The ecology of the red algae *Ramicrusta textilis*, its dynamic with corals and the evaluation of possible management strategies to minimize its threat to coral reefs around Puerto Rico

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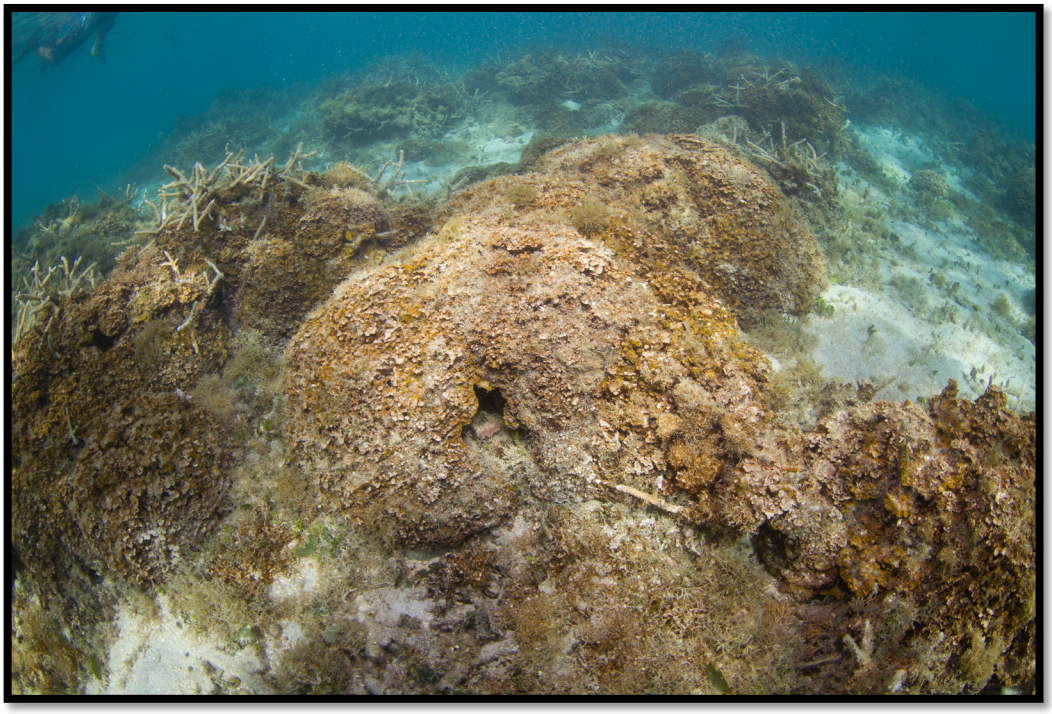

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SUMMARY

The encrusting red alga, commonly known as Ramicrusta (*Ramicrusta textilis*), is present in Puerto Rico and has been observed overgrowing corals and octocorals. This study quantified the presence and distribution of Ramicrusta at Caja de Muertos reefs, south of Puerto Rico. Live corals covered 12.4 % of the reefs benthic composition in shallow (less than 2 m in depth) areas nearshore, while *R. textilis* covered 27.9 % in the same areas. Of the 359 coral colonies surveyed, 50.2 % were partially overgrown by *R. textilis* with *Acropora cervicornis*, *Orbicella faveolata,* and *Millepora alcicornis* being the most susceptible to overgrowth. *Ramicrusta textilis* seems to be the principal live calcareous benthic organism in this back reef environment creating habitat features that support fish and macro-invertebrate communities.

INTRODUCTION

Along with tropical rainforest, coral reefs are one of the most diverse ecosystems on the planet with high productivity and biodiversity (Small *et al.* 1998). Macroalgae are an important (although commonly overlooked) component of the coral reef ecosystem. This benthic group is usually inconspicuous on well-developed reefs where nutrient concentrations are low and grazing pressure is high (Hughes 1994, Littler & Littler 1984, Tsai *et al.* 2004). In the recent past, reports of rapidly declining reef condition and localized phase shifts from scleractinian corals to macroalgae dominance have highlighted the importance of competition for space between corals and macroalgae, the outcome of which can have significant implications for long-term survivorship and growth of corals (Lirman 2001). As reef undergo phase shifts from coral to algae alternate states, a better knowledge of algal-coral completive interactions is necessary to understand current reef dynamics and study future trends.

