Marine Environmental Research 99 (2014) 60–68

Contents lists available at ScienceDirect

Marine Environmental Research

journal homepage: www.elsevier.com/locate/marenvrev

Marine fouling invasions in ports of Patagonia (Argentina) with implications for legislation and monitoring programs

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ARTICLE INFO

Article history:
Received 24 February 2014
Received in revised form
9 June 2014
Accepted 12 June 2014
Available online 20 June 2014

Keywords:
Marine exotic species
Fouling
Ports
Southwestern Atlantic

ABSTRACT

Ports are a key factor in the understanding and solving of most problems associated with marine invasive species across regional and global scales. Yet many regions with active ports remain understudied. The aim of this work was to (a) identify and quantify the marine fouling organisms in all Patagonian ports of Argentina classifying them as native, exotic or cryptogenic species through a rapid assessment survey and experimental studies, (b) survey the environmental and anthropogenic variables of these ports and (c) analyze and discuss these results in the light of the South America context for the study of marine invasive species, legislation and commerce. We found 247 fouling species, including 17 introduced, one of which is a new record for the region, and other 15 species currently considered cryptogenic species that will need further attention to clarify their status. The analysis of mobile and sessile taxa, together with the environmental variables measured in this study and the port movement, allow us to discuss individual ports' vulnerability to future introductions. This is the first large scale study performed for this region on this topic, and it will help in developing monitoring programs and early detection plans to minimize new species introductions along the marine coastline of southern South America.

1. Introduction

The introduction of invasive species is recognized as one of the top five threats to native biodiversity (Sala et al., 2000). An overwhelming number of species are transported worldwide every day by several means, and our understanding of their evolutionary history constantly reveals unexpected complexities (e.g. Geller, 1999; Fortune et al., 2008). Since ocean shipping is considered the most important vector for transporting and introducing species into new areas outside their native ranges (Ruiz and Carlton, 2003; Drake and Lodge, 2007), the monitoring of ports and harbors helps us to predict the vulnerability of local harbors and to develop regional management policies (Bishop and Hutchings, 2011). Indeed, harbors' vulnerability is extremely difficult to predict due to the complexity presented by variables such as propagule pressure

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http://dx.doi.org/10.1016/j.marenvres.2014.06.006
0141-1136/

(Johnston et al., 2009), resource availability (Olyarnik et al., 2009), diversity of resident species and environmental conditions of the receptive habitat (Byers, 2002). Within this context, it is clear necessity to create accurate baseline information about these environmental conditions (Bishop and Hutchings, 2011; Mead et al., 2011).

Port areas concentrate a variety of artificial structures that support many different organisms (Glasby, 1999; Connell, 2001), and it is known that artificial and natural habitats are not equally colonized by fouling species (Connell, 2001). In fact, man-made structures seem to favor the recruitment and survival of fouling exotic species even when the richness of native species is relatively high (Glasby et al., 2007). Indeed, man-made habitats might even act as corridors enhancing the spreading of exotic marine species, as shown by Bulleri and Airoldi (2005) for the invasive *Codium fragile* subsp. *tomentosoides*. Considering that the 90% of the global trade is carried by sea, our understanding of global marine invasion ecology is strongly related to the effort we dedicate to study port areas.

The Southwestern Atlantic (SWA) is currently placing a considerable effort to compile all the records of marine exotic and cryptogenic species (e.g. Orensanz et al., 2002; Scarabino, 2006; Schwindt, 2008). However, the lack of tradition in integrating coastal ecology and the regional maritime history hampers our ability to understand biological invasion patterns in this region (Bortolus and Schwindt, 2007). The earliest fouling studies in warm temperate Argentinean ports date from the 1960's (Bastida, 1971; Valentinuzzi de Santos, 1971), and since then, most cold temperate ports within this region have never been intensively surveyed and their biodiversity remains largely unknown. Argentina has the second longest shoreline of the SWA, after Brazil. However, in contrast with the heavily populated and industrialized coast of Brazil, Argentina has only ten major marine ports along a mostly exposed shoreline with a few marinas associated with recreational activities (Boltovskoy, 2008). Thus, the aim of this work was (a) to identify and quantify the marine fouling organisms in all Patagonian ports of Argentina by conducting a Rapid Assessment Survey (hereafter RAS) and experimental studies, and classifying them as native, exotic or cryptogenic species (b) to survey/describe the environmental and anthropogenic variables of these ports and (c) to analyze and discuss these results in the light of the South America context on marine invasion ecology, legislation and commerce. This is the first large scale study performed for this region on this topic, and it will help in developing monitoring programs and early detection plans to minimize new species introductions along the marine coastline of southern South America.

