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High coral cover at lower mesophotic depths: a dense *Agaricia* community at the leeward side of Curaçao, Dutch Caribbean

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Abstract Coral cover at lower mesophotic depths (particularly >75 m) by zooxanthellate scleractinians is usually very scarce, largely due to the extremely low irradiance levels at these depths. An exception are the *Leptoseris* communities observed near the Hawaiian islands (Central Pacific) that form dense fields, supporting a broad range of associated organisms. Here, we describe a similar high-cover coral community at lower mesophotic depths, but in the Caribbean. The community was observed on the leeward side of Curaçao (Southern Caribbean) using a manned submersible (*Curasub*), and was predominantly composed of plating *Agaricia* corals and an assemblage of reef fishes. Some of the fish species were known from similar depths at other localities, whereas others obtained new depth records. Future surveys are required to establish the extent of similar high-coral communities around Curaçao, and more broadly in the western Atlantic.

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Introduction

Lower mesophotic reef communities (>60 m) consisting of zooxanthellate scleractinians remain largely unstudied due to the logistical difficulty of accessing depths well below regular diving limits. Traditionally, manned submersibles have been used to explore much greater depths (>200 m), and only sporadically they have been employed to investigate deeper sections of tropical coral reefs that include the depth limits of zooxanthellate corals (e.g., Fricke and Schuhmacher 1983; Reed 1985; Macintyre et al. 1991). Only a few studies with manned submersibles concentrated on azooxanthellate coral assemblages or deep-sea communities containing scleractinians (e.g., Fricke and Hottinger 1983; Tempera et al. 2015; Wisshak et al. 2015). Novel technologies, such as Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs) have provided alternative methods of accessing these deep-water communities, but are dependent on camera systems and lack the ability of *in situ* observations by the human eye (e.g. Webster et al. 2008; Bongaerts et al. 2013b; Englebert et al. 2014; Appeldoorn et al. 2015).

In general, the density and reef-building capacity of zooxanthellate corals decrease with increasing depth, usually resulting in very low coral cover at lower mesophotic depths (Kahng et al. 2010). An exception to this general trend are the *Leptoseris*-dominated communities that have been observed at 70–90 m depth in Hawaii that can form dense communities of up to 100 % coral cover (Kahng and Maragos 2006; Pochon et al. 2015). Footage and dredge samples taken at the Great Barrier Reef also show that *Leptoseris* species can

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be locally dominant at greater mesophotic depths but they have not particularly been recorded in high densities yet (Hopley et al. 2007; Bridge et al. 2012; Dinesen et al. 2012). The present report describes the discovery of a large, similarly dense aggregation of *Agaricia* corals from the same family (Agariciidae) at 70–85 m depth and some of its demersal fish fauna as observed from the submersible *Curasub*, based at Substation Curaçao (http://www.substation-curacao.com/).

Material and methods

On 21 March 2014, the submersible *Curasub* was transported on board its mother ship, the R/V *Chapman*, to the reef at Playa Porto (N12°14'01" W068°53'32"), on the leeward side of Curaçao. The submersible launch platform was anchored in 5 m deep water, from where two submersible dives were made: one in the morning (1110–1335 hrs) down to 211 m depth and one in the afternoon (1400–1645 hrs) down to 169 m, with an intermediate change of crew and observers. Depth and temperature were measured by the submersible's gauges, and video was recorded during the 2nd dive (Electronic Supplementary Material = ESM 1).

Results and discussion

During both dives, the submersible passed over a dense coral community overgrowing a steep rocky slope and a terrace at 70-85 m depth. Water temperature varied from 26 to 24 °C in the morning and from 26 to 22 °C in the afternoon across that depth gradient. The coral assemblage consisted entirely of thin foliaceous colonies of *Agaricia* (Agariciidae) of up to nearly 100 % cover (Fig. 1a, b). It is unclear whether the assemblage was mainly composed of *A. grahamae* Wells, 1973 or *A. undata* (Ellis and Solander, 1786), because no samples were taken. Both species look alike from a distance and show much overlap in depth range (Humann and Deloach 2013). The presence of *Agaricia* corals at >60 m depth is not uncommon at Curaçao. At the reef off the Curaçao Sea, Aquarium *A. grahamae* and *A. undata* are dominant coral species at 60–100 m depth (Bongaerts et al. 2015), but they are not densely aggregated there as they are in the site observed in this study, where the size and cover of the assemblage at 70–85 m depth is unusual. At Puerto Rico, *A. undata* has also been observed as the most abundant scleractinian coral at 70 m depth (with only 10 and 13 % cover) but it is not more dominant than sponges and coralline algae here (Appeldoorn et al. 2015).

Most corals were alive, very few were white and appeared to have bleached or may have died recently (Fig. 1c). Dead corals were generally intact but overgrown by crustose coralline algae. The living coral plates were dark brown at the center, light brown distal to the center, and white at the outer margin (Fig. 1; ESM 1). This colour pattern has also been observed in thin coral plates at the leeward side of Curaçao (Bongaerts et al. 2013a: Fig. 7). The lighter colour is caused by the thin skeletal growth that allows light to penetrate through the calcium carbonate