A variety of mechanisms are employed by sessile reef organisms in their ongoing completion for space (Lang 1973, Nugues *et al.* 2004). Several species of red encrusting macroalgae in the family Peyssonneliaceae overgrow corals (James *et al.* 1988, Antonius and Ballesteros 1998, Verlaque *et al.* 2000, Bruckner *et al.* 2008, Pueschel and Saunders 2009, Ballantine and Ruiz 2011), and one species in particular, *Ramicrusta* sp. (Eckrich *et al.* 2011) overgrows many species of corals and other benthic organisms in Lac Bay, Bonaire. This particular alga is in the genus *Ramicrusta*, first reported from the Caribbean in 2009 (Pueschel and Saunders 2009)(Photo 1 Appendix). Despite the competitive abilities of *R. textilis* and several other Peyssonnelid algae, little is known about the taxonomy, range, distribution and abundance for the species in this family. Also the biological and environmental factors governing competitive outcomes among these encrusting algae and other reef organisms are poorly understood.

Because of the recent awareness regarding the high abundances of this algae and the apparent threat it may pose to corals, we investigated the competitive interactions of *R. textilis* in Caja de Muertos Island, Puerto Rico. This study was focused on quantifying the following factors: the proportion of benthic cover in the back reef zone, the proportion of coral colonies of different species in competitive interactions with the Ramicrusta algae and the total area of substratum covered by the algae.

METHODS

The coral reefs studied were located in the back reef zone of the eastern tip of Caja de Muertos at 17°53'52.10" N, 66°30'28.86" W (Figure 1). This zone ranges from 0 to 2 m in depth. It has been previously documented that *R. textilis* is abundant in this zone and is overgrowing corals and other benthic organisms (Ballantine et al. 2011, Ballantine & Ruiz 2013)(Photo 2 Appendix). It forms a thin, crustose layer of variable color (mustard to burgundy) that spreads up from the substrate and grows over living tissues of other organism (Photo 3 Appendix).

Twenty randomly selected stations within the back reef zone were surveyed in from February to March 2015. Benthic cover was determined along a 20-m transect line using the line intercept method (LPI) survey protocol by the National Coral Reef Monitoring Program (NCRMP- NOAA). LPI data includes 100 points, at 20 cm intervals, starting at 20 cm mark and ending at the 20 m mark along the transect tape. Categories included live stony coral (by species), gorgonian (by growth form), macroalgae (by species), turf algae, cyanobacteria, coralline algae, *Peyssonnelia* sp., *R. textilis*, sand and *Millepora alcicornis* (fire coral). Frequency of *R. textilis* overgrowth of living corals was determined by surveying and area 2m on either side of each 20m transect line (total area 80 m^2). Coral colonies greater than 10 cm in diameter were identified, and presence or overgrowth of any part of the colony by *R. textilis* was recorded. *R. textilis* overgrowth was defined as the presence of a thin crustose layer of *R. textilis* growing over living coral tissue (Photo 4 Appendix).