2. Materials and methods

2.1. Fouling sampling

Of the ten main marine ports of Argentina, we surveyed six, all of them situated in the Patagonian region from 40°S to 54°S: San Antonio Este (SAE), Puerto Madryn (PM), Puerto Deseado (PD), Punta Quilla (PQ), Río Gallegos (RG) and Ushuaia (U, Fig. 1). At each port, a RAS (qualitative fouling sampling) was conducted in spring 2005 on the subtidal zone (i.e. just under the intertidal zone but never exposed to the air) by scuba diving and scraping the surface of different pilings ($n = 3–5$ samples per port, 25 × 25 cm each). Samples were collected by expert scientific divers, bagged separately, labeled, fixed in formalin (4%) and then preserved in ethanol (70%) excepting for the algae, which were kept in formalin. Later, samples were sorted and identified to the lowest possible taxonomic level following the recommendations by Bortolus (2008, 2012a, 2012b). Although most authors of this work have expertise

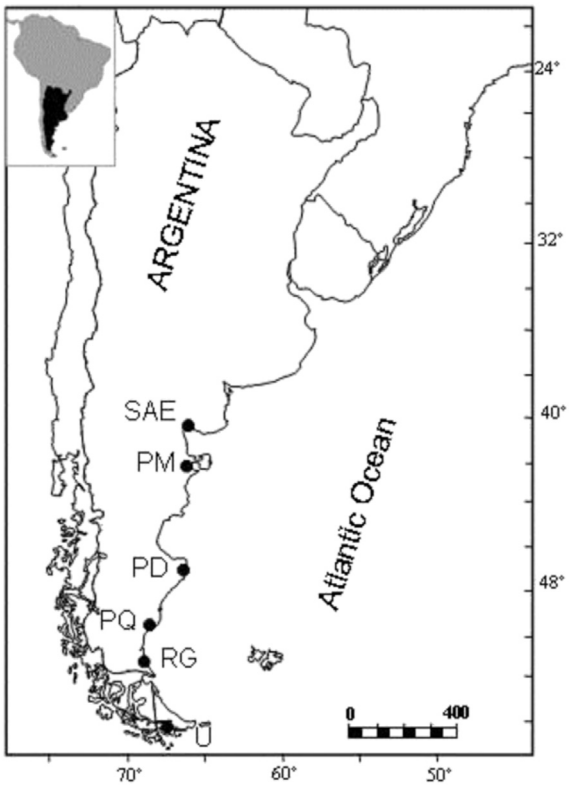

Fig. 1. Studied marine ports of Argentinean Patagonia: San Antonio Este (SAE), Puerto Madryn (PM), Puerto Deseado (PD), Punta Quilla (PQ), Río Gallegos (RG) and Ushuaia (U).

in different taxa, we had the collaboration of several other expert taxonomists in order to cover most of the taxa found (see Acknowledgment section and Appendix A). Vouchers of the collected taxa were deposited in the Centro Nacional Patagónico (CENPAT) Invertebrate Collection. Planktonic and soft-bottom organisms were out of the scope of this study.

To identify the total biodiversity at each port, we complemented the RAS (qualitative sampling) with a survey with fouling plates (quantitative sampling). These plates ($n = 15$ per port, 20 × 20 cm each, one plate per piling) were vertically deployed at each port along the subtidal zone, at 1.5 m below the average low tide, during 18–22 months. All plates were made of fiberglass homogeneously scratched to increase the roughness. Plates were deployed between October and November 2005 (spring) and collected between June and July 2007 (winter). At the end of this period all plates were placed separately in plastic bags and transported in coolers at ~5 °C to the laboratory for processing. In the laboratory each plate was photographed, and the percentage cover of sessile species and the abundance of mobile species, were recorded. Then, all the organisms were removed from the plates, fixed and preserved following Hewitt and Martin (2001). All organisms collected were identified to the lowest taxonomic level possible and deposited in the Invertebrate Collection of the CENPAT. Organisms were classified as native, cryptogenic or exotic following Chapman and Carlton (1991). We noted if a species represented the first record for the region (FR), or if it was never previously mentioned in the regional literature as exotic or cryptogenic species (NM), and also those found outside their known regional geographic range (RE, range extension).

2.2. Port characterization

To assess differences and similarities among ports and to discuss the potential vulnerability of every port to marine invasive species,