Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Marine Pollution Bulletin 52 (2006) 1048–1055
MARINE POLLUTION BULLETIN
www.elsevier.com/locate/marpolbul

Effects of antifouling biocides to the germination and growth of the marine macroalga, *Hormosira banksii* (Turner) Desicaine

Jackie H. Myers [a,b,c,*], Leanne Gunthorpe [b,1], Graeme Allinson [a,2], Susan Duda [b,3]

[a] *School of Ecology and Environment, Deakin University, P.O. Box 423, Warrnambool, Victoria 3280, Australia*
[b] *Department of Primary Industries Research Victoria, Queenscliff, P.O. Box 114 Queenscliff, Victoria 3225, Australia*
[c] *School of Biological Sciences, Monash University, Clayton Campus, Clayton, Victoria 3800, Australia*

Abstract

The International Maritime Organisation's (IMO) ban on the use of tributyltin in antifouling paints has inevitability increased the use of old fashioned antifoulants and/or the development of new paints containing 'booster biocides'. These newer paints are intended to be environmentally less harmful, however the broader environmental effects of these 'booster biocides' are poorly known. Germination and growth inhibition tests using the marine macroalga, *Hormosira banksii* (Turner) Desicaine were conducted to evaluate the toxicity of four new antifouling biocides in relation to tributyltin-oxide (TBTO). Each of the biocides significantly inhibited germination and growth of *Hormosira banksii* spores. Toxicity was in increasing order: diuron < zineb < seanine 211 < zinc pyrithione < TBTO. However, the lack of knowledge on partitioning in the environment makes it difficult to make a full assessment on whether the four biocides tested offer an advantage over organotin paints in terms of environmental impact.

Keywords: Antifoulants; Biocides; *Hormosira banksii*; Tributyltin; Toxicity testing

1. Introduction

Fouling, or the settlement and growth of marine organisms on submerged structures, is estimated to have a global cost of more than $3 billion annually (Jacobson and Willingham, 2000). Organisms attached to ship hulls leads to increased frictional resistance of the ship therefore decreasing speed and increasing fuel consumption. For instance, Fernandez-Alba et al. (2002) estimated that a 1 mm thick layer of algal slime increases hull friction by 80%, and fuel consumption by 17%. Fouling also increases the need for ships to be out of action for hull cleaning which adds further to costs of the shipping industry (Boxall et al., 2000; Evans et al., 2000; Turley et al., 2000; Terlizzi et al., 2001). The common solution to avoid fouling is to make submerged surfaces unsuitable for settlers usually by coating surfaces with antifouling paints.

Antifouling paints have been used for over 100 years to protect submerged structures. These paints contain chemical compounds (biocides), which are released from the paint matrix, to provide a constant threshold concentration of the biocide in the water, therefore inhibiting the development of fouling communities (Boxall et al., 2000; Terlizzi et al., 2001). Organotin biocides have played a major role in reducing the effects of fouling, especially in improving the economy of the shipping industry. Tributyltin (TBT), an organotin biocide, was introduced onto the market in the mid 1960s and until recently, was the most commonly

* Corresponding author. School of Biological Sciences, Monash University, Clayton Campus, Clayton, Victoria 3800, Australia. Tel.: +61 3 9905 5601; fax: +61 3 9905 5613.

E-mail addresses: jhmyers@deakin.edu.au (J.H. Myers), Leanne.Gunthorpe@dpi.vic.gov.au (L. Gunthorpe), graemea@deakin.edu.au (G. Allinson), Susan.Duda@dpi.vic.gov.au (S. Duda).

[1] Tel.: +61 3 5258 0111; fax: +61 3 5258 0270.
[2] Tel.: +61 3 5563 3316; fax: +61 3 5563 3462.
[3] Tel.: +61 3 5258 0312; fax: +61 3 5258 0270.

0025-326X/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.marpolbul.2006.01.010

used antifouling agent. However, TBT spreads from ships hulls and submerged structures and accumulates in marine environments and in biota. The toxic effects of TBT have been observed in non-target invertebrates, micro- and macro-algae (EPA, 1993; Jacobson and Willingham, 2000; Terlizzi et al., 2001). These effects first became apparent in the late 1970s (EPA, 1993), and it was subsequently found that many semi-enclosed water bodies with intensive shipping had become contaminated with TBT. These impacts induced many governments to restrict the use of organotin-based biocides, and in 2003 the International Maritime Organization (IMO) banned the application of organotin biocides. The IMO further requires that by 2008 all vessels be free of organotin coatings (Evans et al., 2000; Turley et al., 2000; Maraldo and Dahllof, 2004).

