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Reef-forming polychaetes outcompetes ecosystem engineering mussels

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ABSTRACT

In order to understand changes in the functioning and the community structure of intertidal ecosystem in sewage-impacted sites, a long-term monitoring coverage study (2004–2011) was carried out on abrasion platforms of the SW Atlantic. The intertidal zone is characterized by the mytilid *Brachidontes rodriguezii*, an ecosystem engineer. Since the austral spring of 2008, a demographic explosion of an invader polychaetes, *Boccardia proboscidea,* has produced massive biogenic structures around the sewage discharge outfall. Cover percentage of this polychaete reached almost 100% in sewage-impacted sites but low or no coverage at all in Reference Sites. The density of *B. rodriguezii* declined due to the biogenic reefs stifles these mytilids. The massive settlement of *B. proboscidea* among mussels, the rapid growth and the tube construction smothers the mussels in sewage-impacted sites.

1. Introduction

Biotic invasions are the result of a process that begins when certain organisms are transported from their native places to new environments (Baker, 1986). Invading species can displace native species through competition, predation or habitat alteration changing the dynamics and structure of benthic communities. Consequently, these species become the dominant species of the community and change the physical characteristics and productivity of ecosystems (Bertness, 1984; Vitousek, 1990).

Boccardia proboscidea Hartman, 1940 is a polychaete from the west Coast of North America, with a distribution extending from British Columbia to Baja California (Hartman, 1941). Today its range also includes Japan (Sato-Okoshi, 2000), southern Australia (Blake and Kudenov, 1978; Hewitt et al., 2004; Lleonart, 2001; Petch, 1995), South Africa (Robinson et al., 2005; Simon et al., 2010), Hawaii (Bailey-Brock, 2000), New Zealand (Read, 2004) and Spain (Martinez et al., 2006), all places where it appears to have been introduced (Kamel et al., 2010). Since the austral spring of 2008 the species has been detected in intertidal sewage-impacted sites in Mar del Plata (Argentina) forming massive reef-like structures. This is the first record of this species of the SW Atlantic (Jaubet et al., 2011).

The intertidal zone of Mar del Plata city (38°S, 57°W) is characterized by the presence of small mytilid *Brachidontes rodriguezii* (d'Orbigny, 1842) (Scelzo et al., 1996 and references therein), an ecosystem engineer. This species also inhabits areas moderately affected by sewage waters (Vallarino, 2002; Vallarino et al., 2002). This bivalve has formed dense mussel beds and has monopolized all intertidal hard space until the colonization of the introduced barnacle *Balanus glandula* Darwin, 1854 which led to a decrease in its coverage (Vallarino and Elías, 1997). Since the first record of the invader *B. proboscidea* in 2008, the coverage of *B. rodriguezii* has shrunk even further, and in sewage-impacted areas the species has practically disappeared.

Mar del Plata is the largest seaside resort of Argentina, and the wastewater of the city is discharged directly on the coast shoreline (Scagliola et al., 2006). Therefore, a fast and reliable method to measure sewage-induced pollution is needed. An effective method in intertidal rocky shore ecosystems is the cover (percentage) of the main macrobenthic organisms, as suggested by Ellis (2003). A monitoring program based on the cover method allows detecting the effects of the sewage pre-treatment when the plant stops for their maintenance (Elías et al., 2009). This program also allows the detection of polychaetes masses identified as *B. proboscidea* around sewage discharge.

The aim of this work was to show the progressive occupation of intertidal space by the invader polychaete *B. proboscidea* and the subsequent displacement of the mussel beds in sewage-impacted sites. A secondary goal was to describe briefly the *B. proboscidea* biogenic reef. Some hypotheses about the mechanisms of the competitive exclusion with the mussel beds were suggested and discussed.

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2. Materials and methods

2.1. Study site

The coast of Buenos Aires Province in the zone of Mar del Plata city is dominated by sandy beaches only interrupted by quartzite outcrops and almost horizontal abrasion platforms (geological formation of consolidated loess, limestone or stony rocks). The sewage outfall of Mar del Plata city is located to 9 km towards the north of the city center (N°11 route, km 507). This intertidal urban effluent discharges 241,920 m^3 of untreated sewage daily during winter season (flow average rate of 2.8 m^3 seg^{-1}) and 302,400 m^3 daily during summer ones (average of 3.5 m^3 seg^{-1}) into the coastal marine waters. Fishery, fish flour factories, tourism, restaurants and textile industries are the main industrial activity of the city and thus they are the responsible of supplying large amounts of grease (18 tons/day, 63% has industrial origin and the other 37% has domestic origin) to the urban wastewater (Scagliola et al., 2006, 2011).

Data obtained for several studies conducted by Mar del Plata Public Sanitations Works (OSSE) from 2000 to 2010 demonstrated that the sewage has a high content in organic matter and low levels of heavy metals (below the values required in national and international normative). The effluent pretreatment retains 20–25 tons (wet weight) of solids daily and the raw sludge contains 86% of organic mater. The annual average concentrations of the major constituents of the liquid effluent were: nitrogen total: 63.13 mg lt^{-1}; phosphorus total: 6.88 mg lt^{-1}; oil and grease: 67.11 mg lt^{-1} (Scagliola et al., 2006, 2011).