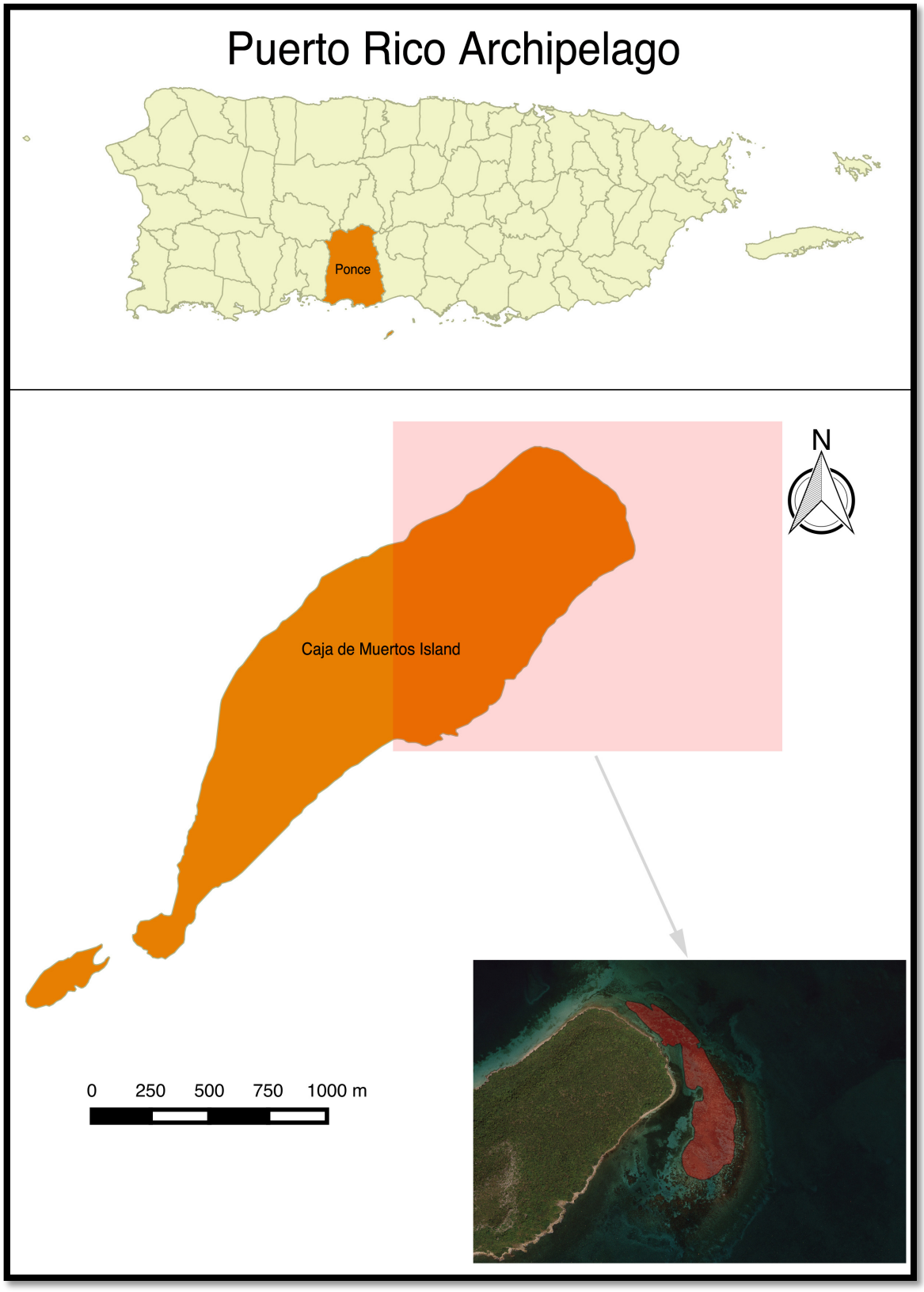

Figure 1 Study area in Caja de Muertos Island, Ponce Puerto Rico.

RESULTS AND DISCUSSION

The dominant benthic substrate of the back reef at Caja de Muertos was sand and *R. textilis*. Mean (± SD) percent of proportion of benthic cover was 30.5 (± 18) for sand and 27.9 (± 18.9 for *R.textilis*)(Table 1). *Ramicrusta textilis* covered more than twice the area than live coral 12.4 (± 4.69). *Ramicrusta textilis* covered 158,400 m^2 of the back reef area (Figure 2). The remainder of the area surveyed was comprised of macroalgae 14.7 (± 5.6), turf algae 8.7 (± 7.16), *Peyssonnelia* spp. 3.1 (± 8.14), coralline algae 1.3 (± 2.9), cyanobacteria 1 (± 2), and *Millepora alcicornis* 0.4 (± 1.26).

Table 1 Mean percent benthic cover ± SD by substrate category using line intercept method (20m) in Caja de Muertos, Ponce (n=20).

