Floating pontoons create novel habitats for subtidal epibiota

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Abstract

Urban structures in the form of pontoons and pilings represent major coastal habitats for marine organisms and understanding the factors causing abundances of organisms to differ between these and natural habitat has been neglected in the study of coastal ecology. It has been proposed that composition of substrata explain differences previously described between subtidal assemblages of epibiota on rocky reef (sandstone) and pontoons (concrete) in Sydney Harbour, Australia. This study tested the hypothesis that differences in the composition of substratum (sandstone vs. concrete) independent of type of habitat (rocky reef vs. pontoon) affects the development of epibiotic assemblages. This was tested by experimentally providing substratum of the two types in both habitats. Epibiotic assemblages were unaffected by the composition of substratum but strongly affected by the type of habitat; demonstrating that pontoons constitute novel habitats for epibiota. This result highlights a need for determining how current ecological understanding of subtidal epibiota, which is heavily based on studies of urban structures (pilings and pontoons), relates to natural reef. Future tests of hypotheses about the nature of these differences will not only contribute to better ecological understanding of epibiota and their use of urban structures as habitats, but also to better predictions of future changes to the ecology of coastal habitats. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Artificial habitats; Disturbance; Fouling; Sessile; Man made

1. Introduction

Urbanisation (sensu McDonnell and Pickett, 1990) of coastal areas is set to continue with more than half (67%) of the global population living on the coast (Hammond,
1992), doubling within 30 years (Norse, 1995). Considerable change to the ecology of coastal habitats is anticipated as natural habitat continues to be destroyed and replaced by urban structures such as pilings, pontoons and rock walls (Glasby and Connell, 1999). Urban structures are often built over rocky reef, the predominant habitat for some of the world’s most diverse sets of sessile plants and animals (epibiota) that attach to hard substrata (Moore and Seed, 1986; Womersley, 1987, Shepherd and Davies, 1997). The urban structures that replace rocky reef support a large subset of these epibiotic species (Connell and Glasby, 1999) and, therefore, represent a major coastal habitat occupying thousands of hectares.

Despite this apparent surrogacy for rocky reef there is concern that urban structures may not substitute natural reef (Glasby and Connell, 1999). Urban structures support different epibiotic assemblages to those on natural reef (Butler and Connolly, 1996; Connell and Glasby, 1999; Glasby, 1999a), and may act as different habitats for epibiota. Such heterogeneity of habitat is one of the most important features influencing the processes that affect patterns of abundance (Kolasa and Pickett, 1991). Consequently, urban structures may cause considerable change to the identity and abundances of epibiotic species within an area.

Understanding urban structures as marine habitats and how to improve their surrogacy for natural reef is an area of urgent need in coastal ecology. An immediate priority is the identification of factors that cause taxa to differ in abundance between urban structures and reef. Even though a substantial amount of our ecological understanding of subtidal epibiota is based on studies done on urban structures (primarily pilings and pontoons), they have been treated as convenient habitats, rather than the basis for hypotheses about their effects on epibiota (e.g. Osman, 1977; Sutherland and Karlson, 1977; Dean and Hurd, 1980; Keough, 1984; Butler, 1991; Osman and Whitlach, 1995; Brown and Swearingen, 1998). Consequently, there is little understanding of the effects of urban structures on epibiota, and even less on how our current understanding of their ecology relates to natural reef.

Composition of substratum appears an obvious factor that may explain differences in abundances of taxa between urban structures and rocky reef. Urban structures are made of materials naturally foreign to the marine environment (e.g. concrete) and are quite different to rocky reef. Previous work has shown composition of substratum to affect the recruitment and development of epibiota on settlement plates (e.g. Crisp and Ryland, 1960; Harlin and Lindbergh, 1977; McGuinness, 1989; Anderson and Underwood, 1994). Recent comparisons of rocky reef to several urban structures show the abundances of epibiota to be more similar among surfaces made of the same material (concrete pilings and concrete pontoons), and these most different to those on sandstone reef (Connell and Glasby, 1999). Although differences in composition of substratum correlate with differences in epibiotic assemblages, this is also true of several other factors (e.g. age: introduced structures vs. seasoned reef) (Connell and Glasby, 1999).

In this study, the effect of substratum on the development of assemblages of epibiota was analysed experimentally to assess whether known differences in composition of substrata (concrete vs. sandstone) explained observed differences in structure of epibiotic assemblages between rocky reef and urban structures. Compared to rocky reef, pontoons support the most distinct assemblages of epibiota (Connell and Glasby, 1999) and would
constitute novel habitats unless substratum explains this dissimilarity. I tested the hypothesis, therefore, that the development of epibiotic assemblages is affected by differences in the type of substratum (sandstone vs. concrete) independent of type of habitat (rocky reef vs. pontoon).

