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Aquatic Invasions Records

Expansion of the invasive corals *Tubastraea coccinea* and *Tubastraea tagusensis* into the Tamoios Ecological Station Marine Protected Area, Brazil

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Abstract

The scleractinian corals *Tubastraea coccinea* Lesson, 1829 and *Tubastraea tagusensis* Wells, 1882 are the first alien corals to be introduced into the South Atlantic and threaten native marine organisms due to their noxious attributes. This study aimed to determine the spatial distribution and relative abundance of these species throughout the Tamoios Ecological Station Marine Protected Area (MPA). Monitoring was carried out at 33 sites by two snorkel divers swimming parallel to the shore and observing the substrate, diagnosing and visually estimating the relative abundance of both species on a scale: dominant, abundant, frequent, occasional, rare or absent. The study presents new records which demonstrate that the MPA is being invaded by both species and that *T. tagusensis* is leading the invasion from west to east. Most sites are near the original probable point of introduction into the region.

Key words: alien, coral, spatial distribution, *Tubastraea coccinea*, *Tubastraea tagusensis*

Introduction

With increasing globalization and the consequent increase in international trade, aquatic and terrestrial species have been accidentally or deliberately transferred to areas outside their natural geographic distribution, where they can find suitable environmental conditions for their survival and may become more efficient than native species in their resource use (Lopes et al. 2009). According to the International Union for the Conservation of Nature – IUCN the introduction of species is a major cause of biodiversity loss. After the arrival and establishment of exotic species their distribution and abundance may increase exponentially, causing change to the receptor community and necessitating management of their impact on native species through costly control measures. The intensity of ecological change caused by invasive alien species also increases over time, reducing the natural capacity of ecosystems to recover from their condition before the invasion. For these reasons the control of invasive alien species is highly desirable and should be conducted with the greatest possible urgency (Wittenberg and Cock 2001).

The stony corals *Tubastraea coccinea* Lesson, 1829 and *Tubastraea tagusensis* Wells, 1982 (Phylum Cnidaria: Class Antozoa) are considered to be exotic to the southwest Atlantic (De Paula and Creed 2005). The genus was first reported in southeast Brazil in the late 80's incrusting oil and gas platforms in the Campos Basin and more recently has expanded to the rock shores of Ilha Grande Bay (De Paula and Creed 2005) and along the coast to Ilhabela, on the north coast of São Paulo State (Mantelatto et al. 2011).

The Tamoios Ecological Station is a Marine Protected Area (MPA) established as a Wholly Protected Conservation Unit by Federal Decree 98864/90 in 1990, which provides for the co-location of nuclear power plants and ecological stations (Brasil 2000). The station is composed of 29 discontinuous islands, islets, reefs and slabs and surrounding seas (= 1km distance) comprising a total area of 8,700 hectares of

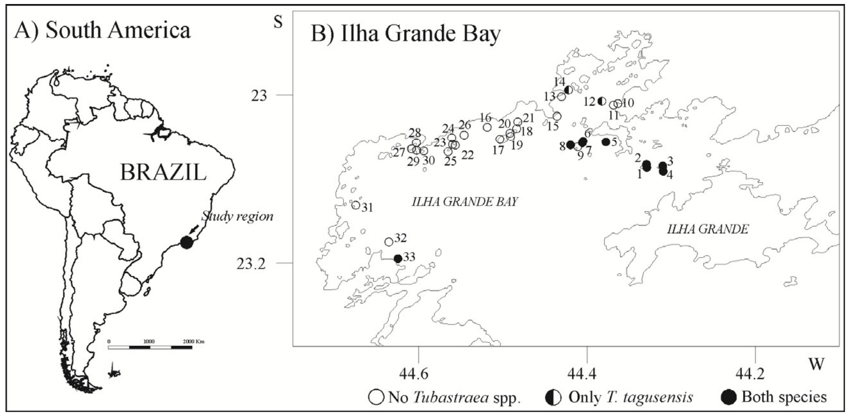

Figure 1. Location of **A**) the study region and **B**) spatial distribution of exotic corals at the Tamoios MPA, Brazil. See Appendix 1 for details.

which 97% is marine (Amorim and Nunes 2006). According to the National System of Protected Areas the main goal of conservation units is the preservation of nature and therefore threats such as exotic species should be prevented, monitored, controlled and eliminated.