Substrate type	Mean percent cover	±SD
Sand	30.5	18
Ramicrusta textilis	27.9	18.9
Macroalgae	14.7	5.58
Stony corals	12.4	4.69
Turf algae	8.7	7.16
Peyssonnelia sp.	3.1	8.14
Coralline algae	1.3	2.9
Cyanobacteria	1	2
Millepora alcicornis	0.4	1.26

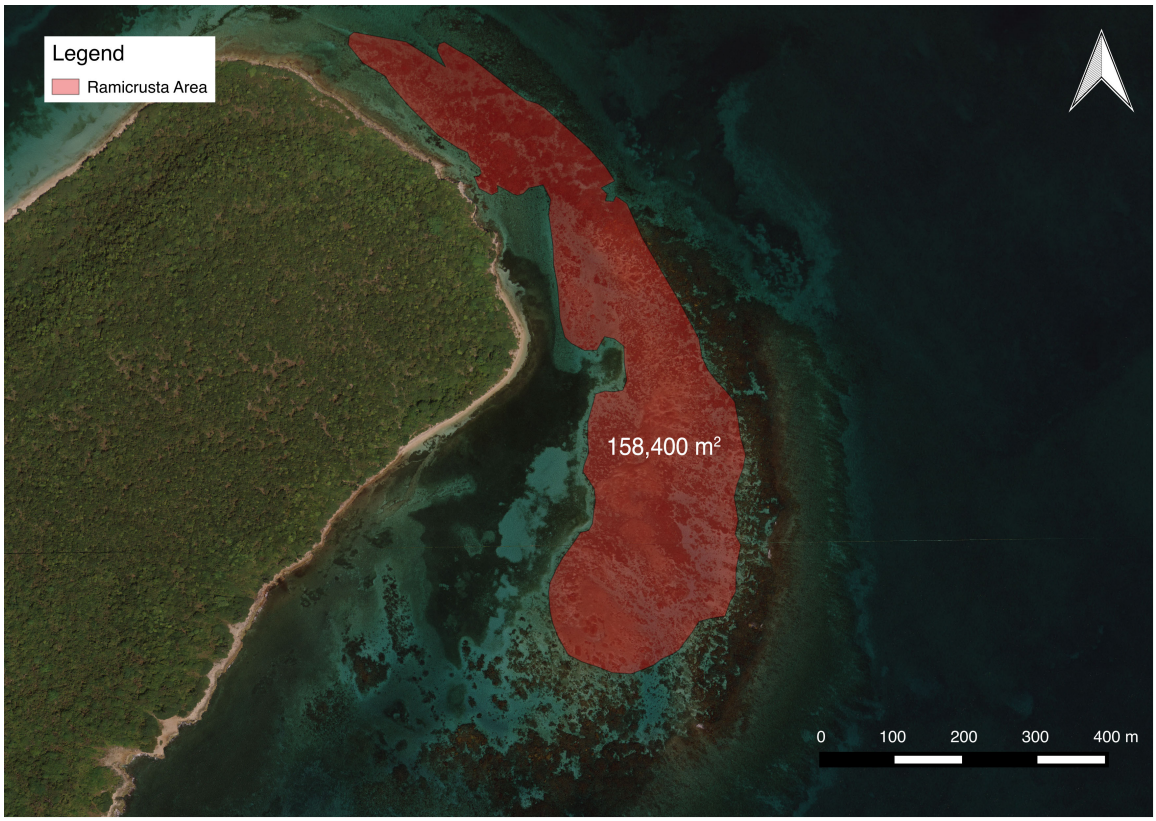

Figure 2 Area covered by *Ramicrusta textilis* in the back reef zone of Caja de Muertos, Ponce.

Ramicrusta textilis was overgrowing 11 species of stony corals, a hydrocoral, and sea rods (Table 2). *Porites astreoides* was the most abundant coral species (n = 124) followed by *Acropora cervicornis* (n = 70) and *Orbicella faveolata* (n = 32). Of the 359 coral colonies surveyed, 50.2% were being overgrown by *R. textilis*. Coral species that had more than 50% of their colonies overgrown by *R. textilis* included *A. cervicornis* (Photo 5 Appendix), *O. faveolata, O. annularis, Millepora alcicornis, P. porites,* and *P. astreoides.* No *Acropora palmata* (n=11) were being overgrown by *R.textilis*. No coral recruits were observed growing on the algae *R. textilis* in the transects.

