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NOTE

Prevalence of skeletal tissue growth anomalies in a scleractinian coral: *Turbinaria mesenterina* of Malvan Marine Sanctuary, eastern Arabian Sea

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ABSTRACT: Skeletal tissue growth anomalies (STAs) of corals are capable of causing considerable degradation of reef health. This study is the first report of growth anomalies in *Turbinaria* corals and the first descriptive study of Indian corals. *T. mesenterina* colonies at 2 sites were affected by small, round to irregularly shaped growth anomalies. Prevalence of STAs was observed to be higher in *T. mesenterina* colonies with larger diameters. Prevalence of STAs on *T. mesenterina* was 71% at Site 1 and 40% at Site 2. Affected colonies were seen to be undergoing tissue damage and infiltration by filamentous algae. We describe the gross morphology of growth anomalies which can act as baseline data for growth anomalies from this region, but further investigation is needed to understand the form and etiology of this coral disease.

KEY WORDS: Corals · STAs · Gross morphology · Coral disease

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INTRODUCTION

Coral 'tumors' or skeletal tissue growth anomalies (STAs) are spherical or irregular shaped growths on the coral skeleton. They are characterised by their overgrown corallites (Burns et al. 2011, Stimson 2011). The affected tissue has fewer polyps, reduced zooxanthellae (Cheney 1975, Peters et al. 1986, Domart-Coulon et al. 2006) and reduced fecundity (Stimson 2011). The STAs are easily recognized by their characteristic shape, size and by their lack of normal zooxanthellar pigmentation (pathological bleaching) (Cheney 1975, Bak 1983). Tumor formation is an energy-draining process, as observed by depletion of lipid storage in the affected corals and reduction in the growth of healthy parts of the affected colony, rendering the corals more prone to bleaching (Yamashiro et al. 2001).

Globally, STAs have been reported on hard corals ranging from the Hawaiian Islands (Squires 1965), the Palmyra Atoll, Central Pacific (Williams et al. 2011), Heron Island of the Great Barrier Reef, Australia (Haapkyla et al. 2010), the Philippines (Kaczmarsky & Richardson 2011), the Indo-Pacific (Thinesh et al. 2009, Aeby et al. 2011), Hawaii (Stimson 2011) and the Gulf of Oman (Coles & Seapy 1998). The present study is the first descriptive report of STAs from the Indian coast.

Despite being reported from various coral regions, the etiology of STA is not fully understood. Some of the hypotheses suggest STA formation may be a result of genetic or environmental factors or a combination of both (Coles & Seapy 1998). Some corals develop tumors in response to attack by foreign organisms, including crustaceans, trematodes, polychaetes (Wielgus & Glassom 2002), algae (Morse et

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al. 1981) and endolithic skeleton-boring filamentous fungi (Le Campion-Alsumard et al. 1995). According to Peters et al. (1986) and Coles & Seapy (1998), ultraviolet radiation-induced cell damage is a potential mechanism leading to growth anomalies in corals. The severity may be related to exposure to environmental stressors such as light, high levels of sedimentation (Riegl et al. 1996), turbidity, seasonal temperature extremes (Peters et al. 1986), poor water quality and high nutrients (Bruno et al. 2003).

In efforts to gain more understanding of coral disease in an understudied region in India, we investigated STAs from the foliose coral *Turbinaria mesenterina* (Hexacorallia: Scleractinia: Dendrophyllidae), which dominates the Malvan reef community on the west coast of India, along with *Porites* spp., located along the west coast of India in the Sindhudurg district of the state of Maharashtra. Our objectives were to study the prevalence, distribution and gross morphology of STAs in the foliose coral *T. mesenterina* observed during an underwater survey of the Malvan Marine Sanctuary (MMS) in March 2015.

