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Introduced and native species on rocky shore macroalgal assemblages: Zonation patterns, composition and diversity

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ABSTRACT

The study of the natural and anthropogenic changes in patterns of species and habitat diversity is important for understanding the organization of natural species assemblages. One of the major threats to native marine biodiversity and resource values is the introduction of exotic species. Rocky intertidal shores are considered among the environments that are susceptible to the introduction of organisms like macroalgae. The scope of this work is to study the spatial variation of the native and introduced intertidal macroalgae in rocky shores of northern Patagonia, Argentina. Seasonal sampling of cover, abundance, richness, biomass and diversity of native and introduced macroalgae at three intertidal levels (high, middle and low) was carried out at four wave-protected rocky shores during one year. We found a conspicuous zonation pattern of the dominant species of algae and invertebrates, with the greatest richness, abundance and algal diversity at the low intertidal level, but these variables were heterogeneous through time and space. These differences were mainly due to the variations in the abundance of ephemeral algae. Introduced species represented around 20–25% of the total richness of each locality, being most abundant in those localities that also showed a greater total diversity. This study provides the first assessment of rocky shore macroalgae assemblages from Argentina that incorporates the presence of introduced species and shows that the number of introduced algae species along Patagonian rocky shores had been underestimated. We also encourage the monitoring of the biodiversity and the study of the processes that are involved in the role that introduced species plays in these environments.

1. Introduction

Changes in patterns of species and habitat diversity are important to understand the organization of natural species assemblages (Andrew and Mapstone, 1987). Intertidal communities usually have strong zonation patterns represented by bands of different organisms that occur progressively up a shoreline across environmental gradients (Stephenson and Stephenson, 1949, 1972). These patterns are common in many rocky shores and the organisms are influenced by a combination of ecological processes such as grazing, competition, facilitation and recruitment (e.g. Raffaelli and Hawkins, 1996; Underwood et al., 2000) and abiotic factors like nutrient availability, exposure and tidal variation (Connell, 1972; Pedersen and Kraemer, 2008).

On rocky intertidal shores, macroalgae have an important ecological role for the organization of the communities, providing food for many species of invertebrates that inhabit in their fronds and also offering protection against predation, amelioration of physical extremes and reduction of water movement (Jenkins et al., 1999). Intertidal macroalgae assemblage structure and biomass of the key taxa can vary across multiple spatial scales along the coastline (Smale et al., 2010). Recent investigations have also showed that small-scale spatial variability may override more general patterns of distribution (Liuzzi and López Gappa, 2008; Wieters et al., 2012). The physical features of the environment, and consequently the structure of the local assemblage, may change abruptly over very small spatial scales (Metaxas et al., 1994). In this sense, the detection and monitoring of rare and declining species and the effects of regional and global change are an important issue in long term conservation and management of biodiversity (Lubchenco et al., 1991).

Rocky intertidal shores are susceptible to the introduction of organisms such as macroalgae, since this type of substratum allows their settlement (Arenas et al., 2006). Introduced marine macroalgae are a matter of concern since they may modify both ecosystem structure and function by monopolizing space, developing into ecosystem engineers and changing food webs (Thresher, 2000). There is a limited understanding of the distribution and ecology of

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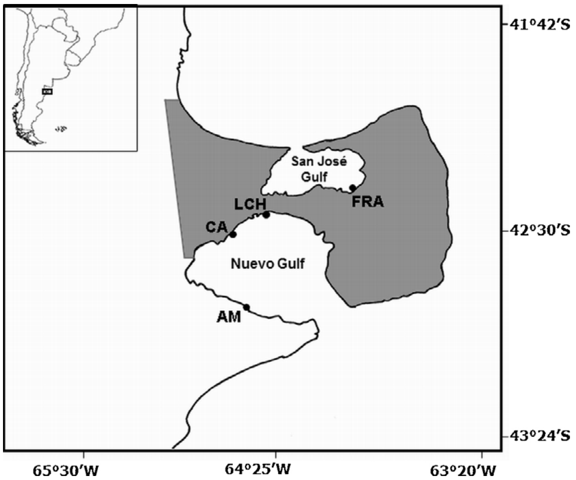

Fig. 1. Map showing locations of the sampling localities: Fracasso (FRA), Las Charas (LCH), Casino (CA) and Ambrosetti (AM). Limits of the Península Valdés Protected Area are shaded in gray.

inconspicuous introduced macroalgae and their introductions are underestimated due to misidentifications (Schaffelke et al., 2006). Three cryptogenic and four introduced species have been reported in Argentina (Raffo and Schwindt, 2011), but this is a very low number compared with other countries such as Australia with 14 species (Ruiz et al., 2000), United States with 20 species in the Northwest Atlantic (Mathieson et al., 2008) and France with 45 species (Hewitt, 2003). Macroalgal communities of the rocky shores along the northern Patagonian coast of Argentina are composed of small or medium-size species (between 0.5 and 20 cm high) and different morphological types, including turf forming algae (e.g. *Corallina officinalis*), filamentous algae (e.g. *Polysiphonia*, *Ceramium*), foliose algae (e.g. *Ulva*) and crustose algae (e.g. *Ralfsia*) (Díaz et al., 2002; Liuzzi and López Gappa, 2008).

