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Succession in an intertidal benthic community affected by untreated sewage effluent: A case of study in the SW Atlantic shore

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ABSTRACT

A study of benthic succession related with sewage pollution was conducted in a warm-temperate coastal area of Mar del Plata city, Argentina. The effect of nutrient enrichment and starting period of the succession was tested after cleared space in the intertidal rocky shore benthic community. The time of recovery after a disturbance in enriched sites was considerably lower (20–29 weeks) than in non-enriched sites based on the diatom *Berkeleya* sp. and the polychaete *Boccardia proboscidea* developed in the early succession stage, and *Brachidontes rodriguezii* or *B. proboscidea* occurring with *Polysiphonia* sp., *Petalonia fascia* and *Ulva* spp. developed in the late succession stage of the enriched sites. The very low time at which the community recovered in the enriched environments turned out to be one of the assets of the present study and this parameter can be used as a quick indicator of sewage pollution in the area.

1. Introduction

The nutrient enrichment of coastal marine environments is a phenomenon of global concern. One prominent mode in which the human populations increase the mobilization of nutrient elements to coastal areas is through the discharge of sewage outfall (Nixon, 1995; Cloern, 2001). Thus, contamination with sewage outfall is one of the main anthropogenic stressors in intertidal rocky shore benthic communities, and it had been intensely studied in temperate coastal waters (López Gappa et al., 1990, 1993; Soltan et al., 2001; Díaz et al., 2002; Arévalo et al., 2007; Díez et al., 1999; Elías et al., 2006; Muniz et al., 2011). The concentration of dissolved nitrogen and phosphorus in the water column regulate the growth rates of epilithic algal communities (Kraufvelin, 2007; Littler et al., 2010), promoting the development of early successional stages macrophytes in the surrounding communities (Littler and Murray, 1975; Soltan et al., 2001; Bokn et al., 2003; O'Shanahan Roca et al., 2003; Martinetto et al., 2010) owed to their high nutrients requirements (Karez et al., 2004). The most extreme environmental response to a nutrient enrichment is the intensive algal blooms registered in lagoons, bays or even open coastal systems (Menesguen, 1992; Sfriso et al., 1993; Valiela et al., 1997; Teichberg et al., 2010). However, other response to nutrient enrichment could be, for example, a less dramatic change of the abundance and the species composition of the algal community (Orfanidis et al., 2001; Ballesteros et al., 2007; Arévalo et al., 2007; Pinedo et al., 2007; Dongyan et al., 2007; Pinedo et al., 2013). Moreover, the organic enrichment produced by sewage outfall may modify the faunal composition in near-shore benthic environments, predicting a peak in opportunists' organisms, mainly certain polychaetes species (Pearson and Rosenberg, 1978; Borja et al., 2006; Jaubet et al., 2011; Elías et al., 2015).

Studies of disturbed communities with nutrient enrichment have generally focused on the ecological analysis of communities, field descriptions of populations, or laboratory analyses of physiological responses of individual organisms (López Gappa et al., 1990, 1993; Díaz et al., 2002; Karez et al., 2004; Elías et al., 2006; Ballesteros et al., 2007; Arévalo et al., 2007; Pinedo et al., 2007; Dongyan et al., 2007; Torres and Caille, 2009; Littler et al., 2010). However, studies of benthic succession related to nutrient enrichment have not been developed in extension (Murray and Littler, 1978), especially in South America (Fricke et al., 2015). Mar del Plata, the largest coastal city of Argentina, holds a pre-treatment sewage plant which had been discharging directly in the intertidal zone since 1989 until December of 2014, when the City Council inaugurated a submerged sewage outfall which extended the point of discharge a distance of 4 km from the coastline along the seafloor. Previous to this modification, the area showed an increasing nutrient enrichment condition, turning into a sewage-polluted habitat (Vallarino et al., 2002; Elías et al., 2006; Elías et al., 2009; Jaubet et al., 2011; Sánchez et al., 2013). The benthic community near the sewage discharge area has being studied for over the past 15 years, chiefly assessing the effect of organic enrichment over the epilithic mussels bed-forming *Brachidontes rodriguezii* (family Mytilidae) (Vallarino et al.,

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2002; Elías et al., 2006; Sánchez et al., 2013) and the invasive polychaete *Boccardia proboscidea* (family Spionidae) (Jaubet et al., 2011; Garaffo et al., 2012; Jaubet et al., 2013; Elías et al., 2015). The macrobenthos community affected by the sewage outfall shows populations of *B. rodriguezii* in a lower density and with bigger individuals than those inhabiting non-impacted areas (Vallarino et al., 2014), and with eventually high density of the tube-building reef *Boccardia proboscidea* (Jaubet et al., 2011, 2013). Regarding to the algal assemblage, a recent study assessed the variability of the species coverage at different distances of the outfall, being the tube dwelling diatom *Berkeleya* sp. more abundant near the sewage outfall whereas *Ulva* spp. was distributed with similar abundances in both impacted and non-impacted areas (Becherucci et al., 2016).