MATERIALS AND METHODS

Study site

The MMS is a marine protected area (MPA) and nearshore coral reef with an area of 29.12 km^2 (Government of India 2001) located between 16° 02′ 00″ N–16° 03′ 90″ N and 73° 25′ 00″ E–73° 29′ 25″ E (Fig. 1) — the only protected reef along the central west coast of India. The patch reef, located in the core area of the MMS's MPA harbours 74 species of fishes, 73 species of sea weeds and 9 coral species, as well as 181 other associated flora and fauna species (Parulekar 1981). Two sites were selected randomly along a distance gradient of 2 km, both composed primarily of rocky substratum, followed by dead coral rubble, an absence of branching *Acropora* corals due to high wave exposure (Qasim & Wafar 1979), annual bleaching events (De et al. 2015), abundant macroalgae and low numbers of herbivores, possibly due to overfishing (authors' pers. obs.). Depth ranged between 1.5 and 4 m and 5 and 7 m in Sites 1 and 2, respectively.

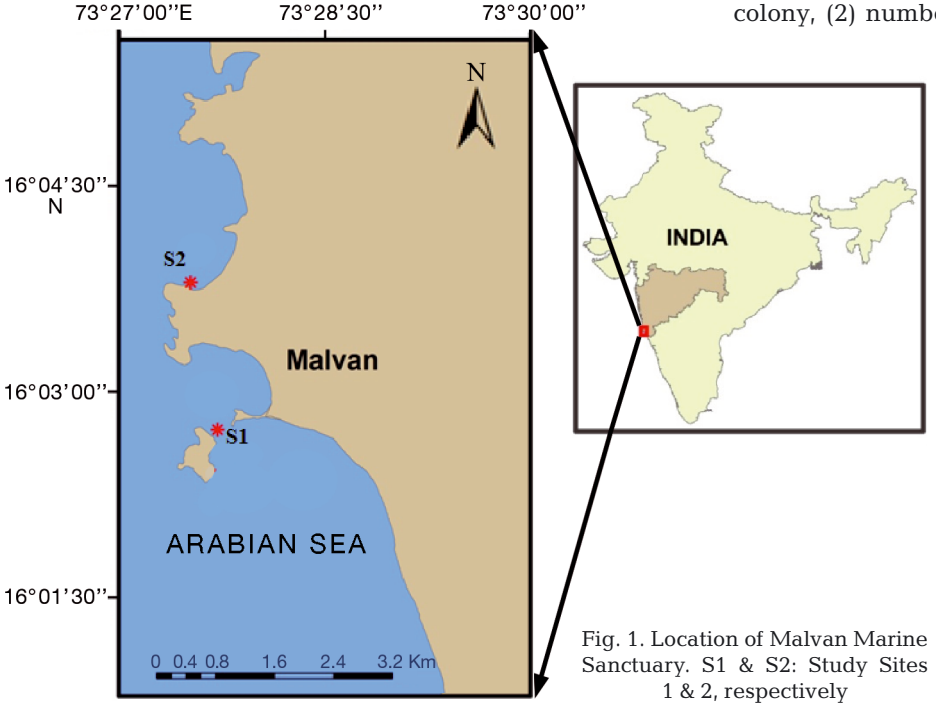

Fig. 1. Location of Malvan Marine Sanctuary. S1 & S2: Study Sites 1 & 2, respectively

Underwater survey

Surveys were done at both sites during March 2015 with the aid of SCUBA. At each site, belt transects (Hill & Wilkinson 2004) (50 × 2 m) were laid in triplicate, separated by a distance of ~50 m, perpendicular to the shore, along the depth contour of 2–4 m in Site 1 and 5–7 m in Site 2. All the *Turbinaria mesenterina* colonies falling within the belt transect were enumerated. Distribution and prevalence of STAs on *T. mesenterina* at both sites were recorded. We documented (1) diameter of the colony, (2) number of growth anomalies per colony and (3) size of the growth anomalies on *T. mesenterina* colonies. STAs on *T. mesenterina* were also recorded with digital photographs and videography, using Nikon AW120 (14 megapixels) and GoPro Hero4 (12 megapixels) underwater cameras. Locations were mapped with a Garmin GPSMAP 78S and the distances between the sites were determined. The growth anomalies on *T. mesenterina* corals were described morphologically following Work & Aeby (2006). Percent cover of coral, algae, sand and rocks was calculated using a 50 m long-line intercept transect (English et al. 1997) at both sites in triplicate.

