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Invasion of aquarium origin soft corals on a tropical rocky reef in the southwest Atlantic, Brazil

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ABSTRACT

Non-indigenous species (NIS) can cause substantial change in ecosystems and as marine invasives they can become a major threat to coastal and subtidal habitats. In September 2017 previously unknown and apparently NIS soft corals were detected on a shallow subtidal tropical rocky reef at Ilha Grande Bay, southeast Brazil. The present study aims to identify the species, quantify their distribution, abundance, and their interactions with native species. The most abundant NIS belonged to the recently described genus *Sansibia* (family Xeniidae) and the less common species was identified as *Clavularia* cf. *viridis* (family Clavulariidae). They were found along 170 m of shoreline at all depths where hard substrate was available. *Sansibia* sp. dominated deeper communities, associated positively with some macroalgal and negatively with the zoantharian *Palythoa caribaeorum*, which probably provided greater biotic resistance to invasion. Both species are of Indo-Pacific origin and typical of those ornamentals found in the aquarium trade.

1. Introduction

Non-indigenous species (NIS) can cause substantial change in ecosystems resulting in loss of biodiversity, decline of native and commercial species and changes in the function and structure of communities and ecosystems (Carlton, 1985; Carlton and Geller, 1993; Ruiz et al., 1997; Grosholz et al., 2000; Mack et al., 2000; Carlton, 2009; Thomsen et al., 2014) and as marine invasives they can become a major threat to marine coastal and subtidal habitats (Bax et al., 2003). They may also increase economic costs or result in lost earnings (Bax et al., 2003; Pimentel et al., 2005; Williams and Grosholz, 2008).

Biological invasions of the marine realm have become more frequent as overseas commerce expands between different regions of the globe. Shipping is considered to be the most important of all the human-mediated transport pathways of NIS within the marine environment (Carlton and Geller, 1993; Hewitt et al., 2009; Piola and McDonald, 2012), and ballast water and biofouling have received the most attention (reviewed by Minchin et al., 2009). Aquariums and trade in aquarium and ornamental species are emerging as another important source of species likely to invade aquatic habitats (Padilla and Williams, 2004). These trades are thought to be responsible for the establishment of some of the highest profile marine invasive species such as the Indo-Pacific lionfish, *Pterois volitans* (Linnaeus, 1758), on the east coast of North America and in the Caribbean, and the green alga, *Caulerpa taxifolia* (M.Vahl) C·Agardh, 1817, in the Mediterranean Sea and southern California, U.S.A. (Padilla and Williams, 2004; Minchin et al., 2009).

Corals (used here as a generic term covering many Anthozoa) are a common component of marine aquaria and about 900,000 live scleractinian coral pieces are imported per year around the world (Jones, 2008). There is therefore a huge potential for the introduction of NIS coral over the planet. Despite this potential, a review by Padilla and Williams (2004) did not list any NIS corals as introduced through the aquarium and ornamental trade, although a soft coral that has recently

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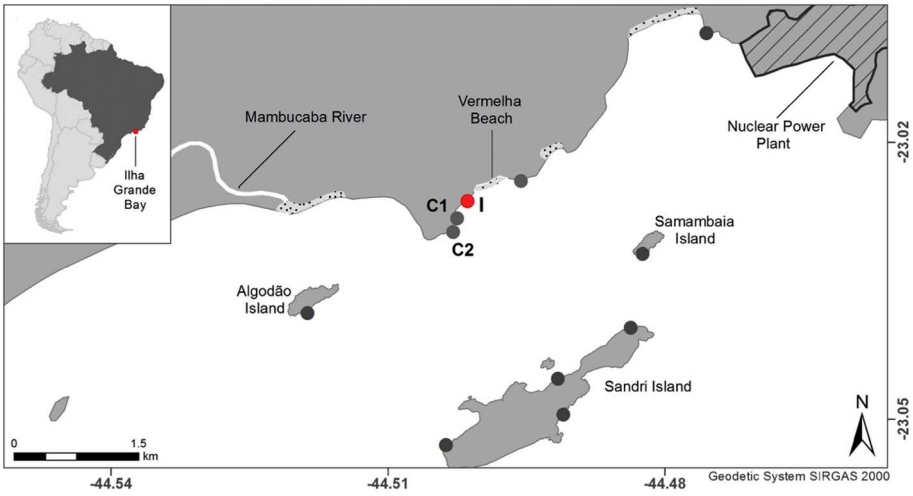

Fig. 1. Study sites at Ilha Grande Bay, southwestern Atlantic, Brazil. Invaded site in red and not invaded sites in gray. C1 = Control site 1; C2 = Control site 2; I = invaded site. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

been discovered overgrowing coral reefs in Venezuela appears to be an example (Ruiz Allais et al., 2014).