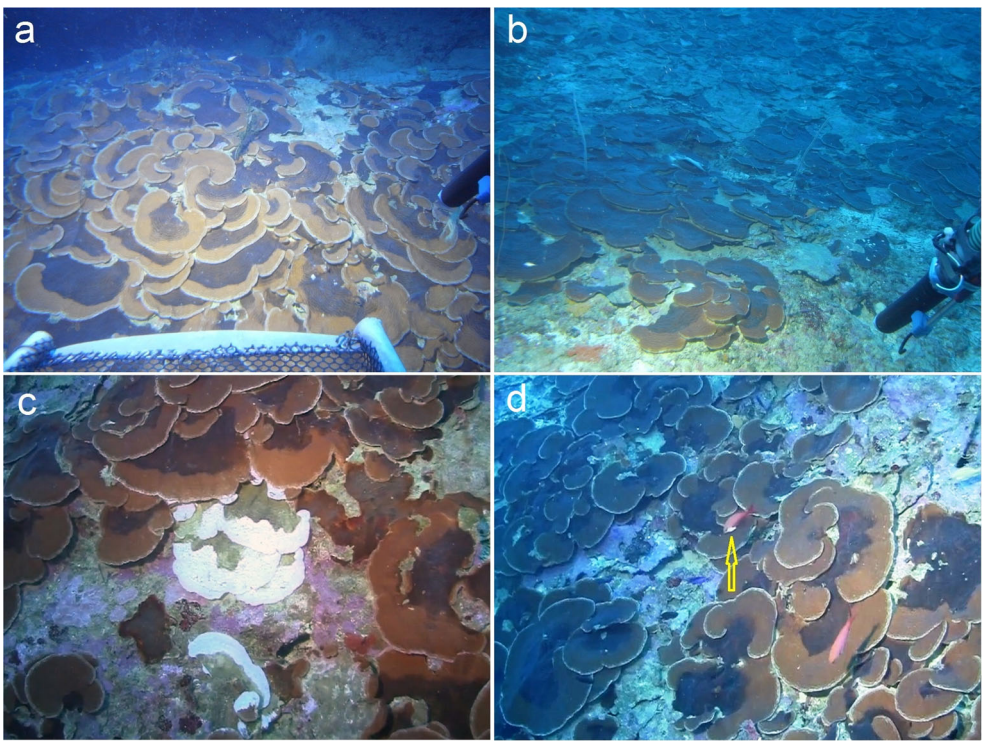

Fig. 1 *Agaricia* reef community at 70-85 m depth, leeward side of Curaçao: **a** downslope view from ~ 75 m; **b** upslope view at ~ 85 m; **c** bleached or recently dead corals at 68 m; **d** one *Paranthias furcifer* with a parasitic isopod (arrow)

skeleton, whereas the dark color is caused by algal overgrowth at the underside.

It is also clear that the corals are important as fish habitat. Numerous fishes were swimming over the coral plates, representing at least the following species: *Cephalopholis cruentata* (Lacepède, 1802) and *Paranthias furcifer* (Valenciennes, 1828) (Serranidae); *Chromis enchrysura* Jordan and Gilbert, 1882, and *Chromis cyanea* (Poey, 1860) (Pomacentridae); *Haemulon vittatum* (Poey, 1860) and *H. flavolineatum* (Desmarest, 1823) (Haemulidae); *Neoniphon marianus* (Cuvier, 1829) (Holocentridae); *Clepticus parrae* (Bloch and Schneider 1801) (Labridae); and *Scarus taeniopterus* Lesson, 1829 (Scaridae) (ESM 1). These fishes mainly hovered or swam above coral, but a few were observed to seek shelter within the coral aggregation (ESM 1: 33 sec). At least three individuals of *P. furcifer* hosted large parasitic cymothoid isopods (Fig. 1d, ESM 1: 1 min 35 sec). No attempt was made to investigate the presence or absence of smaller fishes living cryptically in the coral.

None of the observed fish species is uncommon, and most have been reported at similar depths off the Bahamas, Belize, Florida, Jamaica, or Puerto Rico (Colin 1974, 1976; Itzkowitz et al. 1991; Bryan et al. 2013; Bejarano et al. 2014). *Haemulon flavolineatum* was previously recorded only down to 50 m (Itzkowitz et al. 1991; Robertson and Van Tassell 2015). There is a general paucity of information regarding Caribbean deep-reef fish communities. Our knowledge of their depth distributions and community structure increases measurably through video-documented studies such as the one presented here.

Deep reef communities can be studied very well from manned submersibles that are equipped with sample tools and cameras, which enables the researchers to remain relatively comfortable underwater for some hours and to observe and collect anything attracting attention. This has resulted in mesophotic depth records of three reef fish species during the present dives, and a fourth one during another dive session (Baldwin and Robertson 2015). New information obtained in such a way can be important for clarifying the possible role of deep reef assemblages in coral reef conservation with regard to global change (Bongaerts et al. 2010). The *Curasub* has also been indispensable in the recent discovery of new fish species at Curaçao, from mesophotic depths at 70–80 m (Baldwin and Robertson 2015) to depths at 120–300 m (e.g., Baldwin and Robertson 2013, 2014; Baldwin and Johnson 2014), as well as new species of deep-living molluscs from 130–315 m depth (Harasewych 2014; Harasewych and Tëmkin 2015), and sponges from 145–160 m depth (van Soest et al. 2014). Recent dives off Substation Curaçao resulted in a second locality record for an echinoid-associated deep-water shrimp (Fransen 2014) and a depth record for an *Agaricia*-associated gall crab (Van der Meij et al. 2015).

Discarded fish lines were seen over the assemblage (ESM 1). Used beer bottles and cans were observed on both dives, although this is not visible in the video. Such items, car tires, and anchors were also seen at great depths near Sea Aquarium (Bongaerts et al. 2015). This implies that even deep reefs are not immune to anthropogenic impact, and should therefore be included in the planning of marine protected areas.

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