Statistical analysis

A chi-squared test of independence, using Statistica 13, was used to analyse the difference between the prevalence of STAs in Sites 1 and 2. The relation between *Turbinaria* colony diameter and number of tumors in Site 1 was analysed by Spearman rank order correlation analysis using Statistica 13.

RESULTS

The substrate was observed to be dominated by marcoalga-covered rocks and dead corals. *Porites* spp. was the most dominating coral, followed by *Turbinaria* spp. in both the sites (Table 1).

STA morphology

Growth anomalies on *T. mesenterina* appeared as distinct globular, pigmented to partially bleached masses of coral skeleton (Fig. 2A). The growth anomallies were described with morphological diagnosis (Table 2). Approximately 30% of the growth anomalies were infiltrated by filamentous algae (Fig. 2A). In ~25% of cases the growth anomalies had grown and coalesced together (Fig. 2B). Tissue damage, where the bare coral skeleton was covered with algae and with a total loss of polyps (Fig. 2C), was prevalent in ~70% of the colonies with growth anomalies. Distribution of the growth anomalies was mostly towards the periphery of the colonies, extending towards the rim. Colonies were damaged by a high amount of sedimentation at both sites (Fig. 2C). STA prevalence on *T. mesenterina* was 71% in Site 1 and 40% in Site 2 (Table 3). Chi-squared tests of independence to determine the difference between prevalence of STAs at Sites 1 and 2

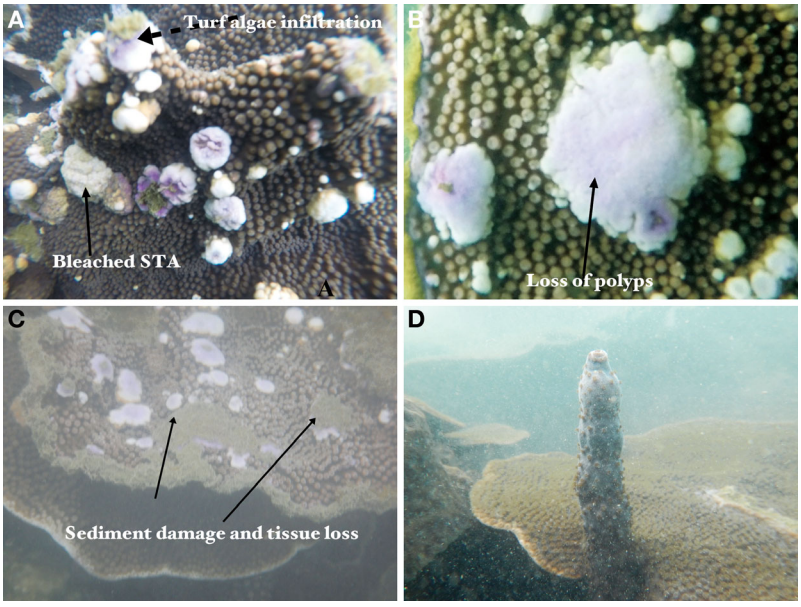

Fig. 2A–D. Skeletal tissue growth anomalies (STAs) on *Turbinaria mesenterina*. (A) Note multifocal distribution of variably sized nodular growth overlaid by unpigmented tissues (solid arrow) some of which are ulcerated and overgrown with turf algae (dashed arrow). (B) An enlarged STA, showing loss of polyps. (C) A colony with signs of sediment damage and tissue loss. (D) Pillar-like atypical growths on *T. mesenterina* colonies

Table 1. Percent cover of algae, coral, sand and rock at the 2 study sites. CCA: crustose coralline algae

	% Cover	
	Site 1	Site 2
Macroalgae	24.20	16.48
Turf algae	10.56	9.22
CCA	1.84	4.76
Porites spp.	15.00	17.76
Favites spp.	9.44	7.80
Plesiastrea spp.	6.32	5.80
Turbinaria spp.	13.90	13.46
Siderastea spp.	1.52	0.12
Coscinaria spp.	1.10	0.10
Sand	6.08	11.72
Rock	10.04	12.78

Table 2. Description of skeletal tissue growth anomalies (STAs) on *Turbinaria mesenterina* (method adapted from Work & Aeby 2006). See also Fig. 2 in the present study