On September 18, 2017 previously unknown and apparently NIS soft corals were detected in the benthos on shallow subtidal tropical rocky reefs at Ilha Grande Bay, Rio de Janeiro State, southeast Brazil (23.026°S, 44.501°W, Fig. 1), during routine monitoring by the Sun Coral Project of the genus *Tubastraea* (a pest coral previously introduced by shipping, see Creed et al., 2017b). Closer examination revealed two well-established and distinct morphotypes apparently competing with native species. The aim of the present study was to identify the species present, quantify their distribution and abundance, identify interactions with native species and evaluate community change in order to better plan management objectives and execute the incursion response.

2. Materials and methods

2.1. Study site

The present study was conducted on Vermelha rocky reefs (Fig. 1) which are located at the inner part of Ilha Grande Bay, a partially mixed tropical estuarine system (Ikeda et al., 1989) south of Rio de Janeiro state, Brazil. The nearby rocky reefs are covered by boulders that give way to a sedimentary sand plain which starts at a 4–7 m depth. The main oceanographic influence at Ilha Grande Bay is the seasonal variation of the South Atlantic Central Water (SACW) and the Coastal Water, which dominate in summer and winter, respectively (Creed et al., 2007). During summer, a stratification of the water column as a result of temperature and salinity variations may occur (Creed et al., 2007) and nutrient concentration and primary productivity in sub-superficial waters reach maximum values as a result of enriched waters from SACW (Mesquita et al., 1983). Due to its scenic beauty and singular biodiversity that comprises > 900 marine species (Creed et al., 2007), the bay region contains a number of protected areas. However, it also faces a number of human pressures including sewage discharge, marinas, ports, oil terminal, gas and oil platform anchorage areas, thermal pollution from a nuclear power plant and intensive ship traffic (Creed and Oliveira, 2007).

2.2. Analyses of octocorals specimens

In October 2017 specimens were collected under SISBIO license no. 19606-1 along the entire extent of the distribution and preserved in 95% ethanol. Species were identified to genus and, where possible, to species using standard morphological and molecular methods as follows. Sclerites were isolated from the polyps and coenenchyme of a colony by dissolving the tissue in sodium hypochlorite (household bleach), and examined under light microscopy for comparison to published species descriptions. DNA was extracted from polyps using the Qiagen DNEasy Blood & Tissue Kit and the manufacturer's recommended protocol. Two mitochondrial (*mtMutS*, *COI* + *igr1*) and a nuclear (*28S rDNA*) gene region used widely for barcoding in octocorals were amplified by polymerase chain reaction and Sanger sequenced using previously published primers and protocols (McFadden et al., 2011; McFadden and Ofwegen, 2013). Sequences were aligned to reference alignments that included representatives of all octocoral families plus all stoloniferous taxa for which data exist (McFadden and Ofwegen, 2012) and to a dataset comprising ~70 taxa belonging to family Xeniidae (McFadden, unpublished data). In addition, sequences were compared to all available GenBank records using BLAST. To visualize the relationships of the taxa from Brazil to other octocorals, maximum likelihood trees were constructed for each gene region alone as well as a combined, concatenated dataset using PhyML (Guindon and Gascuel, 2003) with a GTR + I + G model of evolution.

2.3. Distribution expansion

The invasion extent was estimated by two methods at different spatial scales. Ten locations close to the invaded site (0.2–3.4 km distant) were searched for the soft corals (Fig. 1), which due to their coloring and aspect are easy to distinguish from the native fauna and flora. At each site two snorkelers swam parallel to the shore searching for the NIS from the littoral fringe to rocky reef and its sandy sediment interface. Each diver spent about 5 min (~125 m) leaving from the same point on the shore but swimming in opposite directions, so totaling a search of 10 min (~250 m) per site.

At the invaded site snorkelers swam from the beginning of the rocky reefs leaving Praia Vermelha beach (Fig. 1) towards the invaded spot, recording the occurrence and position of the first and last visible colony with a GPS. The two snorkelers spent another 10 min (~250 m) searching on either side of the last colonies to ensure that the spatial distribution was definitive.

2.4. Benthic community surveys

Subtidal hardground benthic community surveys were conducted between September and November 2017 at the invaded site (IS) and at two non-invaded control sites (CS; each control site hereafter indicated