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Effects of recreational activities on Patagonian rocky shores

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ABSTRACT

Recreational activities can be an important source of anthropogenic disturbance in intertidal benthic assemblages. On rocky shores, activities such as trampling, snorkeling and the handling of organisms may have a negative effect on benthic communities by modifying the abundance and distribution of key species. Here, we describe and quantify impacts due to recreational activities on benthic communities on a Patagonian rocky shore by investigating their resilience to two types of human disturbance: vehicle traffic and human trampling. To evaluate the effects of these activities, we carried out an observational study and assessed post-disturbance assemblage recovery. The rocky shores is most intensively visited during summer, and marked differences in the distribution and abundance of benthic species among disturbed and control plots were found after this season. The benthic community on the high intertidal was weakly impacted by disturbance generated due to vehicle traffic in summer (one vehicle on a single occasion, pulse disturbance); which did not affect the cover of dominant species. This suggests that the high intertidal community would be resistant to the passage of one vehicle on a single occasion. The effects of continuous trampling (press disturbance) were drastic and the community of the mid intertidal level did not recover before the next recreational season. Mid intertidal communities exposed to press disturbances require more than one tourist season of human inactivity to recover from anthropogenic effects, suggesting that resilience mechanisms in this community operate at broad timescales. Our findings highlight the need to establish and implement management actions that contemplate the nature of the disturbance and intertidal level to minimize habitat degradation due to human recreational activities.

1. Introduction

Disturbance, both natural and anthropogenic, is one of the main structural factors in coastal communities (Bender et al., 1984; Underwood, 1989; Micheli et al., 2016). For example, the density and distribution of the species that form intertidal communities can be influenced by physical disturbances, such as waves, winds or ice (Underwood, 1998; Gaylord, 1999; Calcagno et al., 2012), as well as by human perturbations, such as recreation activities and tourism (Addessi, 1994; Crowe et al., 2000; Davenport and Davenport, 2006).

The tourism industry has grown exponentially in the last century and coastal cities have become favorite destinations (Miller, 1993; Dadon, 2002; Davenport and Davenport, 2006). Although tourism brings economic benefits, there are usually substantial environmental costs associated with its development (Dadon, 2002; Davenport and Davenport, 2006). Furthermore, the intense use of natural environments may lead to a deterioration of the original attractions. In coastal Atlantic Patagonia, one of the main tourist attractions is Península Valdés (42°30′ S; 64°00′ W), a Natural Reserve created in 1983 and recognized as a Natural World Heritage site by the UNESCO in 1999. Tourism is among the three main economic activities of Puerto Madryn, the closest city to Península Valdés (Secretaría de Turismo, 2015). Puerto Madryn, with ca. 100,000 permanent residents, receives ca. 250,000 tourists each year. Forty percent of visitors arrive in January and February during the austral summer (Secretaría de Turismo, 2015) and stay mostly in sandy city beaches. However, there has been an increase in the use of alternative coastal areas for recreation (<15 km from Puerto Madryn). The activities performed in these areas are not

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regulated nor supervised by the government, with potential consequences on the benthic ecosystem.

Among the activities performed on rocky shores, human trampling has been the focus of many studies in recent decades; its impact can be severe and even simple walking on a rocky shore may affect marine organisms (Povey and Keough, 1991; Milazzo et al., 2004; Huff, 2011; Araujo et al., 2012). Trampling may influence the benthic assemblage directly (*e.g.* by removing individuals) and indirectly (*e.g.* affecting biological interactions between species) (Brosnan and Crumrine, 1994; Brown and Taylor, 1999; Huff, 2011). Another activity that threatens coastal benthic communities and impacts their flora and fauna is the traffic of vehicles (Schlacher et al., 2007; Defeo et al., 2009 for sandy shores). Studies of vehicle impact on coastal biota are focused on sandy beaches and coastal dune ecosystems, where vehicle traffic is relatively common around the world (Stephenson, 1999; Schlacher et al., 2007; Kindermann and Gormally, 2010). On northern Patagonian shores, high amplitude tides permit road vehicles transit the mid and high rocky intertidal shores that have platforms with little slope and a relatively flat consolidated mudstone surface. Dozens of cars transit through the intertidal flats to access recreational fishing sites every year, concurrently excursions are offered by local tourism companies to these intertidal shores.

Of particular conservation concern is the recovery time needed by benthic communities after anthropogenic disturbances. However, the resistance to disturbance through pre-existing compensatory processes may also be of importance by reducing or impeding change in the community (Connell and Ghedini, 2015). When an observable change in structure occurs, assemblage response is frequently related to the strength of the disturbance, its source and duration (Bender et al., 1984). Determining the resilience of a community, understood as the capacity of a system to return to a prior state after a disturbance is crucial for conservation efforts. Disturbances may be categorized in: short-term or pulse perturbations, and persistent or press disturbance (Bender et al., 1984). Mitigation of the effects of pulse disturbances could be relatively simple compared with chronic press disturbances (Bender et al., 1984; Underwood, 1992, 1994; Bravo et al., 2015). Furthermore, specific characteristics of the affected ecosystem, such as, the species involved, their life history and the amount of damage caused also determine the consequences of the disturbance (*i.e.* resistance and resilience of the community) (Underwood, 1998; Milazzo et al., 2004; Araujo et al., 2012; Connell and Ghedini, 2015).

