Small-scale habitat complexity of artificial turf influences the development of associated invertebrate assemblages

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ARTICLE INFO

ABSTRACT

Ecosystem engineers can influence biodiversity by enhancing complexity, and modifying the availability of resources. Understanding the mechanisms by which ecosystem engineers shape biodiversity is central to the concept of 'ecological engineering' of anthropogenic structures to enhance biodiversity. Here the presence and complexity of artificial turf was manipulated on an artificial structure to test the hypothesis that the colonisation of sessile invertebrates and mobile epibiota would vary with habitat complexity. Both sessile and mobile assemblage compositions differed according to the presence of artificial turf, and its complexity. Sessile invertebrates occupied greater proportions of available space on topographically simple 'blank' surfaces or low complexity artificial turf than those with high complexity turf, whereas mobile taxa were generally more abundant on the turf. However, the mobile assemblage was unrelated to the sessile assemblage when examined within each level of initial substrata complexity. Contrary to the increasing number of studies demonstrating nested hierarchical relationships between co-occurring ecosystem engineers, this study provides an example of an ecosystem engineer mimic (artificial turf) leading to the formation of habitat mosaics at small scales. The introduction of complex substrata to otherwise topographically simple artificial structures is a promising means of actively influencing assemblage composition.

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1. Introduction

Ecosystem engineers significantly influence biodiversity by creating and modifying physical habitat (Jones et al., 2010). While ecosystem engineers may have positive, negative or neutral effects on individual species, at the scale of patches or larger they generally have a positive influence on biodiversity (Jones et al., 1997, e.g. Lemasson et al., 2017–in this issue; Teagle et al., 2017–in this issue). Enhancement of habitat complexity, which is characterised by a range of structural components (Tokeshi and Arakaki, 2012), is often cited as a key mechanism by which ecosystem engineers increase diversity (Kovalenko et al., 2012). Indeed, changes in habitat complexity can have large influences on associated assemblages (Cranfield et al., 2004; Tonetto et al., 2014). Greater surface area in more complex habitats is thought to promote species co-existence, however, effects of complexity on diversity are often independent of increases in area (Kovalenko et al., 2012).

Alteration of habitat complexity may modify a number of ecological processes, such as resource availability, recruitment and predation (Tokeshi and Arakaki, 2012; Loke et al., 2017–in this issue; Firth et al., 2017–in this issue), leading to the development of unique assemblages.

Complex habitats may modify predator-prey interactions by providing refuges from predators and decreasing predator foraging efficiency (Russ, 1980; Diehl, 1988; Warfe and Barmuta, 2004). However, where abundances of predators are benefited by complexity, predation may increase (Naylor and McShane, 1997). Greater niche space in high complexity may promote co-existence (Willis et al., 2005), by reducing competition (Sarty et al., 2006). Complex habitat may also act to alter resource availability (Smith et al., 2014) or colonisation dynamics (Taniguchi and Tokeshi, 2004). For example, the morphology of benthic organisms can affect water flow (Abelson et al. 1993), with complex structures such as algal turfs reducing flow (Carpenter and Williams, 1993), and subsequently influencing the supply of food or recruits.

The habitat complexity provided by ecosystem engineers might not only directly influence an associated assemblage, but also indirectly influence it by determining the co-occurrence of other ecosystem engineers (Gribben et al., 2009; Angelini et al. 2011). The interactions among co-occurring organisms are influenced by environmental conditions (Bertness and Callaway, 1994; Bertness and Leonard, 1997; He et al., 2013). For example, in stressful environments, an established ecosystem engineer may facilitate secondary ecosystem engineers by ameliorating stressors (Altieri et al. 2007; Thomsen et al., 2010; Angelini et al. 2011). However, in less stressful systems where competitive interactions are intense (Bertness and Callaway, 1994), mosaics of adjacent

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habitats constituting individual ecosystem engineers may occur (Angelini et al. 2011). The effects of ecosystem engineers are not only dependent on environmental conditions, but also their identity (Sueiro et al., 2011) and intraspecific variation in their population- and individual-level traits (Bishop et al., 2013).

Along urbanised coastlines, the proliferation of artificial structures has resulted in loss of complex natural habitats (Bishop et al., 2017–in this issue). Artificial structures typically have flat, homogenous, surfaces in comparison to the complex natural habitats they may replace, and frequently differ in orientation to natural substrata in having vertical and/or downwards facing surfaces (Glasby and Connell, 1999; Bulleri and Chapman, 2010). Consequently, the assemblages that artificial structures support differ from those of natural rocky reefs (Connell and Glasby, 1999). Natural rocky surfaces are often dominated by native algae such as *Corallina officinalis*, while non-indigenous invertebrates often dominate artificial structures (Dafforn et al., 2012). A key strategy for reducing the impacts of artificial structure has been to design them to more closely resemble natural systems (Bulleri and Chapman, 2010; Dafforn et al., 2015). The addition of complexity through physical modification has been explored through the addition of water-retaining features to intertidal structures (Browne and Chapman, 2011; Firth et al., 2013), but the potential for modifications to mimic the natural habitat complexity provided by ecosystem engineers remains largely unexplored.