2. Methods

2.1. Study area and experimental treatments

The study was done from June (winter) 1998 to January (summer) 1999 in Middle Harbour, the northern part of Sydney Harbour, Australia (33°48’ S, 151°14’ E, Fig. 1). Rocky reefs in Middle Harbour extend about 5 m from the shore and reach a depth of ~4 m. Pontoons are typically moored 5–10 m from the shore and ~5 m above the sandy bottom. The effects of substrata and habitat were tested by experimentally providing new substrata (same age) of the two kinds (sandstone and concrete) on the two habitats (reef and pontoons) at each of four sites ~150 m apart.

Experimental plates (15 × 15 cm) made of either sandstone or concrete were fastened to pontoons and reef so that they were orientated vertically. Sandstone plates were cut from sandstone rock and had a grain size and texture ostensibly the same as cleared areas of subtidal rock. Concrete plates were cut from prefabricated sheets of concrete and had a smooth texture similar to that of concrete pontoons.

Experimental plates were attached to the outer edges on two sides of a pontoon (3 × 4 m) at a depth of approximately 25 cm. Plates were attached to a beam of PVC pipe that

Fig. 1. Map showing location of sites of study within Sydney Harbour. Location of Sydney Harbour is indicated on insert of map of Australia.
was strapped to a bottom edge of a pontoon. Experimental plates on the reef were supported by beams of aluminium 90° angle (1.6 m long) that were bolted to the reef with stainless steel screws so they were at a depth of approximately 1.5 m below low water spring tide and 15 cm from the substratum. PVC brackets were glued on to the backs of plates and these were bolted onto the PVC pipes and beams. Five replicate plates of each type were attached to each habitat (reef and pontoons) so that they were 1–5 m apart in a haphazard order.

After 7 months, each panel was collected and taken to the laboratory for examination under a dissecting microscope in which the abundances of benthic invertebrates were estimated. Primary cover (organisms attached directly to the plate) and secondary cover (organisms attached to primary cover) were estimated for sessile organisms on the front of plates using 64 regularly spaced points within a 13 × 13-cm grid (i.e. a 1-cm boarder around each plate was not sampled to avoid ‘edge effects’). Taxa on the front of plates, but not under a point were assigned a cover of 0.5%.

2.2. Analytical methods

Abundance data were standardised by converting raw data to percentage data before summing the primary and secondary covers for all multivariate and univariate tests. Observations of secondary cover were rare. Multivariate analyses were done using the 41 taxa identified and bare space. Data were fourth-root transformed and the Bray–Curtis measure (Bray and Curtis, 1957) was used to calculate dissimilarities among replicates. To visualise multivariate patterns, non-metric multi-dimensional scaling (nMDS) ordinations were done on the centroids (averages of replicate plates for each habitat and site, n = 5). One-way analyses of similarities (ANOSIM) were done (Clarke, 1993) on all replicates to test for differences between substrata and habitats. The significance level was adjusted for multiple comparisons associated with pairwise tests (Bonferroni procedure; Rice, 1989).

Univariate analyses were done using three-way ANOVAs (e.g. Underwood, 1997) in which all factors (substrate, habitat, site) were crossed, ‘substrate’ and ‘habitat’ were treated as fixed and ‘site’ as random. Data were Arc-sine transformed and significance was judged at = 0.05 unless Cochran’s C-test detected heterogeneous variances. Data with heterogenous variances were judged at the more conservative probability of 0.01.

3. Results

Assemblages on plates were composed primarily of bivalves (*Mytilus edulis*, *Crassostrea gigas*), encrusting bryozoans (*Watersipora arcuata*, *W. subtorquata*, *Cryptosula pallasiana*, *Schizoporella errata*, *Beania magellanica*, *Fenestrulina mutabilis*, *Conopeum seurati*, *Celleporaria* sp., *Microporella* spp.), arborescent bryozoans (*Bugula neritina*, *B. stolonifera*, *Tricellaria inopinata*), barnacles (*Balanus variegatus* and *B. trigonus*), calcareous tubeworms (spirobords and serpulids), solitary ascidians (*Styela pilcata*), colonial ascidians (*Diplosoma listerianum*, *Didemnum* sp.), five taxa of sponges, green algae (Cladophorales, *Enteromorpha*, Ulvales, *Codium*), red
algae (Ceramiales, Laurencia, Hypnea, Rhodymenia), brown algae (Feldmania, Sphacelaria, Dictyotalean spp. Dictyota), and coral (Culicia sp.).

