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硫黄鳥島初記録の有藻性スナギンチャク類

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New records of zooxanthellate zoantharians (Brachycnemina: Zoantharia: Anthozoa: Cnidaria) from Iwotorishima Island in the Ryukyu Islands

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Abstract. During a recent ecological survey of the reefs of Iwotorishima Island in the Ryukyu Islands, three species of zoantharians were noted. Past knowledge of zoantharians from this island is sparse, and only one species has previously been reported; *Palythoa tuberculosa*. In our survey, we also noted *Palythoa tuberculosa*, along with two other zoantharian species recorded for the first time from this island (*Palythoa mutuki* and *Zoanthus sansibaricus*).

Introduction

Iwotorishima Island is a volcanic island, and is the northernmost point in Okinawa Prefecture. While some research has focused on the unusual acidified reefs on the east coast of the island (Inoue et al., 2013), little marine biodiversity research has been performed around the island. Additionally, the assemblages of the acidified reefs on the island have been reported to be dominated by a soft coral species, *Sarcophyton elegans* Moser, 1919, and the zooxanthellate zoantharian *Palythoa tuberculosa* (Esper, 1805) (see Inoue et al. 2013; Wee et al. 2019), further demonstrating that these acidified reefs represent a unique ecosystem due to the high CO_2 levels of the seawater in the lagoon. As the island is relatively isolated and further east from other islands in the Ryukyus, as well as being uninhabited, biodiversity data from the island are of interest and importance, particularly with renewed interest on the marine faunal assemblages of coral reefs and their shifts due to ocean acidification (=OA) (Inoue et al. 2013; Wee et al. 2019).

In September 2020, we had the opportunity to join an ecological survey of the shallow water acidified reefs of Iwotorishima Island. During our shallow water surveys, we noted two additional species of zooxanthellate zoantharians, and report on these new records here.

Materials and methods

Snorkeling in the shallow reef area of the southeastern coast was conducted for three days, September 14–16, 2020. We snorkeled at the same reef as reported in Inoue et al. (2013) and Wee et al. (2019) (centered around 27°52'11.8"N, 128°14'01.8"E) (herein called the "southern reef"), as well as at an additional reef further north on the east coast (centered around 27°52'40.2"N 128°13'41.2"E; "northern reef") (Fig. 1). Within the southern reef lagoon, there was a clear CO_2 vent area on the northern side, and a "control" area with relatively normal CO_2 levels on the southern side (Inoue et al. 2013; also Fig. 1). Between these two areas was an area of medium CO_2 levels (~ 831 ppm in Inoue et al. 2013). These reefs spanned from 0 (intertidal) to 4 m in depth. All observed zoantharians were photographed in situ, and identified following Reimer (2010) and Mizuyama et al. (2018) based on external morphological features; presence or absence of sand in body wall and column, relative amount of emergence of polyps from common tissue (see also Pax 1910), tentacle number, and external coloration.

Results

During snorkeling surveys, we observed three zooxanthellae zoantharian species, as listed below.

***Palythoa tuberculosa* (Esper, 1805)**
(Fig. 2A)

This species, similar to as reported in Inoue et al. (2013), was common in the "medium" CO_2 area of the southern reef, and was also found in the "control" area (Fig. 1) of the shallow inner reef. Additional

