Science of the Total Environment 506–507 (2015) 10–17

Contents lists available at ScienceDirect

Science of the Total Environment

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

Effects of chemical disturbances on intertidal benthic assemblages

Mariana Mayer-Pinto [a,*], Barbara Lage Ignacio [b]

[a] Centre for Research on Ecological Impacts of Coastal Cities, Marine Ecology Laboratories A11, School of Biological Sciences, University of Sydney, NSW 2006, Australia
[b] Departamento de Ciências do Mar, Universidade Federal de São Paulo, Av. Almirante Saldanha da Gama 89, Ponta da Praia, Santos, CEP: 11030-400 SP, Brazil

HIGHLIGHTS

- The effects of contaminants need to be assessed in more natural relevant scenarios.
- We assessed the effects of bleach and permethrin on intertidal assemblages in situ.
- No effects on the structure of assemblages were observed.
- Bleach decreased the number of limpets, which can have great ecological consequence.
- Experiments in situ are needed for relevant information to be used in future ERAs.

ARTICLE INFO

Article history:
Received 5 August 2014
Received in revised form 18 September 2014
Accepted 27 October 2014
Available online 14 November 2014

Editor: C.E.W. Steinberg

Keywords:
Pollution
Rocky shores
Pesticide
Bleach
Permethrin
Sodium hypochlorite

ABSTRACT

Contamination is a particular harmful type of chemical disturbance and predicting their effects on natural systems is very complex. Effects of disturbances vary in space and time and depend, among other things, on the type and age of organisms, the habitat being studied and the complex interactions occurring in the systems. Most impact analyses of contaminants are however still done with limited number of selected organisms under laboratory conditions. Manipulative experiments done in situ are important to measure ecologically relevant responses of contaminant effects on marine systems. Ecological approaches on contamination studies, accounting for interactions among species and the environment are essential to understand how such disturbances affect systems. We evaluated the effects of bleach and permethrin, two common and pervasive contaminants, on intertidal benthic assemblages in two different successional stages, mature and young. There were no impacts on the overall structure of assemblages, regardless of their age. The lack of effects on the structure of assemblages might be due to the intrinsic characteristic of the habitat studied, which provide few sinks for contaminants, as well as the inherent features of the organisms themselves. Bleach did cause, however, a decrease in the abundance of limpets, which can have further consequences to these systems. This study shows the importance of studies on chemical disturbances done under relevant natural scenarios and that efficient management policies of natural systems will only achieve successful responses with properly designed experiments under natural conditions.

1. Introduction

Chemical contaminants can be found in most systems worldwide and can alter ecosystem structure and functioning, having serious deleterious consequences for natural systems (Rohr et al., 2006). Importantly, there has been an increasing concern of researchers and government agencies to accurately describe the consequences of contamination to ecosystems. Although recent efforts have been made to achieve these objectives and to improve the predictive power of ecotoxicology (Beketov and Liess, 2012; Vighi and Villa, 2013), much still needs to be done to truly include the 'eco' into 'ecotoxicology' (Chapman, 2002; Van Straalen, 2003). The main goal of determining and predicting the effects of disturbances caused by such toxicants on the diversity and functioning of systems remains therefore a challenging task. The majority of ecological risk assessments and impact analyses of chemical contaminants are still done considering a limited number of selected organisms under laboratory conditions. Ecological approaches on studies with contaminants, taking into account the interactions among species and the environment are essential to have a holistic understanding of how disturbances by contaminants affect organisms, populations and, consequently, natural systems (e.g. Chapman, 2002; Van Straalen, 2003).

* Corresponding author at: Evolution & Ecology Research Centre, School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, New South Wales 2052, Australia. Tel.: + 61 2 93858701.
E-mail address: m.mayerpinto@unsw.edu.au (M. Mayer-Pinto).

http://dx.doi.org/10.1016/j.scitotenv.2014.10.095

Rocky shores are the most common coastal habitats, constituting exposed and sheltered coastlines worldwide (Thompson et al., 2002). These systems provide important services and goods for humans, such as food, tourism and natural costal defence (Menge and Branch, 2001; Costanza et al., 2014). They are, however, constantly threatened by anthropogenic activities, including contamination by chemical toxicants. Industrial and domestic run-offs, including off-site transport of agricultural or non-cultivated land via storm-water runoff, and releases of irrigation tail-water, spray drift and accidental spills are some of the pathways by which contaminants such as biocides and pesticides enter coastal systems (Jones, 2005; Moreira et al., 2010; Carballeira et al., 2012).

Sodium hypochlorite, commonly known as bleach, is a particular pervasive type of biocide. Bleach is one of the most common disinfectant worldwide and is usually found in runoff close to urban centres (Zoller and Sosis, 2005). It has been used for more than 100 years as a biocide in households, hospitals and marine aquaculture industries (e.g. Sano et al., 2004; Roberts et al., 2010; Grabsch et al., 2012). Bleach is also commonly used as an antifoulant at industrial seawater cooling systems, affecting both micro- and macro-organisms (e.g. Lopez-Galindo et al., 2010; Moreira et al., 2010; Piola et al., 2010). Only in Australia, more than 13,000 tonnes per year of bleach is used by industries in the different areas of water and wastewater utility business (Alvarez-Gaitan et al., 2011). Globally, industrial and residential applications for bleach are forecast to grow in the next few years due to necessity of clean water and proper sanitation practices (IHS, 2012), increasing the threat that this contaminant may pose to natural coastal systems.