The invasion of exotic species is considered the primary cause of loss of biodiversity in protected areas and on oceanic islands (Zalba and Ziller 2007) and the detection and control of these species is crucial for the preservation of these highly sensitive areas. As the Tamoios MPA is by nature highly sensitive to biological invasion and two highly invasive corals have been registered close by, the present study aimed to systematically investigate the potential marine biological invasion of *T. coccinea* and *T. tagusensis* throughout the MPA.

Methods

This study was conducted in September 2009 and March 2010 (Figure 1A). The marine portion of the MPA is characterized by islands with rocky shores, rocky shoals and slabs harboring subtidal benthic communities typical of the tropical rocky shores of the region, made up of macroalgae (multi-species turf forming, crustose coralline and foliose brown algae), heterotrophic filter feeders (mainly sponges, bryozoans and ascidians) and symbiotic autotrophs (corals and zooanthid mats). These form a mosaic over the rocky reefs and are structured into areas according to vertical gradients associated with depth of the coast (irradiance, nutrients, temperature, desiccation, sediment) and the horizontal gradients, such as light, wave action and sedimentation (Creed 2009).

The methods utilised were those previously used by De Paula and Creed (2005) and Creed and Oliveira (2007) for the large-scale mapping of the distribution of corals *T. coccinea* and *T. tagusensis*. At each site two divers, using snorkel, swam in opposite directions parallel to the rocky shore, in five one-minute transects (approximately 25m in length per minute). In each transect the divers estimated the density of coverage of each species of *Tubastraea*, assigning a DAFOR scale (Sutherland 2006) and values for classes of relative abundance: Dominant = extremely obvious populations forming many essentially monospecific patches ≥1m^2 diameter of at least one depth level, with very frequent isolated colonies and/or smaller patches spread throughout the substratum (score = 10); Abundant = frequently occurring essentially monospecific patches of 50-100 cm diameter, with frequent isolated colonies and/or small patches spread throughout the substratum (score = 8); Frequent = isolated colonies and/or small patches observed to be spread constantly throughout the substratum, with occasional occurrence of patches 10-50 cm in diameter (score = 6); Occasional: less than 10 colonies or small groups but more than 5 colonies per minute dive (score = 4); Rare = between 1 and 5 colonies found during a 1 minute dive (score = 2); Absent (score = 0). The study was carried out at 33 points previously selected from a nautical chart throughout the Tamoios MPA. At arrival the coordinates of each point were first registered with a Global Positioning System (Appendix 1).

