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Colonisation, competitive ability and influence of *Stragulum bicolor* van Ofwegen and Haddad, 2011 (Cnidaria, Anthozoa) on the fouling community in Paranaguá Bay, Southern Brazil

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ABSTRACT

The octocoral *Stragulum bicolor* exhibits fast growth and frequently overgrows other invertebrates. This species has probably been introduced on the Brazilian coast. This study aims to evaluate the ability of *S. bicolor* to colonise previously occupied substrates and its influence on the fouling community throughout the successional process and to verify whether the community limits its growth. Experimental plates (15 × 15 cm) subjected to various treatments (cumulative control, cumulative with removal of *S. bicolor*, cumulative with removal of other species and non-cumulative) were submerged at 1-m depth for a period of 26 months in Paranaguá Bay in southern Brazil. The cumulative plates were photographed monthly, and the non-cumulative plates were recovered every two months and replaced with new ones. Species richness, diversity and evenness were compared between the control and experimental treatment without *S. bicolor*. The number of colonies, area and growth of *S. bicolor* were compared between the control and treatment without other species. Recruitment was compared among non-cumulative and without *S. bicolor* treatments. The effects of *S. bicolor* on species richness, diversity and evenness were sporadic. The community did not limit the area and growth of *S. bicolor*, and the number of colonies was higher on the control plates. Although the number of recruits was higher on non-cumulative plates in certain periods, the presence of an already developed community did not prevent recruitment. *S. bicolor* had no adverse effect on community development. However, this species was efficient in occupying both pre-colonised and clean substrates. It is important to monitor the population of *S. bicolor* in Paranaguá Bay because this species has probably been introduced in this region and has the potential to become invasive.

1. Introduction

Stragulum bicolor van Ofwegen and Haddad, 2011 is an octocoral species from the Clavulariidae family. Since 2000, this species has been registered at several sites along the Brazilian coast, where it was probably introduced (Bumbeer and Rocha, 2012; van Ofwegen and Haddad, 2011). Paranaguá Bay, where it was first recorded, is a high vessel-traffic area. Artificial structures, such as concrete pills, floating piers, ships and boat hulls, are very common due to the presence of ports and marinas in this region. Vessels act as vectors of species introduction (Farrapeira et al., 2011; Floerl and Inglis, 2003), and artificial structures can attract alien species, promoting their dispersion and acting as stocks for their populations (Bulleri and Airoldi, 2005).

In the marine environment, competition for space is very intense among benthic organisms on consolidated substrates. The production of chemical defences is one of the major strategies of colonial, sessile, soft-bodied invertebrates to survive in habitats where competition and predation are intense (Lindquist, 2002). In marine benthic communities, while some species can inhibit the settlement and overgrowth by other organisms (Hay, 2009), others can cause tissue necrosis of competitors (Aceret et al., 1995). Octocorals, especially alcyonaceans, are rich in chemical defences that play an essential role in their survival (Coll, 1992), as shown by the low predation (Fabricius, 1995; Griffith, 1994) and epibiosis rates (Sammarco and Coll, 1992) of these organisms.

Most Alcyonacea have low recruitment, growth and reproduction rates (Benayahu and Loya, 1987; Fabricius, 1995). However, *S. bicolor* exhibits rapid growth (personal observation). In a previous study in Paranaguá Bay, this species was found on a variety of invertebrates such as bryozoans, barnacles, sponges and bivalves, among others (Altvater, 2009). This overgrowth can cause death of these organisms, suggesting the high competitive potential of this species.

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Competitive interactions between alcyonaceans and other organisms are well documented in the literature. In Hawaii, the exotic species *Carijoa riisei* overgrows black corals, altering its population dynamics (Kahng and Grigg, 2005). The soft coral *Chromonephthea braziliensis* van Ofwegen, 2005 (identified as *Stereonephthya* aff. *curvata*) had allelopathic effects on the native gorgonian *Phyllogorgia dilatata* Esper, 1806, causing necrosis of its tissues (Lages et al., 2006). The direct contact of three species of soft corals has caused local mortality in scleractinian corals (Sammarco et al., 1983). Additionally, *Sinularia flexibilis* (Quoy and Gamard, 1833) and *Sarcophyton glaucum* (Quoy and Gamard, 1833) have an allelopathic effect on the recruitment and survival of hard corals (Maida et al., 2001). All these previous studies indicate that soft corals are efficient competitors for space.

Experimental panels have been widely used to assess interspecific competitive interactions among sessile invertebrates (Blum et al., 2007; Kremer and Rocha, 2011; Nandakumar, 1995). Here, we performed manipulative field experiments in polyethylene plates to measure the effects of *S. bicolor* on the fouling community of Paranaguá Bay.

The present study aimed to 1) evaluate the ability of *S. bicolor* to colonise preoccupied substrates; 2) evaluate the influence of *S. bicolor* on the fouling community throughout the successional process; and 3) evaluate the influence of the fouling community on *S. bicolor* growth.

