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Biocontrol of fouling pests: Effect of diversity, identity and density of control agents

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ABSTRACT

Augmentative biocontrol, using native natural enemies, has been suggested as a promising tool to control marine biofouling pests on artificial structures. However, there are still important knowledge gaps to be addressed before biocontrol can be considered as a management tool. In a field experiment on floating marine structures we examined intra- and interspecific consumer interactions among biocontrol agents on different surface orientations. We tested the effect of identity, density and diversity of three invertebrates (the 11-arm seastar *Coscinasterias muricata*, the sea urchin *Evechinus chloroticus* and the gastropod Cook's turban *Cookia sulcata*) to reduce established biofouling and to prevent fouling growth on defouled surfaces. High densities of biocontrol agents were not more effective at fouling control (cover and biomass) than low densities. Nor did multi-species treatments function more effectively than mono-specific ones. However, biocontrol agent identity was important, with the 11-arm seastar and Cook's turban being the most effective at fouling reduction and prevention, respectively. Surface orientation had a strong effect on the effectiveness of control agents, with the best results obtained on vertical compared to diagonal and underside surfaces. This study confirmed the potential of biocontrol as a management tool for marine pest, indicating that identity is more important than richness and density of control agents. It also highlighted the limitations of this approach on diagonal and underside surfaces, where control agents have limited retention ability.

1. Introduction

Biofouling communities on artificial marine structures such as marinas, ports, aquaculture farms and seawalls, are a reservoir for marine pests, including non-indigenous species (Carlton, 1989; Bulleri, 2005; Glasby et al., 2007; Ruiz et al., 2009). Reduction of pest populations on fixed artificial structures (e.g. marina pontoons, wharf piles, aquaculture farm structures, break waters) can constrain their spread to adjacent habitat, and reduce the probability of vector inoculation, thus limiting further spread (Drake, 2004; Forrest and Hopkins, 2013; Atalah et al., 2015). The ability to eradicate or control marine pest populations has been constrained by the lack of tools that are effective and practicable at operational spatial scales. Most approaches to marine pest control rely on mechanical removal (e.g. by divers) or chemical treatments (Hewitt et al., 2005). Mechanical removal is often labour-intensive and impractical to apply at broad spatial scales, and may also have limited effectiveness (Piola et al., 2009). Chemical treatments generally rely on the use of toxicants, which can have negative and persistent environmental effects (Myers et al., 2000). Accordingly, there is a need for cost-efficient and environmentally acceptable alternatives.

Augmentative biocontrol (using native species as control agents) has been proposed as a promising alternative or complementary pest management tool (Lafferty and Kuris, 1996; Goddard et al., 2005; Atalah et al., 2013a, 2013b, 2014). The utility of augmentative biocontrol to supress marine pests has been assessed on transport vector hubs (Atalah et al., 2014), within an aquaculture context (Lodeiros and García, 2004; Dumont et al., 2011) or in natural habitats (Thibaut et al., 2001; Ross et al., 2004; Davis et al., 2005; Atalah et al., 2013b). For example, native invertebrate consumers (both predators and grazers) have the ability to prevent establishment, or to reduce biofouling cover and biomass on marina pontoons and wharf piles (Atalah et al., 2014). However, there are still research gaps that need to be addressed before biocontrol can be considered as a tool for the management of

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marine pests. For example, the effects of density and diversity of control agents on the suppression of marine pests have been largely overlooked. Predator and consumer diversity can drive important changes in ecosystem structure and function (Myers and Worm, 2003; O'Connor and Crowe, 2005; Byrnes et al., 2006; Bruno and Cardinale, 2008). Similarly, biocontrol effectiveness can be significantly altered by incorporation of multiple consumer species (Rosenheim et al., 1993, 1995; Snyder et al., 2006). Multispecies biocontrol may lead to increased pest suppression due to consumer synergisms (Hixon and Carr, 1997; Cardinale et al., 2003) or complementary resource consumption (Byrnes et al., 2006). On the other hand, negative inter-specific interactions between control agents could reduce pest suppression (Finke and Denno, 2004, 2005).

Substrate orientation is an important consideration in the assessment of effectiveness of biocontrol. Vertical and underside surfaces are common in artificial structures in the marine environment. Community structure is markedly different between biofouling colonising different surface orientations (Glasby and Connell, 2001). Perhaps more importantly, grazing by invertebrates can be substantially reduced on horizontal undersurfaces where the risk of dislodgment is high (Trussell et al., 1993; Miller et al., 2007; Sui and Merz, 2014). In this context, it is crucial to identify biocontrol agents that perform well on a range of surface orientations.