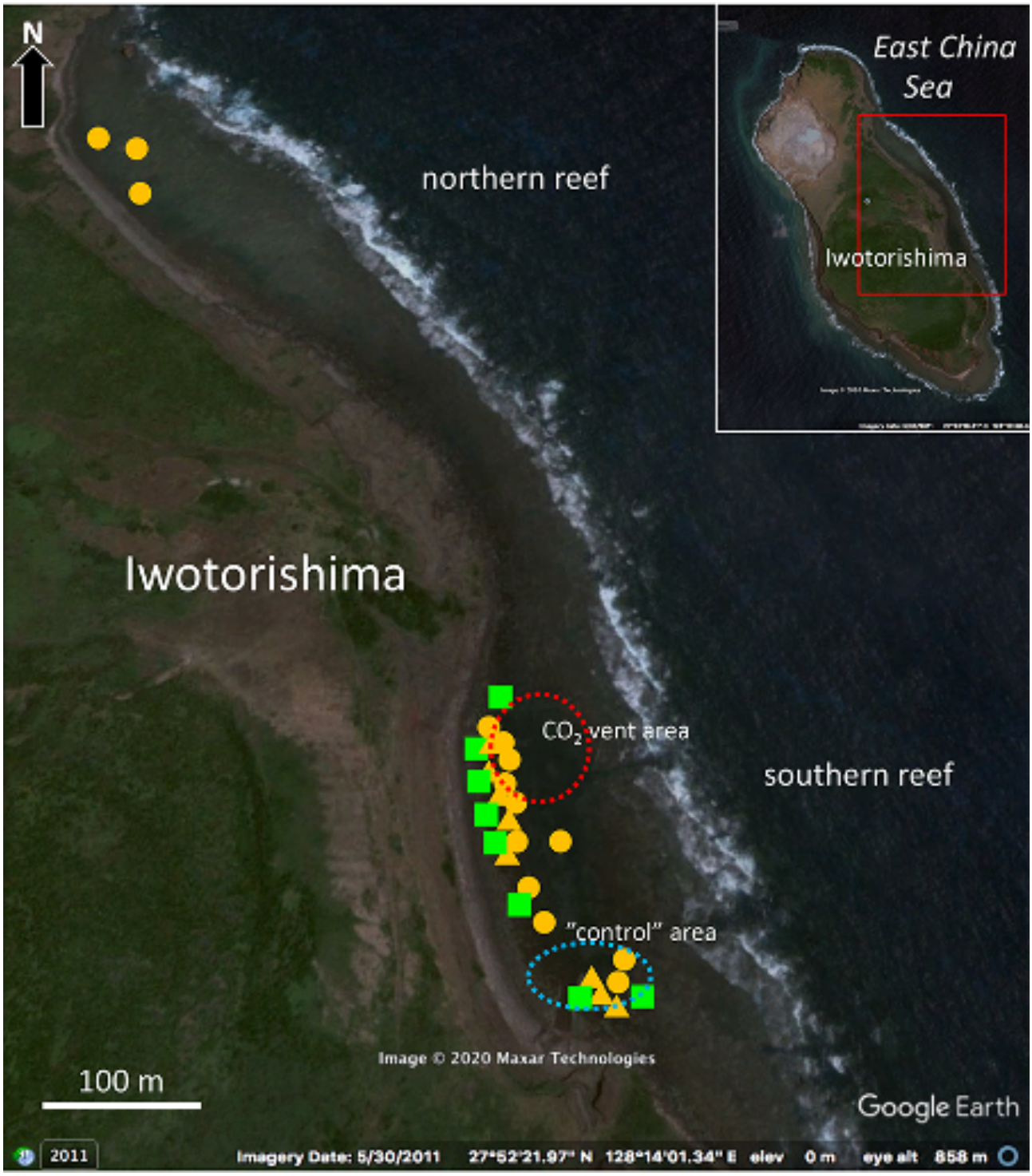

Fig. 1. Map of Iwotorishima Island showing the locations of the study sites, with the CO_2 vent area (dotted red circle) and "control" area (dotted blue circle) shown. Approximate locations of aggregations of colonies of zooxanthellate zoantharians shown. Orange circles = *P. tuberculosa*, orange triangles = *P. mutuki*, and green squares = *Z. sansibaricus*.

colonies were also observed in the reef to the north of the seep area (Fig. 1), although they were not nearly as common as at the southern reef. Colonies at Iwotorishima Island were slightly darker in color than colonies observed around reefs of other colonies of Okinawa Prefecture, due to the uptake of dark volcanic sand (Haywick & Mueller 1997) (Fig. 2A). In areas in the southern reef, this species was the dominant or second-most dominant benthos, after *Sarcophyton elegans* soft coral colonies (Fig. 2B). This species was found most commonly in 1 to 2 m of water.