Table 2 Percent coral colonies being overgrown by *Ramicrusta textilis* in 20 x 2 m belt transect in Caja de Muertos, Ponce (n=20).

Coral species	Total of colonies surveyed	No. colonies overgrown by *Ramicrusta*	Percent of colonies being overgrown
Porites porites	12	6	50.0
Porites furcata	5	1	20.0
Porites astreoides	124	62	50.0
Siderastrea siderea	10	2	20.0
Acropora cervicornis	70	65	92.9
Acropora palmata	11	0	0.0
Orbicella faveolata	32	27	84.4
Orbicella annularis	16	11	68.8
Dendrogyra cylindrus	1	1	100.0
Pseudodiploria strigosa	18	5	27.8
Millepora alcicornis	13	9	69.2
Agaricia sp.	17	0	0.0
Sea Rods	46	32	69.6
Total	**359**	**221**	**50.2**

In conclusion *R. textilis* is locally abundant and is capable of overgrowing a wide variety of benthic organisms (Eckrich *et al.* 2011, Ballantine & Ruiz 2013). This may cause decreased resilience of the coral reef and has the potential to alter coral community composition. This may be representative of the coral-algae phase shift documented at other sites in the Caribbean (Photo 6 Appendix). Recent reports have highlighted the abundances of this algal genus in various reefs around Puerto Rico (reported from Mona Island, Punta Guaniquilla in Cabo Rojo, Arrecifes de la Cordillera in Fajardo and Culebra Island) and the competitive advantage it is showing overgrowth of many coral species.

Moreover, preliminary evidence from multiple coral reef ecosystems around Culebra Island and the southwestern Puerto Rican shelf (Hernández-Delgado, unpublished data) suggests that no coral recruitment occurs over *Ramicrusta* spp.-dominated bottoms. Also, reef fish communities, in particular, herbivore fish guilds, show significant alterations in such habitats. The long-spined black sea urchin, *Diadema antillarum*, is largely absent from these habitats. This suggests that lack of herbivorous organisms might be a critical factor promoting dominance by *Ramicrusta* spp. and that rapid substrata dominance may halt natural reef recovery processes by limiting successful coral recruitment and coral tissue regeneration.

A recent visit to Cayo Blanco north of Vieques Island, *D. antillarum* seemed to be feeding on *Ramicrusta* sp. (Photo 7 appendix 1). There is a need to address such impacts across multiple spatial scales, depth zones and reef environmental conditions, therefore the identification of this species should be a priority in coral reef monitoring programs and further research is required to address this threat.

FURTHER RESEARCH AND POTENTIAL MANAGEMENT STRATEGIES

Currently there are many information gaps that preclude any recommendations for management strategies. Important components of the information needed and programed for this research (reproduction and tissue regrowth) were not conducted due to administrative constraints.

- Clarify *Ramicrusta* diversity in Puerto Rico (possibility of multiple species)
- Measure the regrowth capabilities of *Ramicrusta* spp. (need long-term monitoring)
- Reproduction analysis to formulate possible removal strategies (repeated sampling)
- Gut contents removal of *Diadema antillarum* for feeding evidence of *Ramicrusta* spp.
- Characterization of the non-cryptic faunal community associated with the physical structure created by *Ramicrusta* spp. and other habitats to understand the magnitude and value of habitat impacts of this encrusting alga
- The fish associated with the encrusting algae *Ramicrusta* spp. should be characterized around Puerto Rico to understand the effect of potential interactions (i.e. parrotfish grazing and habitat value)
- Standardized comparison with other reefs in which *Ramicrusta* spp. are present (i.e. Mona Island, Culebra, Arrecifes La Cordillera, Vieques Island, Playa Buye)
- Implement a pilot project to introduce *Diadema antillarum* to the back reef of Caja de Muertos for a possible bioremediation (if in fact *D.antillarum* feed on *Ramicrusta* spp.)