In northern Patagonian rocky shores (41-55° S; 63-70° W), extreme desiccation is one of the most important ecological features (Bertness et al., 2006). Organisms are exposed to strong, dry winds, combined with low humidity and scarce rainfall (Bertness et al., 2006). In northern and central Patagonia, physical stress is the main structuring factor in the benthic intertidal communities, where biotic interactions, such as predation (Hidalgo et al., 2007) and herbivory (Bazterrica et al., 2007), have a secondary role. In general, the zonation pattern of intertidal Patagonian rocky shores is characterized by the presence of different species of algae in the lower areas (low intertidal), mainly dominated by the calcareous algae *Corallina officinalis* (Kelaher et al., 2007; Raffo et al., 2014). The middle level (mid intertidal) is dominated by two tiny mytilids species: *Brachidontes rodriguezii* and *B. purpuratus* (Silliman et al., 2011; Rechimont et al., 2013), which are arranged to form a dense matrix of organisms that can have several layers of individuals. Finally, the invasive barnacle *Balanus glandula* and the pulmonate limpet *Siphonaria lessoni* characterize the highest areas of the intertidal (high intertidal), where the percentage of bare rock is usually high (Schwindt, 2007; Raffo et al., 2014). Of these dominant species *C. officinalis*, *Brachidontes* spp. and *Balanus glandula* are considered to be engineer species. These species provide habitat, shelter and food for a number of associated organisms (Jones et al., 1994). The dominance of the engineers across the different levels of the intertidal ecosystem highlights the importance of facilitation as a dominant force under harsh environmental conditions (Silliman et al., 2011). Thus, the study of how these species are affected by and respond to disturbance provides information about what may happen to the rest of the community (Eckrich and Holmquist, 2000; Benedetti-Cecchi et al., 2001; Araujo et al., 2012).

Despite the marked growth of coastal recreational activities, there are very few studies that have evaluated their effect on intertidal benthic communities in Argentina (Dadon, 2002, 2005; Herrmann et al., 2009 in soft bottom communities). The purpose of this study was to describe and quantify impacts due to recreational activities on benthic communities in a Patagonian rocky shore by investigating their resilience to two types of disturbance: vehicle traffic (high intertidal) and trampling (mid intertidal). We are not aware of any studies on the direct effect of recreational activities on rocky shore benthic communities in Argentina. Furthermore, to our knowledge this is the first study where the impact of vehicles on a benthic assemblage is described and analyzed for any rocky shore. We hypothesized that the two activities would affect benthic species, decreasing their coverage and increasing the proportion of bare rock. Also, the magnitude of the impacts would be related to the intensity of the disturbance and the level in which they occurred.

2. Materials and methods

2.1. Study site

The study was performed at Punta Este (PE), an intertidal rocky shore located 10 km south of Puerto Madryn, Southwestern Atlantic coast. Punta Este is a wave-protected shore on the west coast of Golfo Nuevo (42°47′ S; 64°57′W). Westerly winds are predominant, persistent and intense all year round (Paruelo et al., 1998) with an annual mean speed of 15.4 km/h and reaching up to 114 km/h. The annual mean air temperature is 14.2 °C, with a minimum of −9.2 °C in winter (July) and a maximum of 37.2 °C in summer (January) (Laboratorio de Climatología, CENPAT-CONICET, data for 2014). At PE tides are semidiurnal with mean amplitude of ~4 m which exposes a sedimentary rock platform (consolidated limestone). Three intertidal levels can be distinguished (Rechimont, 2011): the high intertidal has a slope of 3.8° and high percentage of bare rock with the presence of the algae *Ulva prolifera* and small patches of the invasive barnacle *Balanus glandula* and the limpet *Siphonaria lessoni*. In the mid intertidal, the slope is 7.4° and a single-layered bed of *Brachidontes* spp. mussels characterized this level. The low intertidal has a slope of 20.2° and the calcareous alga *Corallina officinalis* is dominant, with the presence of other algal species such as *Codium* sp., *Ceramium* sp., *Dictyota dichotoma* and the invasive *Undaria pinnatifida* as well as the gastropods *Tegula patagonica* and *Trophon geversianus*. The rocky shore is commonly used by visitors due to its proximity to roads, easy access, clear waters and protection from the wind blowing from land to the sea, by an adjoining cliff.

2.2. Effects of vehicle traffic on the benthic community

Vehicle traffic was identified from observations as one of the human activities with high potential of harm to the benthic community. Damage caused by a vehicle on the compacted mudstone floor can be easily identified by the tracks left on it. These can last for several weeks and can be distinguished from that caused by multiple vehicles through direct observation of the tracks. We