Representative specimen: RUMF-ZG-04464, Fujukan University of the Ryukyus Museum.

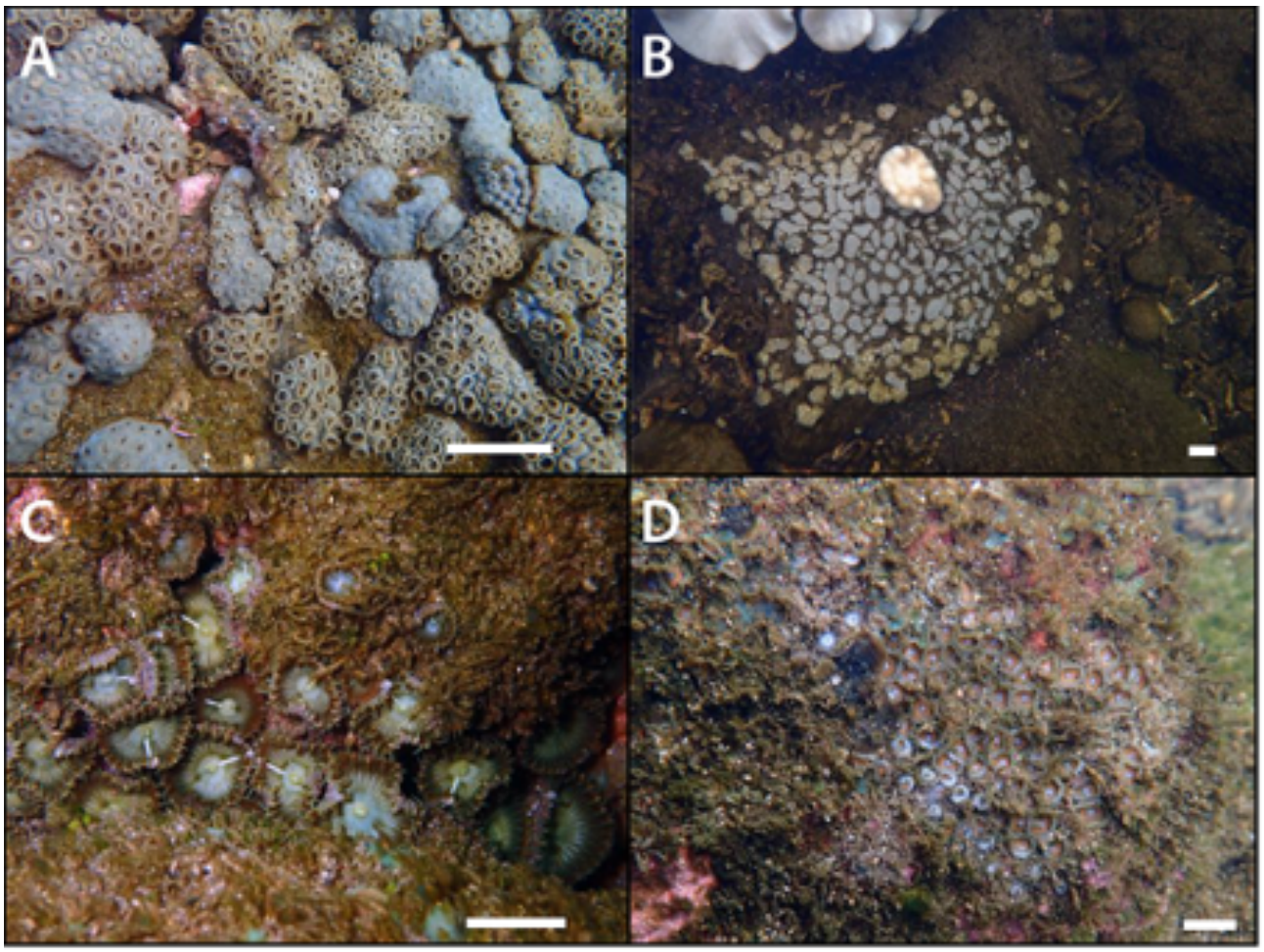

Fig. 2. Zooxanthellate zoantharians in situ at Iwotorishima Island. A) *P. tuberculosa*, showing the slightly dark coloration from inclusion of volcanic sand. B) *P. tuberculosa* with *Sarcophyton elegans*. C) *P. mutuki*, and D) *Z. sansibaricus*. Scale bars: A, B = approximately 5 cm; C, D = approximately 1 cm.