The area of the present study also undergoes natural disturbance events, because severe wind storms (from the S-SE sector) (Manolidis and Alvarez, 1994) produce patches of opening space in littoral areas which may suffer different patterns of species recovery. Given that the benthic community of the study area responds to sewage outfall discharge varying its functioning and structure (Garaffo et al., 2012; Jaubet et al., 2013) the present study was designed to determinate: 1) if the macrobenthos characteristics of impacted areas with nutrient enrichment show lower time of recovery during succession, and 2) whether a primary effect of environmental enrichment and starting period of the succession alters the diversity and composition of macrobenthos communities.

2. Methods

2.1. Study area

The study area was located on the north coast of Mar del Plata city, Buenos Aires, Argentina (38° S, 57° 33′ W) (Fig. 1). Along the north city shoreline sandy open beaches alternate with extended abrasion platforms composed of compact sedimentary rock, sometimes cemented by crystalline calcium carbonate (Amor et al., 1991). The area is affected by a littoral current (flowing predominantly from South to North). The tidal regime is semidiurnal with tidal amplitude ranging from approximately 0.8 m to 1.6 m during exceptional tides. Sea surface temperature shows a great seasonal variation (9.3 °C in winter and 20 °C in summer) (Guerrero and Piola, 1997), while sea pH remains between 7 and 8.5 (Isla et al., 1998). Sánchez et al. (2013) observed that both sediment organic matter and water turbidity in sewage impacted areas of Mar del Plata were 1% and 50% higher than in non-impacted areas respectively.

2.2. Experimental design

Four sampling sites distributed along the coastline at increasing distances from the local sewage outfall were selected. One sampling site was located at 800 m (hereinafter site IS) south of the point of discharge, whereas the other sampling sites were located at 3.7 km (IN), 8 km (R1) and 9 km (R2) to the north of the outfall (Fig. 1). According to previous studies sites IS and IN were considered impacted sites whereas sites R1 and R2 were treated as reference non-impacted sites (Elías et al., 2006; Sánchez et al., 2013; Jaubet et al., 2015; Becherucci et al., 2016). In each sampling site, eight experimental plots (square areas of 0.40 m^2) were randomly distributed in independent rocks on the mid height level of the eulittoral shore (Raffaelli and Hawkins, 1999). At the beginning of the experiment, each experimental plot was scraped aimed by a spatula, thus removing all organisms in the plots and then washed with a solution of sodium hypochlorite. In order to avoid an “edge effect”, the plots were scraped leaving a thick 10-cm perimeter which was maintained in

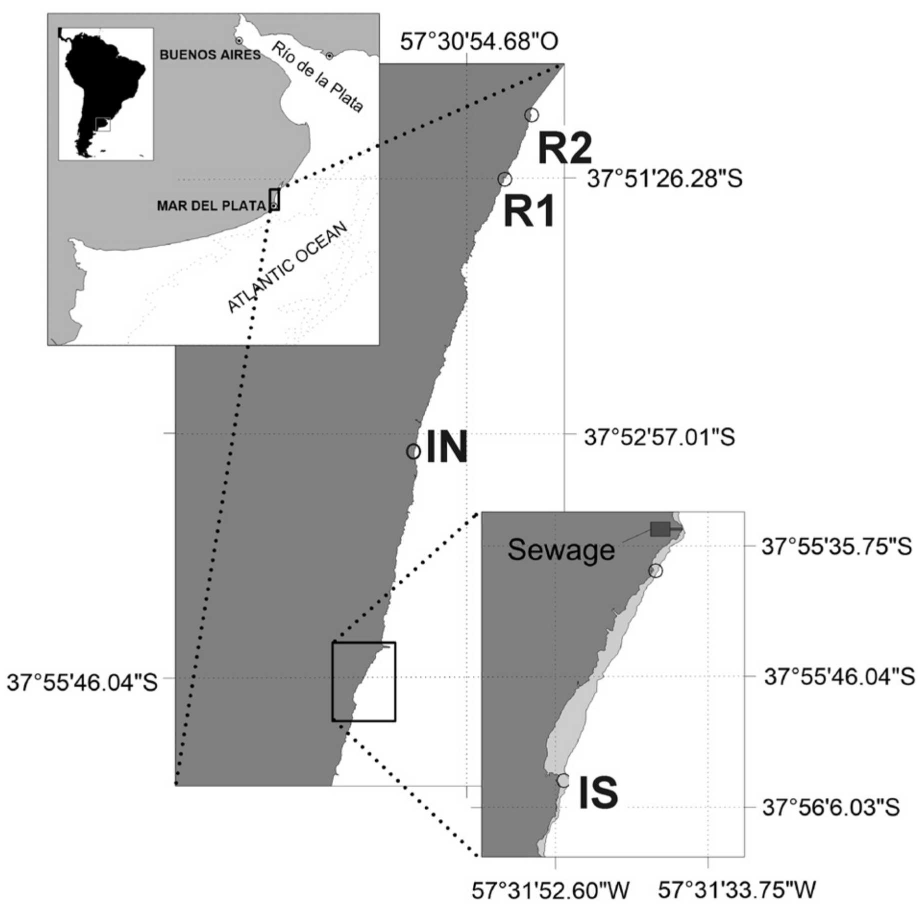

Fig. 1. Distribution of sampling sites (IS, IN, R1 and R2) and intertidal sewage outfall location in the study area. Site IS was located at 800 m to the south of the outfall, site IN at 3700 m north, R1 at 8000 m north and R2 9000 m to the north of the outfall.