Permethrin is a widely used pesticide for agricultural, industrial and domestic control of insects. It has also been used as a marine antifoulant agent (Feng et al., 2009). According to the Environmental Protection Agency of the United States of America (EPA), approximately 900 tonnes of permethrin are applied annually to agricultural, residential and public health use sites (EPA, 2006). Although this compound is toxic to many freshwater and marine organisms (e.g. Sanchez-Fortun and Barahona, 2005), the application of permethrin in the United State is increasing as this pesticide is being used to replace other types of pesticides, considered more toxic (DeLorenzo and Fulton, 2012). Understanding the effects that these chemicals, i.e. bleach and permethrin, have on coastal organisms and/or assemblages is therefore pivotal for the devise of efficient management and remediation policies.

Although the effects of biocides and pesticides, in general, on single or multiple species at micro and mesocosm experiments are well described in the literature (e.g. Cripe, 1994; Boone et al., 2004; Emmanuel et al., 2004; Relyea and Diecks, 2008; Tlili et al., 2011), the effects of such toxicants on community structure level are rarely assessed (Beketov and Liess, 2012) (but see e.g. Rohr and Crumrine, 2005; Schaefer et al., 2007), despite numerous pleas for a shift in this approach (e.g. Chapman, 2002; Relyea et al., 2005; Relyea and Hoverman, 2006; Rohr et al., 2006). Permethrin, for instance, has been shown to inhibit barnacle settlement (Feng et al., 2009) and exposure to bleach at concentrations of 0.7 mg L^{-1} (residual chlorine) has caused 100% mortality of mussels of 3–4 cm size (Masilamoni et al., 2002). Furthermore, some algal species of the genus *Ectocarpus*, such as *Ectocarpus variabilis* and *Ectocarpus siliculosus* have been reported to be extremely sensitive to bleach (Rosemarin et al., 1994). In fact, this toxicant has caused mortality of many species of brown algae (of the genera *Fucus*, *Chorda* and *Pilayella*) (Rosemarin et al., 1994; van Wijk et al., 1998; Carballeira et al., 2011). Such effects do not, however, take into consideration the complex conditions of natural systems and how these can influence the impacts of contaminants.

The severity of impacts caused by contaminants on natural systems depends on the type of contaminant, their intensity and frequency of exposure, on the interaction with physical and chemical parameters/conditions naturally found on the environment; on the vulnerability of the organisms being disturbed; and on the prevalent type of competitive relationships occurring in the system (see e.g. Sousa, 2001; Fleeger et al., 2003). It is also generally thought that organisms and/or assemblages in early stages of development are more susceptible to effects of disturbances, in general, than those in later or 'mature' stages (Sousa, 1980; Altman and Whitlatch, 2007; Markey et al., 2007). These myriads of factors and their interactions make the effects of contamination on diversity and ecosystem functioning hard to predict (McMahon et al., 2012). Furthermore, such effects are frequently confounded by the natural spatial and temporal variability of the biological realm (see e.g. Underwood, 1996). Assessing the effects of contaminants in an ecological relevant context is therefore essential to have more accurate results, including possible indirect effects of such toxicants, and consequently improve our ability to make more accurate and precise predictions (e.g. Rohr and Crumrine, 2005). Hence, manipulative experiments, primarily in situ conditions, where relevant natural scenarios and biological interactions are considered, are an important tool to properly evaluate the effects of disturbances by chemical contaminants on natural systems.

In this study, we evaluated the effects of bleach and the pesticide permethrin on natural assemblages at intertidal rocky shores. Using manipulative experiments in the field, we tested: (i) whether different intertidal species would be affected differently by the two types of contaminants: bleach and permethrin; which would then lead to different assemblages after the disturbance; and to test (ii) whether intertidal assemblages in different stages of development would respond

Table 1
Multivariate analyses of variance (PERMANOVA) of the mature assemblages.

Source	df	Mature assemblages	
		MS	*F*
Sites (Si)	1	3463	1.68 ns
Treatments (Tr)	3	1797	0.87 ns
Si × Tr	3		Pooled
Residual	23	2032	
Pooled	26	821	

Sites (Si) were random with 2 levels. Treatment (Tr) was fixed with 4 levels. $n = 4$; ns = not significant.

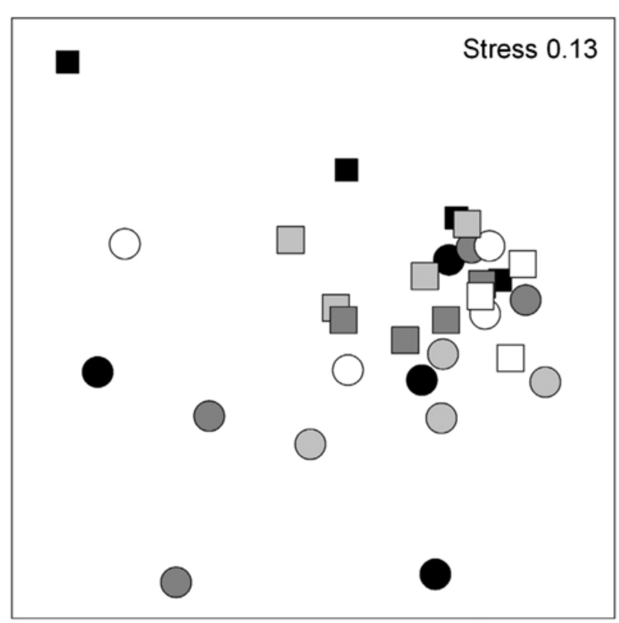

Fig. 1. nMDS of mature intertidal assemblages exposed to algicide (black); pesticide (light grey); fresh-water control (dark grey) and control treatments (white) at site 1 (circle) and site 2 (square) at Cape Banks.