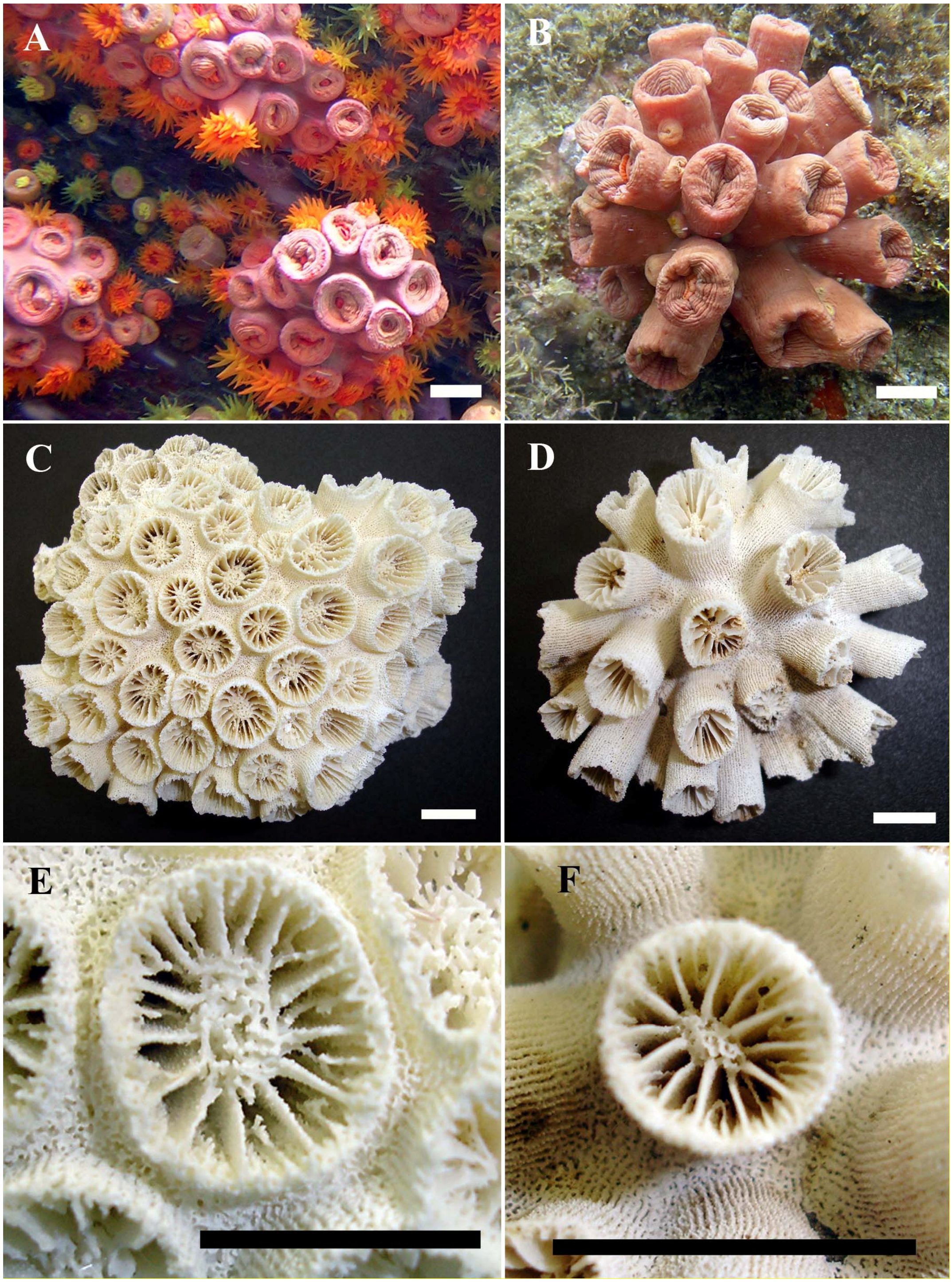

Figure 2. The invasive corals *Tubastraea* spp. **A**) living colony of *T coccinea*; **B**) living colony of *T. tagusensis*; **C**) complete skeleton of colony of *T. coccinea*; **D**) complete skeleton of colony of *T. tagusensis*; **E**) detail of corallite and septal arrangement in *T. coccinea;* **F**) detail of corallite and septal arrangement in *T. tagusensis*. Bars = 1cm. Photographs by Joel C. Creed.

Results and discussion

Tubastraea coccinea, which originated in the Pacific Ocean, is considered a cosmopolitan invasive species and can be found in the Atlantic, Pacific and Indian oceans; the species has been reported as invasive in Puerto Rico since 1943, then in 1948 in Curacao, Dutch Antilles and by the late 90's throughout the Caribbean (Cairns 2000; Fenner 2001; Sammarco et al. 2010), in Florida and the Gulf of Mexico (Fenner and Banks 2004; Sammarco et al. 2004; Sammarco et al. 2010), Colombia, Panama, the Bahamas and throughout the Antilles (Humann and DeLoach 2002; Sammarco et al. 2010) and in Brazil (De Paula and Creed 2004; Sammarco et al. 2010). *T. tagusensis* has been considered as endemic to the Galapagos Archipelago and so far has only been recorded as exotic to Brazil. The presence of both species represents the first introduction of a scleractinian coral into the South Atlantic (De Paula and Creed 2004).