The IMOs restrictions have led to the development of new paints incorporating 'booster biocides'. These booster biocides are used to improve the efficiency of the paint's formulation, predominantly by inhibiting the primary growth of fouling organisms (Voulvoulis et al., 1999; Terlizzi et al., 2001; Thomas et al., 2001). Currently there are nine booster biocides approved for use in amateur and professional antifouling products. These are chlorothalonil, dichlofluanid, Igarol 1051, TCMS pyridine, TCMTB, diuron, kathon 925 and 5287 (otherwise known as seanine 211), zinc pyrithione (Zpt) and zineb (Voulvoulis et al., 1999; Boxall et al., 2000; Thomas et al., 2001). These biocides are intended to be environmentally less harmful compared to the organotin biocides, however the environmental effects of these 'booster biocides' are poorly known. This is due in part to their recent introduction, limited usage as biocides and a perception that they are less toxic than TBT (Evans et al., 2000; Terlizzi et al., 2001; Maraldo and Dahllof, 2004).

Australian authorities rely heavily on data obtained from overseas species to determine the risks associated with exposure to biocides in aquatic environments. Australia has a diverse range of marine ecosystems, some unique, which may have different sensitivities compared with European and American species. Therefore, it may not always be appropriate to base guidelines on the sensitivities and responses of northern hemisphere species. There is a need to evaluate the impacts of the new biocide formulations on local Australian temperate species.

Hormosira banksii is an important representative of the macroalgal communities of temperate Australia. This species provides shelter and microhabitat for a number of marine organisms including worms, crustaceans and molluscs, and is found on rock platforms surrounding areas of high shipping activity. *Hormosira banksii* is therefore at risk of being exposed to the effects of biocides.

The aim of this study was to evaluate the toxicity of four new biocides in relation to tributyltin-oxide (TBTO) by measuring impacts on *H. Banksii* (Turner) Desicaine germination and growth.

2. Materials and methods

2.1. Bioassay protocol

Hormosira banksii portions were collected at low tide from 13th Beach, Barwon Heads, Victoria, Australia (Fig. 1) and transported back to the laboratory (18–20 °C), placed onto a flat surface lined with paper towel and allowed to dry for 2 h at 18–20 °C. Algae were then placed into brown paper bags and stored overnight at 4 °C. Gamete release was initiated according to the procedure of Myers et al. (in press). In short, *Hormosira banksii* portions were placed into warmed natural seawater (30 °C) for 30 s then laid out on clean paper towel so no one alga touched another alga. Gamete release occurred within minutes. Female gametes were observed as a green extrusion on the plant's surfaces and were collected first followed by male gametes, which extruded as an orange colour on the plant's surface. The density of eggs and sperm was

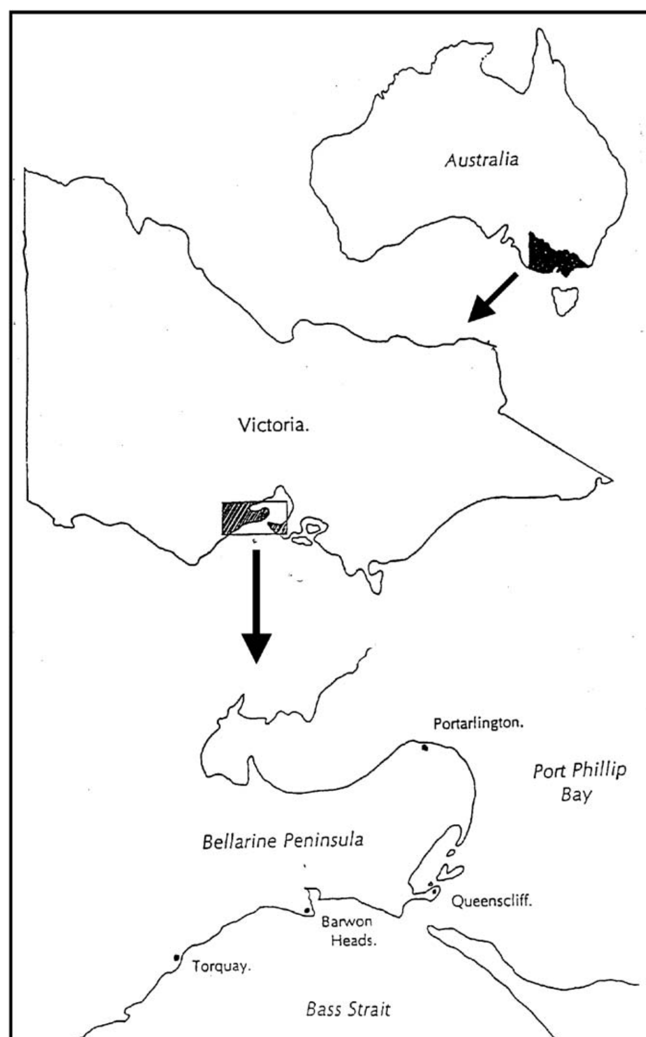

Fig. 1. Map of Australia showing location of sampling sites for *Hormosira banksii*. Inset shows a map of Victoria and a map of the Bellarine Peninsula, region where 13th Beach, Barwon Heads is located.