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APPENDIX 1

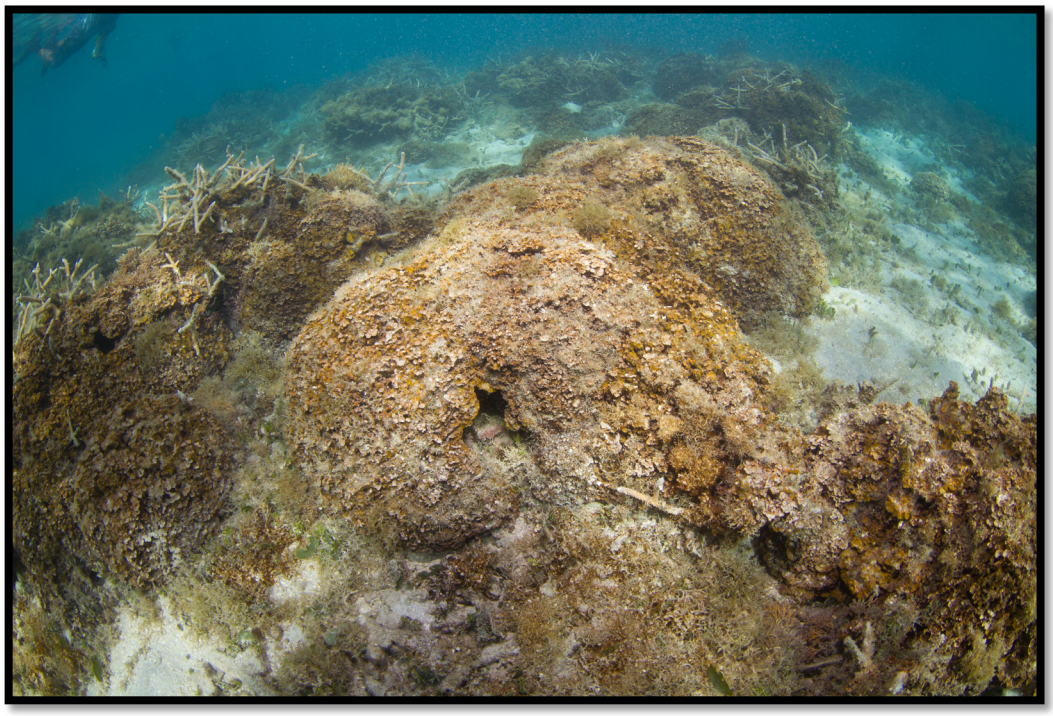

Photo 1 *Ramicrusta textilis* formations.

Photo 2 *R.textilis* overgrowing *Acropora cervicornis*.