Creed (2006) demonstrated that both species are noxious to native fauna. This was further confirmed by Lages et al. (2010) who demonstrated experimentally how the invasive corals can alter native community and species interactions. Furthermore Lages et al. (in press) demonstrated significant modification in benthic communities under biological invasion, although one species of sponge has been reported to overgrow the corals (Meuer et al. 2010). As the Tamoios MPA is currently undergoing invasion we predict substantial benthic community change as the range extends.

The two species are characterized by having only the polypoid stage and are ahermatypic and azooxanthellate [i.e. they do not live in symbiosis, are not dependent on sunlight and can thus be found in shady places such as caves, caverns and beneath boulders (De Paula and Creed 2005) as well as below the photic zone]. *T. coccinea* is characterized by having approximately spherical colonies with a white corallum and red-orange coenosarc. The corallum can reach up to 105 mm in diameter and corallites are slightly spaced and protrude on average 3.2mm from the coenosteum (De Paula and Creed 2004). *T. tagusensis* is characterized by having approximately spherical colonies, usually globular, convex, with a yellow coenosarc. The white corallum can reach up to 150 mm in diameter. Large corallites are raised on average 18.5mm above the coenosteum (De Paula and Creed 2004).

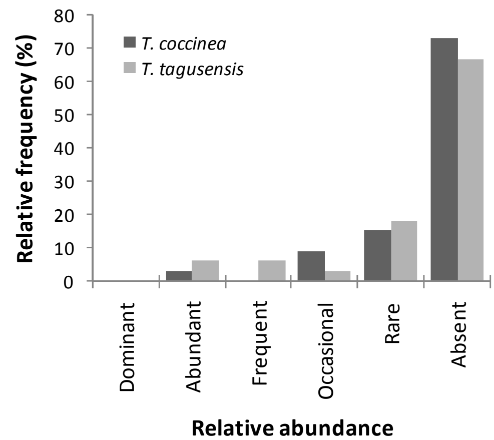

Figure 3. Relative frequency of abundance of *Tubastraea coccinea* and *Tubastraea tagusensis* at thirty-three sites throughout the Tamoios MPA, Brazil.

Both invasive species (Figure 1, 2) were registered at nine sites (27%) and at two more sites only *T. tagusensis* was found (6%). At the other sites no *Tubastraea* spp. were observed. The spatial distribution of the sites with these corals was clumped with most sites being closer to Ilha Grande, where the initial introduction of the corals to the rocky shores of the Bay is thought to have occurred (Figure 1). The site most severely invaded was Queimada Grande Island with a mean relative abundance of 8.0 for *T. coccinea* (Figure 2C, E) and 7.6 for *T. tagusensis* (Figure 2B, D, F) (Appendix 1).

These data suggest that the Tamoios MPA is being invaded from the east to west in a stepping-stone fashion through the islands. Also *T. tagusensis* seemed to be on the leading edge of the invasion when compared to *T. coccinea*. An outlying point at Catimbaú Island (point 33, Figure 1B) would suggest that a secondary introduction may have occurred and that this point represents a new bridgehead for the further range expansion of the corals. A frequency analysis of the abundance index in the Tamoios MPA also demonstrated that most sites have not yet been invaded, but that there is a gradual colonization of new locations: the corals were rare at 15.2% of locations (*T. coccinea*) and

18.2% of locations (*T. tagusensis*) respectively. The corals were abundant in 3% of the MPA (*T. coccinea*) and 6% (*T. tagusensis*) respectively (Figure 3). These results are alarming as they clearly demonstrate the insertion of these invaders into the native communities of the MPA and their subsequent expansion. As Creed (2006) demonstrated the antagonistic effects of these corals on native species and Lages et al. (2010; in press) demonstrated substantial native community modification, these observations support the view that the sun corals represent a real and present danger to the biodiversity of the Ilha Grande Bay, especially within the Tamoios MPA. We would therefore recommend the following management actions: 1) the implementation of a control program within the MPA with the objective of eradication of the two coral species before they spread to other parts of the MPA; 2) continued regular monitoring of MPA to detect further outbreaks, assess impacts on native communities and guide mitigation measures.

