deployed from the drill ship *Deepsea Metro 1* at three locations (Table 1). Mzia-2 and Mzia-3 were separated by 9 km and Pweza-3 was a further 160 km north of Mzia-3. The sites were dominated by soft

sediment but Pweza-3 also had some areas of hard substratum. The names Mzia-2, Mzia-3 and Pweza-3 refer to the names of the drilling locations (Kiswahili names for marine organisms, barracuda and octopus).

Primary observation

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

Each original frame from the time-lapse camera deployment, prior to cropping for Fig. 1 and Supplementary material video 3, was examined and the presence of the fish, its alignment under the antipatharian, notable behaviour and the presence of potential prey items were recorded. The area of seabed imaged and the length of the ophidiid and antipatharian individuals were estimated using the acceptance angles of the camera and its height above the seabed, using a three-dimensional rotational matrix (Morris et al. 2014), where pitch was set as the angle of the camera from the vertical and roll and heading were set at zero to obtain the coordinates of the image corners and thus allow area and scale to be determined. Using these methods, the area of seabed imaged was estimated as 8.48 m². Much of this area was distant and unrealistic to analyse.

Supporting observations

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

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 ^a	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

^a First of multiple observations of this specimen

Estimating activity of the fish

Tail-beat frequency (TBF) was estimated from the HD video observations as an indication of fish activity (this was not possible from the time-lapse footage because frames were not continuous). One tail beat was recorded

as one complete oscillation of the tail (Ohlberger et al. 2007). This was carried out for the “Primary observation” and “Supporting observation 2” because the fish appeared to be of comparable size. TBF was not estimated for “Supporting observation 1” because the size of the fish was not comparable. As the video clips were short, the tail oscillations were

Fig. 1 Time-lapse footage of Ophiidid (*Bassozetus* sp.) and antipatharian (*Schizopathes* sp.) showing the changes in the antipatharian position relative position of the fish during a 30-h time-lapse camera deployment at Mzia-3 site in the western Indian Ocean

counted for discrete sections of footage. No statistics were carried out on these data because of their limited scope.

Results

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

Primary observation (Mzia-3)

The main observation of the association between *Bassozetus* sp. and *Schizopathes* sp., (termed primary observation) was observed on two separate occasions by the ROV at the Mzia-3 site before the decision to deploy the time-lapse camera to record it in more detail. The *Schizopathes* sp. specimen is estimated to have been 480 mm in length from the visible holdfast to the apex. The widest point (lower pinnules) was estimated at 630 mm. There was a circular impression on the sediment, with a small mound where the holdfast attaches, created as the pinnules sweep over the seabed as the colony moves in the current. The *Bassozetus* specimen observed under this antipatharian was approximately 400 mm in length. The first observation of this association (4 November 2013) showed *Schizopathes* sp. with *Bassozetus* sp. underneath (Supplementary material: video 1). The video footage indicates gentle undulation of the *Bassozetus* specimen's body with TBF estimated at 25.38 min^{-1} (Table 2). When the same specimens were encountered on 6 November 2013, the fish was again under the antipatharian (Supplementary material: video 2), with an initial TBF of 28.13 min^{-1} . A second estimate

of the TBF, also under the antipatharian, on 6 November was considerably higher (40.00 min^{-1}). There appears to be an effect of the ROV on the fish in this instance, resulting in the higher TBF. As the ROV departed, the fish left the cover of the coral swimming away rapidly (TBF: 57.27 min^{-1}). The fish was not observed to return to the antipatharian at this time.

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

Supporting observation 1 (Mzia-2)

At Mzia-2 (1622 m depth), another *Schizopathes* antipatharian was observed. (Fig. 2a; Supplementary material: video 4). The 62-s clip shows a smaller antipatharian with a small unidentified fish (probably a juvenile ophidiid) in a similar orientation to the primary observation.

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

Site	Association	Position of fish	Behaviour of fish	Duration (s)	Tail-beat frequency (min^{-1})
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 ^a	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

^a Fish may be experiencing effects of current induced by presence of ROV

Fig. 2 Supporting observations. **a** Small fish, indicated by an arrow, under a *Schizopathes* sp. specimen at the Mzia-2 site (1622 m). **b** Ophiidid (*Bassozetus* sp.) close to a *Schizopathes* sp. specimen at the Pweza-3 site (1380 m) (note crustaceans under the antipatharian near the apex of the colony, indicated by an arrow)

Supporting observation 2 (Pweza-3)

The third example (1380 m depth) was another similar ophiidid swimming in close proximity, but at no point underneath a *Schizopathes* sp. antipatharian (Fig. 2b; Supplementary material: video 5). Some crustaceans were also visible beneath the antipatharian (shown by arrows in Fig. 2). The ophiidid was initially at a greater distance from the antipatharian but gradually moved in towards the coral and remained in close proximity for the remainder of the clip. In two video clips of the fish holding station, TBF was 36.23 and 34.96 min⁻¹. In another short clip of the fish, it was actively swimming away from the ROV (TBF: 56.00 min⁻¹).

Discussion

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

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

Returning to the antipatharian indicates it is useful to the fish as a geospatial marker, at least on the time scale studied here. Nothing is known of the range of *Bassozetus* nor whether the genus utilises a territory or home range. Knowledge of the range of deep-water fishes is generally poor. Pop-up Satellite Archival Tagging studies are limited to the gulper shark *Centrophorus squamosus*, which reportedly travel long distances, likely within a relatively narrow depth range (Rodríguez-Cabello and Sánchez 2014). Information on other species has been inferred from stable isotope analysis (Trueman et al. 2012), for example ontogenetic changes in range (Longmore et al. 2014).