Prior to the experiment, I predicted that the development of epibiotic assemblages is affected by differences in the type of substratum (sandstone vs. concrete) independent of type of habitat (rocky reef vs. pontoon). The two-factor nMDS plot indicated that the multivariate differences in the structure of assemblages were greater between habitats than between substrata (Fig. 2). That is, centroids representing assemblages revealed greater separation between plates attached to pontoons and reef than between plates made of concrete and sandstone. Correspondingly, measures of dissimilarity indicated that assemblages were most different between pontoons and reef, and that assemblages were most similar between plates made of sandstone and concrete in the same habitat (Table 1).

Most differences in abundance of individual taxa occurred between pontoons and reef rather than between plates made of sandstone and concrete (Figs. 3 and 4, Tables 2 and 3). All but one of the 12 taxa tested (serpulids) differed in abundance between habitats. The abundance of only three taxa differed between types of substrata (spirorbids, concrete > sandstone; red and green algae, concrete < sandstone).

Cover was consistently greater on pontoons than reef for three taxa (aborhorecent bryozoans, colonial ascidians and the mussel, Mytilus edulis), although the magnitude of

![Fig. 2. Two-factor nMDS ordination comparing centroids of epibiotic assemblages on plates made of sandstone (grey letters) and concrete plates (black letters) that were attached to rocky reef (R) and pontoons (P). The structure of assemblages differed between reef and pontoons despite being on plates of the same substrata; concrete (ANOSIM: R = 0.83, P < 0.05) and sandstone (ANOSIM: R = 0.92, P < 0.05). Similarly, tests did not detect significant differences between plates made of concrete and sandstone attached to pontoons (ANOSIM: R = 0.04 P > 0.05) and reef (ANOSIM: R = 0.08, P > 0.05).]
Table 1
Bray–Curtis measures of dissimilarities between habitats and surfaces (the larger the value the more dissimilar the assemblage)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Measure of dissimilarity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pontoon concrete</td>
</tr>
<tr>
<td>Pontoon concrete</td>
<td>–</td>
</tr>
<tr>
<td>Pontoon sandstone</td>
<td>35.8</td>
</tr>
<tr>
<td>Reef concrete</td>
<td>56.4</td>
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<tr>
<td>Reef sandstone</td>
<td>57.8</td>
</tr>
</tbody>
</table>

The differences varied among sites (Fig. 3, Table 2; SNK tests on Habitat × Site interaction). The opposite pattern occurred for the tiny calcareous tubeworms (species of spirorbids), which had one of the most extensive coverage of any taxa (Fig. 4a, Table 3a; SNK tests on Habitat × Site interaction).

The abundances of several taxa differed between pontoons and reef at all but one site (i.e. solitary ascidians, pontoons > reef; barnacles, pontoons > reef; red algae, pontoons < reef) or two sites (sponges, pontoons > reef). No particular site was associated with the failure to detect differences between habitats (Fig. 3, Table 2; SNK on Habitat × Site interaction). The remaining taxa (except sepulids) also differed between pontoons and reef, but these differences varied inconsistently among sites (i.e. encrusting bryozoans, green and brown algae) (Fig. 4; Table 3; SNK on Habitat × Site interaction).

4. Discussion

Marine ecologists have a history of taking models developed by terrestrial ecologists and applying them to the marine environment. This practise is often inappropriate (Underwood and Denley, 1984), and this is particularly true for understanding the ecology of urban habitats in the sea. Unlike terrestrial environments, urban structures in...
Fig. 4. Percentage cover of taxa (per 15×15 cm±S.E.) on pontoons (pontoon) and rocky reef (reef) for concrete (unshaded bars) and sandstone (shaded bars) at each of four sites (n = 5). The first four bars of each type of plate (shaded/unshaded bars) in each habitat (pontoon/reef) represent sites 1–4, respectively.

marine environments provide substrate for an abundant and diverse set of plants and animals (Sutherland and Karlson, 1977; Butler, 1991; Glasby and Connell, 1999). As such they create new habitat over the natural habitat they replace influencing epibiotic assemblages in ways we are yet to unravel.

The critical finding of this study was that epibiotic assemblages were affected by habitat (pontoons vs. reef) rather than by the material these were made from. This is an important result because it was proposed that the composition of substratum (i.e. sandstone vs. concrete) explained differences previously described between taxa on rocky reef and pontoons (Connell and Glasby, 1999). Factors other than the composition of the substratum, therefore, appear important determinants of spatial heterogeneity of
Table 2
Analysis of variance comparing the percentage cover of selected taxa between habitats (pontoon vs. reef) and substratum (sandstone and concrete).