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Appendix 1. Location and mean relative abundance of corals *Tubastraea coccinea* and *Tubastraea tagusensis* in Tamoios MPA, Brazil.

N°	Location	Coordinates		*T. coccinea*	*T. tagusensis*
		Latitude, S	Longitude, W	Average (±EP)	Average (±EP)
1	Imboassica Island (northern)	-23°05′12″	-44°19′44″	1.4 (± 0.4)	4.4 (± 0.8)
2	Imboassica Island (south)	-23°04′58″	-44°19′45″	3.8 (± 0.4)	6 (± 0.5)
3	Queimada Grande Island	-23°05′05″	-44°18′36″	8 (0)	7.6 (± 0.6)
4	Queimada Pequena Island	-23°05′28″	-44°18′34″	2.8 (± 0.7)	7.6 (± 0.7)
5	Zatin Island	-23°03′22″	-44°22′39″	0.4 (± 0.4)	0.4 (± 0.4)
6	Island of Cobras	-23°03′18″	-44°24′17″	2.6 (± 0.6)	2.4 (± 0.6)
7	Island of Búzios (northern)	-23°03′25″	-44°24′19″	0.2 (± 0.2)	0.8 (± 0.4)
8	Island of Búzios (south)	-23°03′25″	-44°25′10″	0.2 (± 0.2)	1 (± 0.6)
9	Island of Búzios Pequena	-23°03′43″	-44°24′40″	0	0
10	Araçatiba de Dentro Island	-23°00′36″	-44°21′48″	0	0
11	Araçatiba de Fora Island	-23°00′43″	-44°22′07″	0	0
12	Sabacu Island	-23°00′26″	-44°22′56″	0	0. 2 (± 0.2)
13	Island of Pingo d'água	-23°00′07″	-44°25′49″	0	0
14	Tucum de Dentro Island	-22°59′38″	-44°25′19″	0	0. 2 (± 0.2)
15	Tucum island	-23°01′31″	-44°26′08″	0	0
16	Algodão Island	-23°02′18″	-44°31′07″	0	0
17	Sandri Island (south)	-23°03′10″	-44°30′13″	0	0
18	Sandri Island (north)	-23°02′24″	-44°29′01″	0	0
19	Sandri Island (east)	-23°02′58″	-44°29′27″	0	0
20	Sandri Island (oste)	-23°02′44″	-44°29′29″	0	0
21	Samambaia Island	-23°01′55″	-44°28′56″	0	0
22	Araraquara Island (south)	-23°03′36″	-44°33′23″	0	0
23	Araraquara (north)	-23°03′32″	-44°33′35″	0	0
24	Araraquarinha Island	-23°03′03″	-44°33′39″	0	0
25	Jurubaíba Island	-23°04′04″	-44°33′54″	0	0
26	São Pedro Rock	-23°02′52″	-44°32′46″	0	0
27	Comprida Island (south)	-23°03′51″	-44°36′31″	0	0
28	Comprida Island (north)	-23°03′25″	-44°36′10″	0	0
29	Grande Islet	-23°03′58″	-44°36′08″	0	0
30	Pequena Islet	-23°04′00″	-44°35′39″	0	0
31	Palmas Island	-23°07′53″	-44°40′30″	0	0
32	Ganchos Island	-23°10′30″	-44°38′08″	0	0
33	Catimbaú Island	-23°11′42″	-44°37′29″	0.2 (± 0.2)	0.4 (± 0.4)