A coral structure may be a valuable reference point to indicate an area of higher current flow (Morris et al. 2012) and possibly increased encounters with benthopelagic food sources. Evidence from the images demonstrates sufficient current to change the orientation of the antipatharian and to move material over the seabed. Association with a structure likely provides the benefit of shelter which would enable reduced energy expenditure to achieve positive rheotaxis. The TBF observations, although limited, do support reduced energy expenditure under the coral. The values recorded were comparable to unpublished TBF data (29.8 min⁻¹) of *Bassozetus (levistomatus?)* from the Kermadec trench (T.D. Linley, personal communication). The distinctive triangular shape of *Schizopathes* sp. seems particularly suitable as a shelter for a fish of the size demonstrated here. Several similar observations of fishes apparently using corals for shelter are shown in Fig. 3a–c, with the cusk eel *Barathrites* sp. nestling close to a gorgonian, probably *Acanella* sp., of particular interest (Fig. 3b) (Hecker and Blechschmidt 1980).

At hadal depths, *Bassozetus* sp. appears at baited camera experiments (Jamieson et al. 2009) suggesting they may scavenge or feed on other scavenging fauna, and ostracods have been reported from their gut contents (Angel 1973) along with the remains of fish, polychaetes and crustaceans (Nielsen and Merrett 2000). Deep-sea video observations of other ophiidiids (e.g. *Bassogigas* sp. <http://archive.serpentproject.com/2188/> and *Acanthonus armatus* <http://archive.serpentproject.com/2186/>, A. Gates, personal observations) suggest they swim slowly, hovering in the benthic boundary layer. If they feed on benthopelagic prey items that

Fig. 3 Examples of potential shelter or concealment by deep-sea fishes in close association with individual coral colonies. **a** Arctic rockling, *Gaidropsarus argentatus*, behind *Gersemia* sp. at 1085 m depth in the Faroe–Shetland Channel, NE Atlantic (<http://archive.serpentproject.com/2617/>). **b** Ophiidiid *Barathrites* sp. apparently sheltering behind *Acanella*

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

they encounter in this way, it is feasible that holding station, perhaps aided by the use of shelter, may increase encounters with their food source. The occurrence of 26 suprabenthic crustaceans in the time-lapse images supports this suggestion. The short excursions out of the shelter of the coral may be for the purpose of attacks on passing prey organisms. If such a strategy is employed, the individual observed was using a feeding strategy similar to ambush predators of the deep-sea floor, such as lizard fish (*Bathysaurus* sp.), instead of active foraging as other ophiidiids are thought to use (Gartner et al. 1997). It is also possible that the coral itself attracts prey for the ophiidiid. There were two crustaceans under the antipatharian, shown in Fig. 2, perhaps for protection from predators, as demonstrated by caridean shrimp *Bathypalaemonella serratipalma* inhabiting octocorals (Watling 2011). There are also various other documented crustacean associations with antipatharians (Wicksten et al. 2014; Wicksten and Heathman 2015). It seems unlikely that the fish feeds on the coral itself, given the condition of the antipatharians in the images, although in shallow water fish have occasionally been reported feeding on antipatharians (Wagner et al. 2012).

Avoidance of predators has been suggested as a reason for ophiidiid association with other species. The closely related ophiidiid, *Barathrites* sp., make use of the venomous spines of Echinothuriid urchins for protection from currents and predators (Moore and Auster 2009). The animals reported by Moore and Auster (2009) were juveniles and appear to be of similar size to the fish in Fig. 2. It is feasible that the *Bassozetus* sp. here gains similar benefit by positioning itself under the complex structure of a larger coral colony which may camouflage the fish (non-visual crypsis; Ruxton 2009), disrupting a predator seeking mobile fish prey, perhaps even benefitting from the presence of the spines or secondary metabolites of the antipatharian. Indeed,

there are examples suggesting organisms use corals as a means of anti-predator defence, including the crab *Paromola* sp., which exhibits coral-carrying behaviour (Braga-Henriques et al. 2012). A variety of concealment strategies are reviewed by Guinot and Wickstein (2015), including those that utilise corals. At 400 mm in length, the *Bassozetus* specimen in Fig. 2 is among the larger species encountered in the study area, so predators seem limited. Potential predators at this depth include *Centrophorus* sp., which attended baited camera experiments at the same and nearby sites (A. Gates, personal observations), and do feed on demersal fishes (Dunn et al. 2010), or large deep-diving epi-pelagic organisms. For example, recent ROV observations from nearby include a Scalloped Hammerhead (*Sphyrna lewini*) at the seabed at over 1000 m depth (Moore and Gates 2015).

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

Acknowledgments ARG was funded by NERC through the SERPENT Project for this work. We thank L. Werre, J. Moirana, C. Wood, S. Murray and D. Hudson (BG Group) for funding the SERPENT study in the area. Thanks to the crew of the *Deepsea Metro I* for assistance at sea, especially Oceaneering International ROV supervisors (F. Lynch, R. Makowichuk). We thank Dennis Opresko for comments on the antipatharian identification. Thanks to Barbara Hecker for access to an additional image of an ophiidiid in association with a coral. Thanks to the editor Ricardo Serrão Santos and two anonymous reviewers whose comments improved this manuscript.

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