The incidence of wastewater discharge is about 5000 m to the north and 9900 m to the south, and the beaches in this sector do not fulfill the local compliance criteria. The criterion for the compliance level was the same one adopted by USEPA in 1986 for marine recreational waters, i.e. 35 *Enterococci* geometric mean per 100 ml. The impacted area (where the present work was conducted) is washed by waters with mean geometric values between more than 500 up to 7000 *Enterococci* NMP/100 ml and it had also the greatest counting for Total Coliforms and Termotolerant coliforms (Pérez Guzzi, 2003; Comino et al., 2011).

2.2. Sampling design

The study was carried out from 2004 to 2008 in three limestone sites: Impacted Site and South Impacted Site (50–200 m and 1000–1200 m south of the outfall, respectively) and Reference Site 1 (9000 m-north of the outfall). From 2008, a new reference site was added, Reference Site 2 (8000 m-north of the outfall) (Fig. 1). During the sampling period, all seasons were surveyed at least once. Although the cover of the entire community was measured, this study only shows the cover percentage of *B. rodriguezii* and *B. proboscidea.* Three separate stations 50 m apart were sampled in each site. A total of 10 sample units of 0.25 m^2-squares were taken in each station and averaged in a single value.

2.3. Data analysis

To analyse changes in the long term coverage, three repeated measures ANOVA were used considering the averaged value (3 data) for each site. The first ANOVA analysis included all sampling periods from 2004 to 2011 (without Reference Site 2) and was performed with coverage of *B. rodriguezii*. The others two ANOVA analyses included all sites (with Reference Site 2) but only from 2008 to 2011. These analyses were performed with coverage of *B. rodriguezii* and *B. proboscidea*, because the first appearance of *B. proboscidea* was from November 2008.

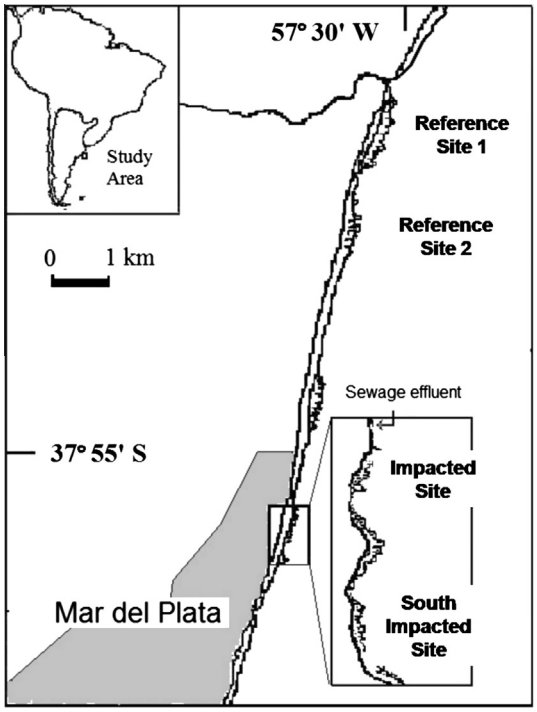

Fig. 1. Location of the four sites sampled around sewage discharge of the Mar del Plata city: Reference Site 1, Reference Site 2, Impacted Site and South Impacted Site, from 2004 to 2011. Position of the sewage effluent is shown.

3. Results and discussion

3.1. Long-term cover percentages

There are highly significant differences in coverage through time (years) and sites (Impacted versus Reference Sites), as well as interactions of *B. rodriguezii* (Table 1) considering the period 2004–2011 in the two Impacted Sites and the Reference Site 1. The analysis along 2008–2011 (including Reference Site 2) also shows highly significant differences in coverage between sites and interactions in the two species (Tables 2 and 3).

Due to the fact that there are significant interactions effects in the Analysis of Variance (ANOVA), the interpretation of the mains effects was performed graphically. The results of the long-term cover percentages in the different sites are presented in Fig. 2.

From 2004 to 2008, the intertidal benthic community of hard substrate around Mar del Plata was dominated by the mytilid *B. rodriguezii* in both References and Impacted Sites. *B. rodriguezii* percent cover reached high values in the Reference Site 1 (up to 80%), whereas in the Impacted Sites the values were significantly lower. In the same period, the polychaete *Boccardia* spp. (cited previously as *B. polybranchia* in Elías et al., 2003; 2006) appeared between the mussel beds but without forming large patches enough to be identified in the cover method. In June 2008, *B. proboscidea* was found in mussel beds in sewage-impacted sites, forming visible incipient masses, without being considered reefs.

In November 2008, the density of *B. proboscidea* increased dramatically, result of the formation of solid biogenic structures named reefs. These reefs covered about 70% of the sampled area at the South Impacted Site (Fig. 2, event 1). In February 2009 *B. proboscidea* covered almost 100% of the substrata at the Impacted Sites. Argentina is the only place in the world where this species has built such structures (Jaubet et al., 2011).

In January 2009, the coverage of *B. proboscidea* reached 30% in the Reference Site 1. This was due to a strong storm that broke