In the present study, we examined interspecific interaction among invertebrate consumers native to New Zealand. The selected taxa have been previously identified as potential biocontrol agents on artificial structures (Atalah et al., 2014), however until now the effects of combining biocontrol agents, at varying densities and on different surface orientations has not been examined. On caged marina pontoons we tested the effects of control agent identity, density and diversity on the ability to control fouling assemblages at a vector hub. We specifically hypothesised that higher consumer diversity and density increase top-down control of biofouling pests We also tested the effect of surface orientation on control agent performance. Survival of biocontrol agents was also quantified. We discuss implications of our findings for pest control and biofouling management on artificial marine habitats.

2. Methods

2.1. Biocontrol agents and study locations

The biocontrol agents used in this study were selected principally based on results from previous studies (Atalah et al., 2013b, 2014, 2015). The selected species fulfilled the following criteria (i) invertebrate consumers widely distributed throughout New Zealand and easily sourced from local areas, (ii) not considered to be of any special value (e.g. endangered), (iii) known to exert a structuring force on fouling communities and (iv) able to be caged. Three species were selected: 11-arm seastar *Coscinasterias muricata* (Family Asteriidae, 235 ± 26 mm diameter); the sea urchin *Evechinus chloroticus* (Family Echinometridae, 57 ± 2 mm diameter); and the gastropod *Cookia sulcata* (Family Turbinidae, 79 ± 4 mm width). Animals were collected from local reefs and transported in tubs filled with sea water to the study site at the Nelson marina (S 41° 15′ 21″S, E 173° 16′ 33.31″) where the experiment was conducted.

2.2. Experimental set-up

A field caging experiment was conducted at the Nelson marina for six months between October 2013 and March 2014. Temperature and salinity ranges during the experiment were 13.3–23.1 °C and 25.1–31.3 psu, respectively. The marina docks float on plastic semi-circular pontoons (100 × 60 × 50 cm, Fig. 1). Pontoons are covered by a diverse assemblage of fouling organisms, including indigenous and non-indigenous ascidians, bryozoans, algae, bivalves and sponges. Plastic cages (2 cm mesh) attached to a PVC frame enclosed each pontoon and prevented animals from escaping (Fig. 1). Cages had a mesh divider in the middle to separate the pontoon in halves, each half constituted an experimental unit. On each experimental unit the flat end of the pontoon constituted a submerged vertical surface of 0.1 m^2. The curved underside of the pontoon was considered in thirds (each ~0.1 m^2), the middle third was designated as 'underside' while the thirds on either side were designated 'diagonal'. Pontoon treatments consisted of heavily fouled surfaces, and defouled surfaces from which biofouling was scraped off prior to cage attachment. The former treatment evaluated the ability of the biocontrol agents to eliminate established assemblages, whereas the defouled treatment investigated whether biocontrol could prevent the accumulation of new biofouling.

2.3. Experimental design

We employed an additive design with replacement (O'Connor and Crowe, 2005; Benedetti-Cecchi, 2006; Byrnes and Stachowicz, 2009) to identify the effects of richness, density and identity of consumers on fouling assemblages. Consumer 'Density' referred to the number of individuals (irrespective of the species identity) per experimental unit and included three levels: zero (Control), Low (13 individuals for urchin and snail treatments, and 2 individuals for the seastar treatment) and High (25 individuals for urchin and snail treatments, and 4 individuals for the seastar treatment). The high density treatments included three levels of 'Richness' (i.e. number of species of biocontrol agent): either one, two or three species (Table 1). Biocontrol agent identity referred to the specific control agent (species) or agent combination used in each level of the factor richness. Agent densities were chosen to have comparable biomass (wet weight) across treatments and were selected on the basis of the effects seen in a previous biocontrol study (Atalah et al., 2014). Treatments were each randomly assigned to four fouled experimental units ($n = 4$). Additionally, prior to the experiment, fouling assemblages were scraped off the 16 experimental units by divers, and low-density single-species treatments (and controls, $n = 4$) were assigned to defouled experimental units.

The experiment was checked monthly and missing individuals (due to mortality and escapes) were recorded and replaced, to maintain nominal treatment densities. Pontoons were photographed at the end of the experiment (6 months) using 0.06 m^2 photo-quadrats, to estimate percentage cover. Three photographs and three scraping samples were obtained from each pontoon: one on the vertical side, one on the diagonal surface and one on the underside. A margin of 1 cm around each side was ignored to avoid edge effects. Scraping samples were obtained using a 10 × 20 cm (0.02 m^2) quadrat. The scraping samples were drained for 2 min before weighing to determine biofouling wet weight (i.e. biomass). Photo-quadrat images were analysed using the random dot method (Meese and Tomich, 1992) on Coral Count Point software (CPCe v4.1, Kohler and Gill, 2006), with 50 stratified random points overlaid on each image. Sessile taxa >1 mm were identified to major taxonomic groups or grouped into morphological criteria and their percentage cover estimated.

2.4. Statistical analyses

The efficacy of the pest control in the analysis was represented