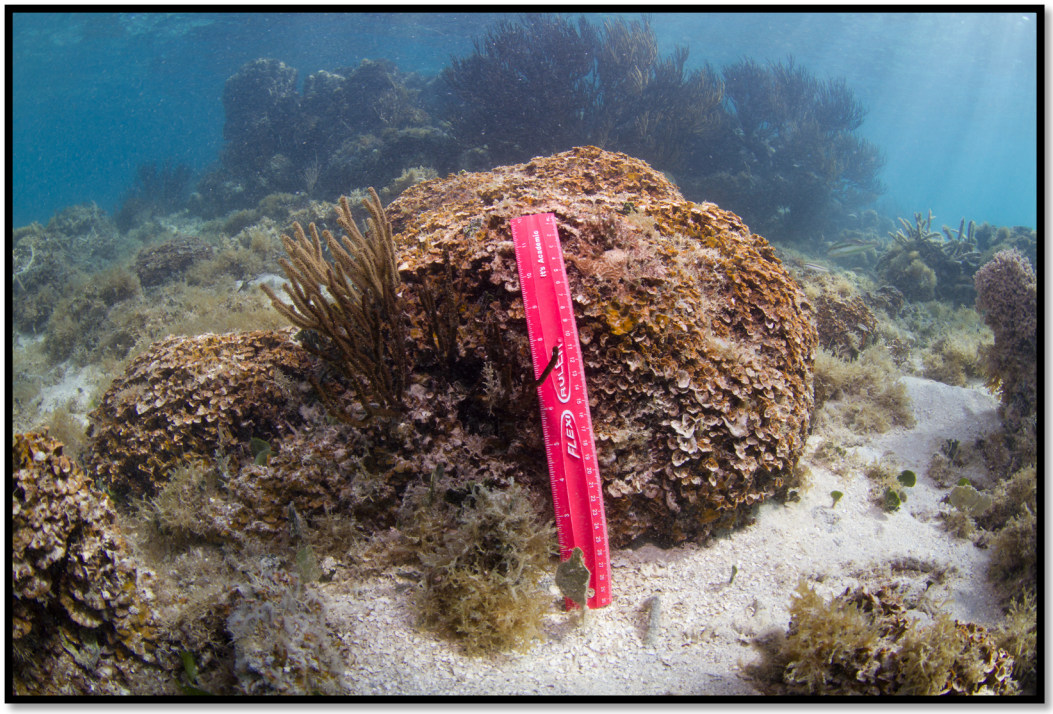

Photo 3 *R. textilis* growing from the substrate.

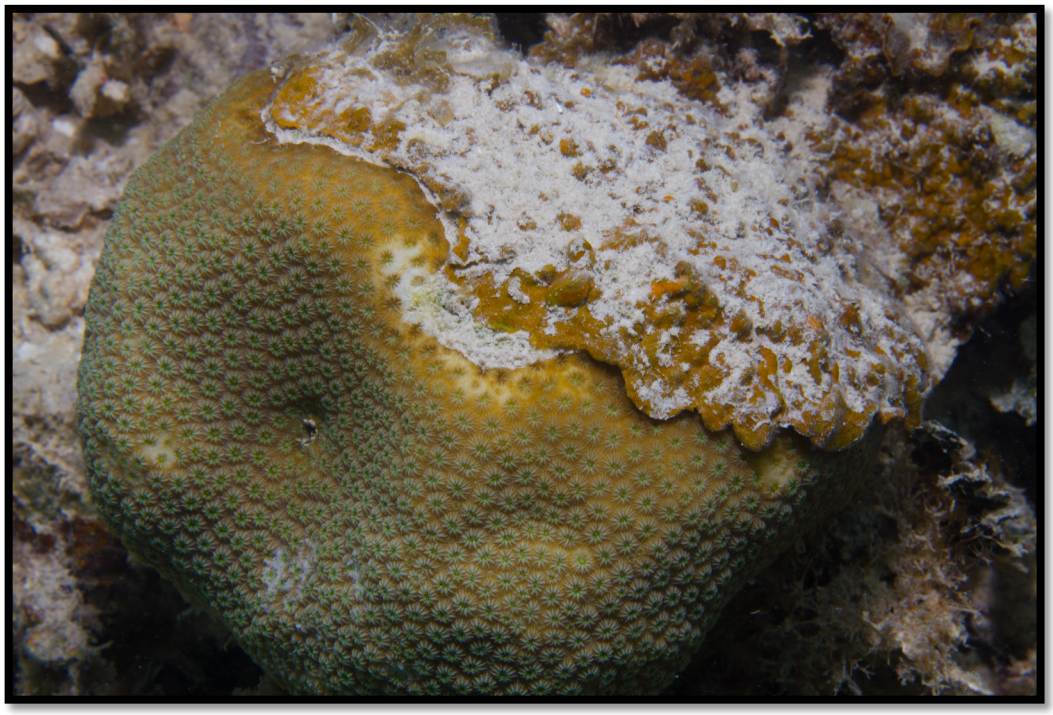

Photo 4 *R.textilis* growing over living coral tissue.

Photo 5 *Acropora cervicornis* colonies overgrown by *R.textilis*.

