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In-situ observation of deep water corals in the northern Red Sea waters of Saudi Arabia

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ABSTRACT

Three sites offshore of the Saudi Arabia coast in the northern Red Sea were surveyed in November 2012 to search for deep-water coral (DWC) grounds using a Remotely Operated Vehicle. A total of 156 colonies were positively identified between 400 and 760 m, and were represented by seven species belonging to *Scleractinia* (3), *Alcyonacea* (3) and *Antipatharia* (1). The scleractinians *Dasmosmilia valida* Marenzeller, 1907, *Eguchipsammia fistula* (Alcock, 1902) and *Rhizotrochus typus* Milne-Edwards and Haime, 1848 were identified to species level, while the octocorals *Acanthogorgia* sp., *Chironephthya* sp., *Pseudopterogorgia* sp., and the antipatharian *Stichopathes* sp., were identified to genus level. Overall, the highest abundance of DWC was observed at Site A1, the closest to the coast. The most abundant species in the study area was *D. valida*, which lives attached to rocky substrates and represented 42% of the total coral population at site A1. Water column attributes at this depth were quite homogenous with temperature ca. 21.6 °C, salinity ca. 40.56, dissolved oxygen ca. 1.75 ml L^{-1} and current velocity from 0.6 to 34.5 cm s^{-1} with a mean value of 9.5 cm s^{-1}. Interestingly, these DWC can cope with high temperature and salinity, compared to those in other regions.

1. Introduction

The ahermatypic and azooxanthellate coral species are less constrained in their distribution by light penetration, temperature and salinity compared to hermatypic and zooxanthellate corals. Usually they occur on continental margins and topographical highs from polar to tropical latitudes, and reaching depths greater than 1000 m (Roberts et al., 2009; Levin and Dayton, 2009). Collectively called "Deep Water" Corals (DWC) or Cold Water Corals (CWC), these include stony corals (*Scleractinia*), gorgonians, sea fans, bamboo corals and black corals (*Antipatharia*), and hydrocorals (Stylasteridae). Among the 723 azooxanthellate scleractinian coral species currently known, the majority (532 species, 73.6%) are solitary in habit while the remainder (191, 26.4%) are colonial. The distribution of DWC is governed by various factors including temperature and calcium carbonate saturation (Cairns, 2007), topographic relief (Mortensen and Buhl-Mortensen, 2004; Buhl-Mortensen et al., 2010; Guinan et al., 2009; Yesson et al., 2012), sedimentary regime and currents (Thiem et al., 2006; Bryan and Metaxas, 2006; Wilson et al., 2007; Dolan et al., 2008).

The Red Sea has an average depth of 500 m, with a maximum of over 2500 m in its axial trough, and is noted for some of the hottest (around 40 °C) and most saline (up to 46) surface seawater in the world (Behairy et al., 1992; Taviani, 1998). The Red Sea bathyal depths house a relatively diverse benthic fauna, adapted to its highly saline and warm deep waters (PERSGA, 2006). Contrary to the well-known shallow-water coral reefs, not much information is available on DWC in the Red Sea basin. Nevertheless, the biodiversity of the present day Red Sea "deep water" benthos seems to be substantially less than in the adjacent Indian Ocean, as a response to restricted water exchange and extreme environmental conditions (Taviani et al., 2007). Previous geomarine investigation of the deep environments of the Red Sea has produced some evidence of subfossil DWC species such as *Javania insignis* Duncan (1876), *Trochocyathus virgatus sensu* Marenzeller (1907), and possibly *Guynia annulata* Duncan (1872), which inhabited the Red Sea during the late Pleistocene, becoming extinct at around the Last Glacial Maximum due to adverse environmental conditions (Bäcker et al., 1975; Taviani et al., 2007).

DWC were first sampled in the Red Sea by the Austrian/Hungarian vessel S.M.S. Pola (1895–1898). Six taxa were recorded from 212 to 987 m by Marenzeller (1907): *Balanophyllia rediviva* Moseley (1881), *Dasmosmilia valida* Marenzeller (1907), *Javania*

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insignis Duncan (1876), *Madracis interjecta* Marenzeller (1907), *Rhizotrochus typus* Milne-Edwards and Haime (1848), and *Trochocyathus virgatus* Alcock (1902). Further records include *Guynia* sp. (Taviani, 1998) and *Acabaria biserialishas* from the northern Red Sea (Schuhmacher, 1973; Grasshoff, 1976; Ben-Yosef and Benayahu, 1999). In addition, submersible surveys in the twilight/aphotic zone (105–205 m) of the Gulf of Aqaba revealed the presence of important coral growth in the form of reefs of azooxanthellate corals, such as *Madracis interjecta* Marenzeller (1907) and *Dendrophyllia* spp. (*e.g.*, *D. minuscula* Bourne, 1905) as main frame builders (Fricke and Hottinger, 1983; Fricke and Schumacher, 1983; Fricke and Knauer, 1986). Roder et al. (2013) reported corals *e.g.*, *Eguchipsammia fistula*, *Dendrophyllia* sp., an undetermined species of *Caryophyllidae*, *R. typus*, solitary red polyp and solitary white polyp, at depths of 230–740 m in the central Red Sea, where they occur at temperatures exceeding 20 °C in highly oligotrophic and oxygen-limited waters.