Where environmental conditions prohibit the natural recruitment of ecosystem engineers to artificial structures (e.g. insufficient light prevents seagrass or algal growth or altered flow affects invertebrate settlement) then the use of habitat mimics is a potential strategy of habitat enhancement. In an early example, researchers suspended artificial seagrass leaves underneath pontoons to increase physical complexity and over time richness, abundance and settlement of fish was enhanced compared to un-manipulated pontoons (Hair and Bell, 1992). Here, an experiment utilising artificial turf was conducted to assess how the complexity of an ecosystem engineer mimic influences the colonisation of sessile invertebrate and mobile assemblages. While algal 'turf' is a broad term that has previously been used to describe a number of algal species, here we consider our artificial turf to share similar physical structural characteristics to the coralline algae *Corallina officinalis* (see also Kelaher, 2002). Artificial turf of similar dimensions used here has previously been demonstrated as a suitable intertidal coralline turf substitute for gastropods, with assemblages on natural and artificial turf converging through time (Kelaher, 2002). We emphasise that the use of artificial turf in the context of this study is to examine practical means of manipulating habitat complexity on a scale relevant to the target assemblages and eco-engineering of hard substrata.

We predicted that with increasing complexity of artificial turf, colonisation of mobile epibiota, that depend on structured habitat, would also increase. However, we predicted that the presence of the turf would inhibit the recruitment of sessile invertebrates, that provide biogenic habitat for mobile invertebrates on subtidal structures (Sellheim et al., 2010; Birdsey et al., 2012) and the composition of mobile invertebrate assemblages would consequently also vary as a function of sessile invertebrate assemblage composition.

2. Materials and methods

2.1. Sampling site and design

An experimental field manipulation was done at Chowder Bay, Sydney, Australia (33°50″24.22″S, 151°15″12.95″E). Chowder Bay is an embayment of Sydney Harbour, approximately 3.5 km from the mouth of this drowned river valley. During this study, the salinity of Chowder Bay averaged 34.6 ppt and temperature 20.4 °C.

The development of sessile and mobile epibiota assemblages was compared between three treatments, each of which varied in complexity – topographically simple 'blank' PVC, low complexity artificial turf

and high complexity artificial turf. Each of the treatments was constructed on a 10×10 cm PVC settlement plate. Blank plates were lightly sanded to facilitate settlement. The high and low complexity turf treatments each had a 10×10 cm square of artificial turf, comprising polyethylene strips attached to a polypropylene/polyester base with latex backing, which in turn was glued to the PVC settlement plate. The polyethylene strips of the high complexity turf were 18 mm long, 1.5 mm wide and arranged in clumps of 10 fronds at a density of 192 clumps per 10×10 cm. Low complexity turf was constructed from high complexity turf, by trimming the bristles to their plastic base (2–3 mm long). There were twelve settlement plates per treatment.

Two PVC settlement plates, of the same treatment, were attached to each of eighteen 27×65 cm PVC panels using cable ties. Plates were arranged on panels so that their nearest edges were 10–30 cm apart. This design gave six panels of each of the three experimental treatments, with n = 36 plates in total. Panels were hung from a dock and suspended approximately 50 cm from the benthos at ~3 m depth at low tide. Brick weights were attached to the panels to keep them stable. Each panel was located approximately 1 m from the nearest neighbouring panel and randomly positioned with respect to complexity treatments. The settlement plates were orientated downwards as is often the orientation of artificial surfaces introduced to marine environments (e.g. the underside of pontoons and jetties). Downwards orientated surfaces are unable to support the algal communities of upwards orientated surfaces (Irving and Connell, 2002), necessitating eco-engineering interventions that rely on algal mimics as opposed to living macrophytes.

Assemblages were left to develop for 12 weeks between October 2012 and January 2013. Upon collection, plates were carefully removed from the water, detached from the panels and immediately placed into separate containers to prevent inter-replicate mixing of mobile epibiota. While recognising some mobile epibiota may not have been retained by the collection procedure, all plates were handled in a comparable manner. The mobile epibiota were sieved through a 300 μm mesh and stored in 80% ethanol prior to census. Mobile epibiota from one settlement plate per panel (n = 18) were enumerated under a dissecting microscope and were identified to family for Amphipoda and Isopoda, order for Copepoda, family for Gastropoda (except when assigned to the clade Nudibranchia), or to the level of Ostracoda, Nemertea, Platyhelminthes, Polychaeta, Asteriidae or Caridae.

The sessile invertebrate assemblage on every plate was counted live under a dissecting microscope ($40\times$). A regularly spaced 7×7 grid was used to determine cover, giving a total of 49 points per replicate, with the two points falling on the attachment holes excluded from analyses. On the high complexity turf treatment, sessile invertebrates could attach to both the backing and to the fronds themselves, such that effectively two distinct surfaces could be colonised. Accordingly, a separate count (7×7 grid) was performed for both the 'understory' and 'canopy' surfaces of the high complexity treatments. Data were then pooled for the 'understory' and 'canopy' surfaces for each high complexity replicate, with the total divided by two to account for the additional sampling effort required to census the greater surface area of the high complexity treatment. Sessile taxa were recorded to the lowest possible taxonomic level and then subsequently assigned to functional groups based on structural morphology. The sessile functional groups identified included barnacles, calcified or non-calcified polychaetes, colonial or solitary ascidians, calcified arborescent or encrusting bryozoans, non-calcified stoloniferous bryozoans, encrusting or non-encrusting bivalves, ciliophora, hydroids, and encrusting or non-encrusting sponges.

2.2. Data analyses

Permutational multivariate analyses of variance (PERMANOVA, Anderson et al., 2008) separately tested for differences in the composition of the sessile and mobile assemblages among the three complexity treatments. The analysis of the sessile assemblage had two factors,