Description	
Distribution of STAs	Multifocal to coalescing
Location on colony	Peripheral
Edges	Indistinct
Margins	Undulating, serpigious
Shape	Circular to irregular
Relief	Nodular to exophytic
Size	Small
Number	1–50
Colour	Brown, purple to bleached
Texture	Rugose
Morphological diagnosis	
Extent	Mild to moderate
Time	Chronic, subacute process
Lesion	Discolouration, reduced number of polyps, tissue loss, infiltrated by filamentous algae
Structures affected	Skeleton, polyps

Table 3. Description of STAs on *Turbinaria mesenterina* found in the MaIvan Marine Sanctuary (n = 3 transects per site)

Site	Location	Depth (m)	No. of *Turbinaria* colonies (mean)	Colony size (mean, cm) Max.	Min.	No. of colonies with STAs (mean)	STA size (mean, cm) Max.	Min.	STA prevalence (mean, %)
1	16°02′41″N, 73°27′41″E	2–4	24	35	2	17	3	0.2	71
2	16°03′54″N, 73°27′26″E	5–7	10	200	20	4	2	0.3	40

revealed no significant difference in prevalence (χ^2 = 2.84, p = 0.0919, df = 1) between sites. Spearman rank order correlation analysis showed a significant positive relationship between *T. mesenterina* colony diameter and number of tumors for Site 1 (n = 15, Spearman R = 0.708, p = 0.0031). Another growth abnormality in the form of distinct pillar-like skeletal growths (Fig. 2D) with fewer polyps were observed in 4 colonies of *Turbinaria* spp. (ending in small branches). Normal colonies consist typically of unifacial horizontal plates or sometimes vertical growths. The prevalence of this abnormality on *Turbinaria* was 8.33 and 20% at Sites 1 and 2, respectively, and did not differ significantly between the 2 sites (χ^2 = 0.93, p = 0.3360, df = 1).

DISCUSSION

STAs have been reported in around 16 Caribbean and 24 Indo-Pacific scleractinian corals (reviewed by Sutherland et al. 2004). Amongst them, acroporids are the most susceptible to developing growth anomalies (Cheney 1975, Bak 1983, Peters et al. 1986, Coles & Seapy 1998, Yamashiro et al. 2000). Atypical morphology in the form of 2 'arms' has been observed in a *Turbinaria peltata* colony (Chou & Ng 2010), but there have been no previous reports of tumor-like growth anomalies in *Turbinaria*, globally. Therefore, this study provides the first evidence of STAs for the *Turbinaria* genus and is the first descriptive study of STAs from Indian corals. The STAs of *Turbinaria* recorded here show similar characteristics to growth anomalies observed in other genera. The STAs observed here are globular and bleached and, in ~25% cases, had coalesced together, which agrees with the description of growth anomalies in *Acropora valenciennessi* (Coles & Seapy 1998). Similary, Gateno et al. (2003) and Work et al. (2008) characterised growth anomalies with few or no polpys which is consistent with the trend observed in this study. The size of the coral colony was the most significant predictor of the prevalence of STAs in Site 1. Our results agree with the previous description by Loya et al. (1984), which suggested that large colonies had more STAs per unit mean colony diameter as compared to smaller colonies, and larger colonies are more susceptible to external damage. Domart-Coulon et al.(2006) also reported larger colonies of *Porites compresssa* with higher numbers of STAs.The healthy parts of the colony were seen to undergo damage, which agrees with Peters et al. (1986) who showed that growth anomalies in *Acropora palmata* are progressive, leading to death of the surrounding normal tissue. Skeleton growths on *Turbinaria* spp. (Fig. 2D) could be a response to sediment accumulation. Although *Tubinaria* corals usually have horizontal plates or lamellae morphology, atypical growth form (funnel-shaped) has been observed to concentrate sediments in the centre of the colony (Riegl et al. 1996).

Our study has established the presence of STAs on *Turbinaria* corals, with growth anomalies similar to those characteristic in other coral genera. Although this study does not answer the question of the etiology of coral growth anomalies, it provides a strong case for further study in the MMS, which is a relatively understudied reef area.

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