***Palythoa mutuki* (Haddon & Shackleton, 1891)**
(Fig. 2C)

This species was less abundant than *P. tuberculosa*, but still quite commonly observed during snorkeling surveys, and occurred in patches (Fig. 2C). The species was always slightly shallower and more shoreward from *P. tuberculosa*, often in water approximately 50 cm deep. Colonies were observed in the "medium" CO_2 and "control" areas of the southern reef, but were not observed in the more northern reef (Fig. 1).

Representative specimen: RUMF-ZG-04465, Fujukan University of the Ryukyus Museum.

***Zoanthus sansibaricus* Carlgren, 1900**
(Fig. 2D)

Similar to *P. mutuki*, this species was not as abundant as *P. tuberculosa*, but was still quite common on the southern reef at both "medium" CO_2 and "control" areas. *Z. sansibaricus* was predominantly found on large rocks that dot the shallow intertidal and subtidal areas of the bay, and was usually slightly shallower than *P. mutuki*, in the lowest parts of the intertidal zone. This species was not observed in the northern reef.

Representative specimen: Not obtained due to limited time at Iwotorishima Island.

Discussion

Overall, the results of our snorkel survey fit well with past observations from other locations in Okinawa Prefecture, as these three species are generally the most commonly observed species on reefs (Irei et al. 2011). As well, both *P. mutuki* and *Z. sansibaricus* are known from the lower intertidal zone (Kamezaki et al. 2013; Mizuyama et al. 2018), while *P. tuberculosa* is known as a habitat generalist. All three species have wide ranges across the Indian and Pacific Oceans (Reimer & Hickman 2009; Polak et al. 2011; Hibino et al. 2014; Risi & Macdonald 2015; Reimer et al. 2017).

Very little work has been specifically done on

zooxanthellate zoantharians (e.g. genera *Palythoa* and *Zoanthus*) and OA, and the effects of CO_2 seeps on the zoantharian species observed at Iwotorishima Island is unknown. However, as zoantharians do not make calcium skeletons, and based on the abundances of the species we observed at Iwotorishima Island, it appears that at least for "medium" levels of CO_2 (= 831 ppm) as reported in Inoue et al. (2013) there may not be negative effects to these zooxanthellate zoantharians from this environment.

However, this theory needs to be approached with caution based on the results of other recent studies. López and colleagues (in press) reported negative effects on two *Palythoa* spp.'s growth rates under a pH of 7.5 in tank experiments. Additionally, Wee et al. (2019) noted a decrease in zooxanthellae *Cladocopium* diversity in *P. tuberculosa* around the Iwotorishima Island CO_2 seep compared to the "control" location. Similarly, Graham & Sanders (2016) noted that symbiont partnerships may be critical in assessing the reaction of zooxanthellate species to OA during tank experiments using *Zoanthus* and *Palythoa* spp. In order to better ascertain the resilience of zoantharians and their Symbiodiniaceae to high CO_2 levels, it is clear further observations and experiments are needed. The octocoral and zoantharian dominated CO_2 seep at Iwotorishima Island represents a chance to investigate benthic communities of coral reefs of a possible future.

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要旨 . 硫黄鳥島におけるスナギンチャク類の過去の記録は *Palythoa tuberculosa* イワスナギンチャク 1 種と少ない . 最近実施したサンゴ礁生態調査において , イワスナギンチャクに加え , 硫黄鳥島初記録となる *Palythoa mutuki* と *Zoanthus sansibaricus* キクマメスナギンチャクも記録した .