The goal of our work was to study the spatial variation of the native and introduced macroalgal communities in Patagonian rocky shores. Specifically, the aims of this work were: (1) to describe the zonation patterns of the macroalgae and the associated sessile invertebrates species that inhabit this environment; (2) to determine whether the distributional patterns of macroalgae assemblages vary their composition and diversity in different intertidal levels and localities; and (3) to assess the presence and abundance of the introduced macroalgae species in the context of the native biodiversity.

2. Materials and methods

2.1. Study area

Samples were collected from four similar wave protected rocky shores. These rocky areas were wave-cut siltstone platforms between 100 and 150 m wide, and with slopes varying between 1° and 2° and the same tidal amplitude. Three localities were surveyed inside Nuevo Gulf: Las Charas (42°30′ S, 64°36′ W), Casino (42°36′ S, 64°49′ W) and Ambrosetti (42°30′ S, 64°30′ W), and another one on San José Gulf: Fracasso (42°24′ S, 64°05′ W). Three of these localities (Casino, Las Charas y Fracasso) are located within the Península Valdés Protected Area, listed as World Natural Heritage Site by the UNESCO in 1999; Fig. 1. Sea water temperature fluctuates yearly between 9.7 and 19.6 °C in Nuevo Gulf, and between 9.3 and 15 °C in San José Gulf (METEOCEAN-CENPAT–CONICET). Salinity usually ranges between 33.7 and 33.9 psu in Nuevo Gulf and between 33.48 and 34.26 psu in San José Gulf (Esteves et al., 1986). Tidal regime is semidiurnal with mean amplitudes between 3 and 7 m (Servicio de, Hidrografía Naval Argentina).

2.2. Sampling design

At each locality, three intertidal levels were sampled (high, middle and low) set on the basis of different intertidal topographic surveys respect to the Argentinean hydrographic zero. Samples (quadrats of 35 cm × 35 cm) were placed randomly at each level, in four different times: August 2008 (winter), November 2009 (spring), February 2009 (summer) and May 2009 (autumn) to comprise the changes on the algae community structure throughout the year. Cover (%) of all organisms (including sessile fauna and algae) that could be discerned with the unaided eye was recorded in the field for each sample ($N = 10$ for each site, level and season, total $N = 480$). We did not find any overlapping of algae species during the cover estimations (see also Liuzzi and López Gappa, 2008). Then, all macroalgae within each of six sampling quadrat ($N = 6$ for each site, level and season, total $N = 288$) were scraped off the surface, bagged, labeled and stored at −13 °C. The organisms found were identified in the laboratory to the lowest possible taxonomic level with the help of local taxonomic keys (mollusks: Pastorino, 1995; barnacles: Spivak and L'Hoste, 1976; algae e.g. Boraso de Zaixso, 2004; Piriz, 2009) and complementary specific literature was used to identify those macroalgae species where not found in taxonomic keys (e.g. Hollenberg and Norris, 1977; Hoffmann and Santelices, 1997). Species names and taxonomic classifications were validated with AlgaeBase (Guiry and Guiry, 2012) and updated when necessary. For each quadrat, taxonomic richness (S) was determined as the number of species present in the sample. Macroalgae abundance was obtained as dry biomass (g) of each macroalgae species previously dried in an oven at 60 °C for 5 days and weighed to the nearest 0.001 g in a Sartorius analytical balance. Diversity was determined using the Shannon index (H') (Shannon and Weaver, 1949).

2.3. Data analysis

To describe the zonation patterns of the macroalgae and sessile invertebrate species that inhabit these intertidal environments we used the percentage cover (%) of each species registered in the field in relation to intertidal levels and times of the year (seasons). Distribution and composition of macroalgae assemblages were tested using the multivariate data analysis, PRIMER (Plymouth Routines In Multivariate Ecological Research) statistical package (Clarke and Warwick, 2001). Differences between intertidal levels (high, middle and low) were tested by a one way ANOSIM test and comparison among localities and seasons inside each intertidal level were analyzed by a two way crossed ANOSIM test, with 999 permutations (seasons x localities). These tests were made by Bray–Curtis similarity matrix applying the square root transformation of the data and using a dummy variable to avoid the differences between the dominant and rare species. In each ANOSIM test, the null hypothesis that there were no significant differences among groups was rejected if the significance level (p) was <0.05 (groups for locality comparison: Las Charas, Casino, Ambrosseti and Fracasso; groups for season comparison: autumn, spring, winter and summer). When significant differences were detected among a priori groups, the R-statistic was used to determine the extent of those differences. Similarity Percentages (SIMPER) were used to explain which species characterized each group and distinguished among each pair of groups.

Variation among abundance, richness and diversity in different seasons was tested independently for each locality with a one-way fixed ANOVA. These variables were tested only for the low intertidal level samples because the highest number of macroalgal