The hypotheses to be tested are as follows:

1) *S. bicolor* recruitment is lower in previously colonised substrates.
2) *S. bicolor* causes a decrease in epibenthic species richness and diversity.
3) *S. bicolor* affects the composition and abundance of epibenthic species.
4) *S. bicolor* growth is lower in developed fouling communities.

2. Material and methods

2.1. Study area

Paranaguá Bay is located on the northern coast of Paraná state. It is an estuarine system of approximately 260 km^2 (Bigarella, 2001). This region can be characterised into the following two seasons based on the rainfall indexes: the rainy period, which corresponds to the summer months, and the dry period, with lower rainfall indexes (Lana et al., 2001). Salinity ranges from 12 to 29 in the summer and 20 to 34 in the winter, and the water temperature ranges from 23 to 30 °C in the summer and 18 to 25 °C in the winter (Lana et al., 2001).

The two main ports of Paraná state, Paranaguá and Antonina, are located at Paranaguá Bay (Bigarella, 2001). Paranaguá port is South America's leading exporter of grains (Marone et al., 2000) and the second largest port in Latin America in terms of cargo volume. Therefore, in this region there is heavy ship traffic in addition to many tourist boats.

This study was performed on Ilha da Cotinga (48°28′38″O, 25° 31′ 15″S), located 10 min by boat from Paranaguá port and Paranaguá Yacht Club (Fig. 1). Five rivers discharge in front of the island, Itiberê, dos Correias, dos Almeidas, Guaraguaçu and Perequê.

2.2. Experimental design

Polyethylene plates (15 × 15 cm) were fixed 15 cm from each other, transversely, in a horizontal position, to rectangular experimental structures made of PVC pipes. The structures were then tied to the floating piers of Ilha da Cotinga with ropes at approximately 1 m depth.

Altogether, 40 plates divided into four structures, were subjected to different treatments for 26 months, from January, 2011 to March, 2013. Treatments were performed as follows:

- Cumulative control (control) — Plates were photographed monthly to record the species richness of encrusting invertebrates and determine the percentage of each one. Additionally, the number of colonies and the extent of the area occupied by *S. bicolor* were determined.
- Cumulative without *S. bicolor* (SPP) — Every month, the plates were photographed and then the *S. bicolor* colonies were scraped. The numerical descriptors considered were the species richness of encrusting invertebrates and coverage percentage of each.
- Cumulative with no other organisms (SB) — The plates were photographed monthly and then the other encrusting species were scraped from the plates. Only *S. bicolor* colonies were kept. The number of *S. bicolor* colonies was counted, and the area of each colony was measured.
- Non-cumulative (recruitment) — After 2 months of immersion, the plates were retrieved for analysis in the laboratory and replaced by new ones. The numerical descriptors considered were the number of *S. bicolor* colonies and the cover percentage occupied by each colony.

The photographs were taken with the plates immersed in seawater. The SPP and SB treatments and comparison with the control started in April, 2011, when *S. bicolor* colonies could be visualised in all treatments. During the scraping treatments, the plates were kept immersed

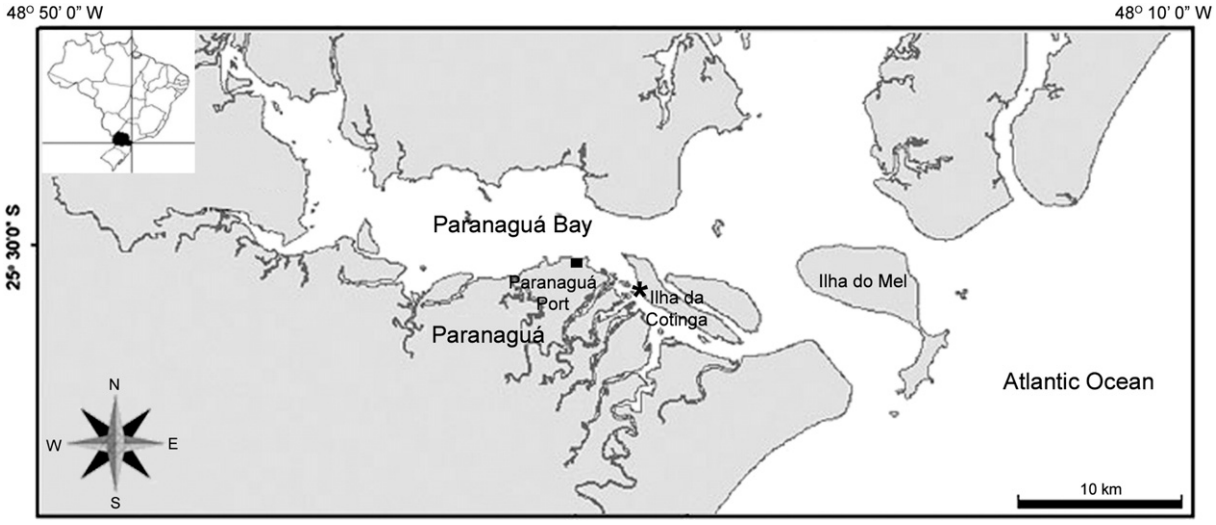

Fig. 1. Map of Paranaguá Bay/PR indicating the experiment site.