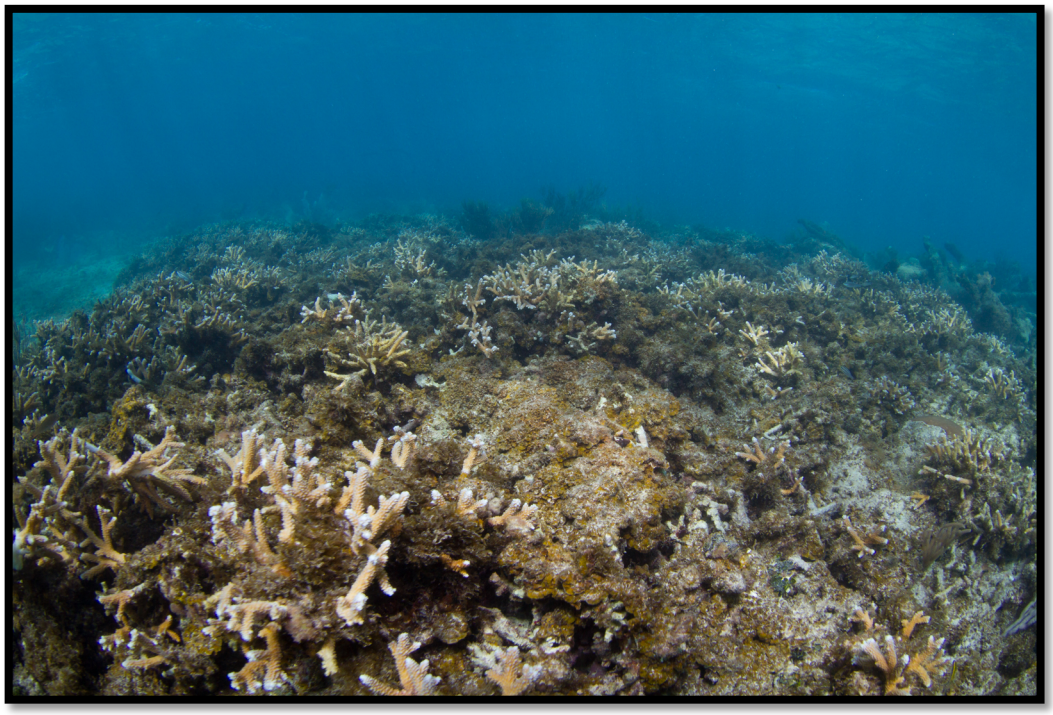

Photo 6 Algae dominated back reef area of Caja de Muertos.

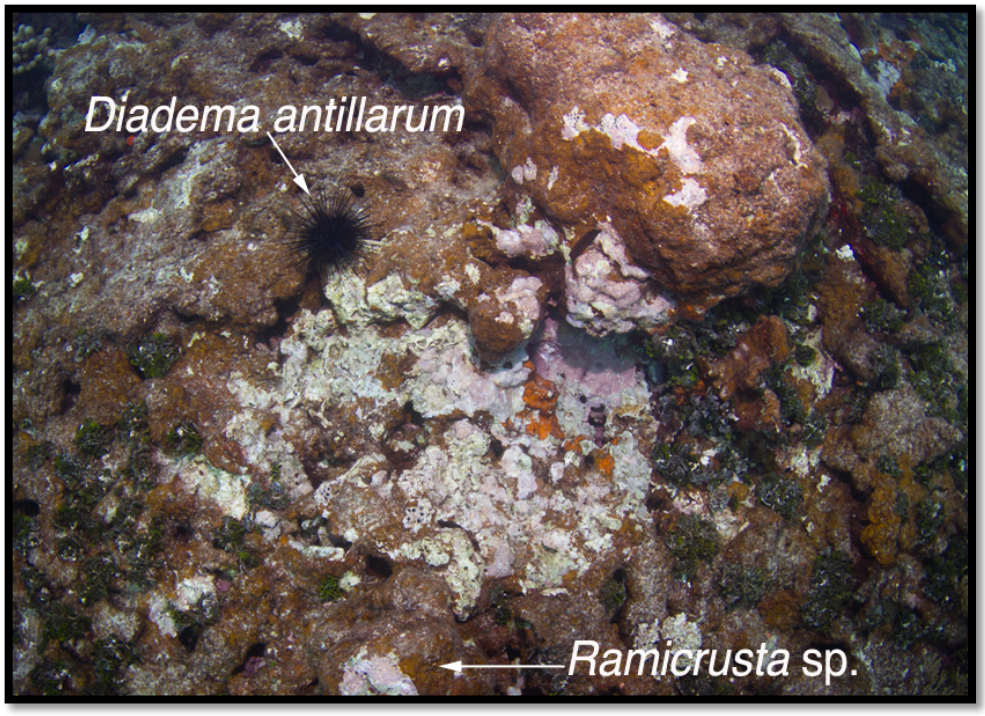

Photo 7 Sea Urchin *D. antillarum* possibly feeding on *R.textilis.*