The exploration of the deep ocean is accelerating steadily, taking advantage of the sophisticated and only slightly invasive technologies such as Remotely Operated Vehicles (ROVs), which are credited with the discovery of a number of DWC sites around the World. However, there are very few published studies on azooxanthellate DWC from the low latitude seas when compared to the studies reported from high latitude seas. Although the presence of DWC in deep waters (400–1000 m) of the Red Sea was first recorded in the late nineteenth century (Marenzeller, 1907), it took more than a century to collect fresh DWC specimens from >250 m depths and provide some details on their distribution and habitat from these waters (Roder et al., 2013). Globally, DWC corals are facing threats from the disturbances caused by deep-sea trawling, impacts associated with oil and gas exploration and development, and ocean acidification. Hence for protecting and conserving the DWC habitats in every region, it is required to locate, map, characterize, and conduct a baseline assessment of DWC habitats. Here, we report an *in situ* study of these DWCs. We provide an inventory of the DWC observed (and collected in some instances) and in conjunction with hydrographical and current data, discuss the conditions that enable their presence and survival at these depths.

2. Materials and methods

2.1. Study area

Three areas located off Duba (Fig. 1) were randomly chosen for the survey. Area 1 (A1) (27°28′12″ to 27°29′49″N; 35°21′46″ to 35°23′42″E) was located at a depth of 312–622 m and approximately 17 km from the coast. Area 2 (A2) (27°24′31″ to 27°26′31″ N; 35°15′7″ to 35°17′2″E) and Area 3 (A3) (27°21′3″ to 27°22′40″N; 35°15′39″ to 35°17′42″E) were located at depth ranges of 636–770 m and 654–766 m, respectively, and approximately 29 and 32 km, respectively, from the coast. In each area, two square-shaped tracks consisting of an inner perimeter of around 6 km and outer perimeter of around of 12 km were surveyed.

2.2. Video survey and analysis

The survey was conducted during November 1–6, 2012 using the Research Vessel *R. V. Aegaeo*, belonging to the Hellenic Centre for Marine Research (HCMR). Sea bottom inspection and sampling was carried out using ROV *Max Rover* (DSSI, USA) operated from the vessel through a 1300 m umbilical cable. The ROV was equipped with a built-in CCD color video system consisting of two wide-angle cameras and a macro-zoom camera making a continuous recording that was stored on a hard disk. In addition, a wide-angle HDTV camera with a shorter recording time was rigged to the ROV in an unconnected housing. The ROV was equipped with a 5-function manipulator arm to facilitate sample collection.

The ROV was navigated using a compass, echo sounder, and sonar with Tracklink ultra-short baseline transponder system (Linkquest, USA) to track its position on the ship navigation computer. A total of 70 h of video was recorded over the course of six days. Video transects were typically flown at an altitude of 2–3 m over the bottom at a vehicle speed of 0.5 m s^{-1}. Distribution of megafauna was mapped from the images obtained with both forward- and downward-looking cameras. Some close-ups of the coral communities were also obtained and these were useful for taxonomic identification of the megafauna. A few specimens of megafauna were collected using the ROV for later identification. A multi beam survey was conducted to map the topography of the study area.

The video footage was visually analyzed to classify the various substrates. The occurrence of DWCs and their positions were used to develop an ArcGIS distribution map. The scleractinians were identified based upon images and actual samples, whenever available. The octocorals and black corals were identified in ROV images with the help of taxonomists and based on published information (Brugler et al., 2013).

2.3. Environmental data collection

Two types of measurements were conducted to characterize the current patterns of the region. A hull-mounted ADCP with deep-water profiling capabilities was used to measure the water current and direction at different depths throughout the track of the vessel within the study area. Two long-range ADCPs were attached to a mooring line and deployed at a station near the surveyed locations to gather the data on water circulation over a period of one month. Profiles of temperature, salinity (conductivity), dissolved oxygen, and depth, with measurements at 1 m intervals, were obtained using a Sea-Bird-9plus CTD system. Water samples obtained during the CTD cast were used for the measurement of nutrients. Concentrations of nitrate, nitrite, phosphate, and silicon were measured photometrically using a SKALAR San Plus model Auto-Analyzer using the analytical methods given by the manufacturer.

Sediment samples were collected from 45 stations in the three areas (15 gridded stations from each area) using a box corer with a 0.1 m^2 sampling area, and were analyzed for the estimation of sediment grain sizes (Carvar, 1971).

3. Results

The visual analyses of video footage and the analyses of sediment samples collected from selected stations revealed two main habitats: mound and intermound. The former corresponds to positive topographic features of various sizes, extending from about 5 to 50 m in height and at least 250 m in lateral extension. The latter consists of level to gently sloping areas situated between the mounds (Fig. 1). Most of the mound and slope areas are formed of hard rocky substrata whereas the intermound areas are mainly covered with mud or fine sediment and locally dotted with smaller reliefs. While Area A1 had extensive rocky mounds and relatively smaller intermound areas covered with muddy habitats, Areas A2 and A3 comprised mainly intermound areas with rare occurrences of small rocks. Plateaus, steep slopes, cliffs, and deep trenches were observed in Area A1. A thin layer of fine sediment over rock was observed at some stations in Area A1. This was