<table>
<thead>
<tr>
<th>Source</th>
<th>(a) Abhorecent bryozoans</th>
<th>(b) Colonial ascidians</th>
<th>(c) Mytilus edulis</th>
</tr>
</thead>
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<tr>
<td></td>
<td>MS</td>
<td>F</td>
<td>P</td>
</tr>
<tr>
<td>Habitat</td>
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<td>1612.32</td>
<td>23.02</td>
</tr>
<tr>
<td>Substratum</td>
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<td>0.18</td>
<td>0.02</td>
</tr>
<tr>
<td>Site</td>
<td>3</td>
<td>80.20</td>
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</tr>
<tr>
<td>H × S</td>
<td>1</td>
<td>43.02</td>
<td>1.37</td>
</tr>
<tr>
<td>H × Site</td>
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<td>5.99</td>
</tr>
<tr>
<td>S × Site</td>
<td>3</td>
<td>10.17</td>
<td>0.87</td>
</tr>
<tr>
<td>H × S × Site</td>
<td>3</td>
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<td>2.69</td>
</tr>
<tr>
<td>Residual</td>
<td>64</td>
<td>11.68</td>
<td>25.08</td>
</tr>
</tbody>
</table>

*The comparison of sites was not relevant for testing the hypothesis. *P < 0.05, **P < 0.01, ***P < 0.001, & where significance was judged at α = 0.01 because variances were heterogeneous (Cochran’s C-test, P < 0.05).

Epibiotic assemblages among urban structures and rocky reef. If pontoons were made of the same material as natural reef (sandstone), they would not act as surrogate habitats for epibiotic assemblages that occur on adjacent reef. Whilst the composition of substratum can influence the abundances of taxa (e.g. Crisp and Ryland, 1960; Harlin and Lindbergh, 1977; McGuinness, 1989; Anderson and Underwood, 1994), it is becoming increasingly clear that is not always the primary determinant of spatial variation (Pomerat and Weiss, 1946; Crisp and Ryland, 1960; Caffey, 1982; Anderson and Underwood, 1994).

Pontoons are intrinsically different from natural reef and the uniqueness of these structures as habitats may be better explained by differences in their shapes, sizes and spatial arrangement. Pontoons provide discrete habitats in the form of new space. Such isolated pieces of substratum are known as habitat-islands (Simberloff and Abele, 1982) or type II patches (sensu Sousa, 1985). Variation in the shape, size and arrangement of these patches affects the colonisation of epibiotic assemblages (Kay and Keough, 1981; Keough, 1984). Some insight into the response of epibiotic assemblages to patchiness comes from studies that create space (Connell and Keough, 1985). In most of these studies, the shape, size and spatial arrangement of experimental patches are based on logistical and statistical convenience, rather than on specific hypotheses about observed patchiness of habitat and known aspects of the biology of organisms studied.

The dual effects of habitat patchiness and differences in the ecology of taxa appear to have some obvious consequences for their abundances among urban structures and rocky reef. For example, urban structures occupy different positions in the water column (vertical distance from reef) and the abundance of a large suite of taxa is strongly affected by proximity to the seafloor (Withers and Thorp, 1977; Glasby, 1999b). In particular, spirorbid polychaetes occur in greater abundance close to the seafloor (Osman, 1977; Glasby, 1999b) and in this study they occurred in greater abundance on the reef than on pontoons that float above the reef. This pattern appears to reflect patterns of recruitment, larvae of many tubicolous polychaetes become more demersal as
Table 3
Analysis of variance comparing the percentage cover of selected taxa between habitats (pontoon vs. reef) and substratum (sandstone and concrete)

<table>
<thead>
<tr>
<th>Source</th>
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<th>F</th>
<th>P</th>
<th>Source</th>
<th>df</th>
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<td>(a) Spirorbids</td>
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<td>99.54</td>
<td>*</td>
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<td>99.54</td>
<td>1420.01</td>
<td>10.20</td>
<td>*</td>
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<td>629.69</td>
<td>36.66</td>
<td>68.82</td>
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<td>74.3</td>
<td>–</td>
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<td>74.3</td>
<td>1274.2</td>
<td>2.76</td>
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<td>&gt;0.05</td>
<td>307.55</td>
<td>6.51</td>
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<td>H × S</td>
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<td>165.59</td>
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<td>*</td>
<td>139.28</td>
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<td>1074.95</td>
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<td>***</td>
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<td>S × Site</td>
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<td>1.63</td>
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<td>(b) Solitary ascidians</td>
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<td>(c) Barnacles</td>
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</table>

^ See Table 2 for details.

they develop (Scheltema, 1986). Oppositely, experimental tests have revealed *Styela plicata* to be most abundant at shallow depths, but in positions away from the seafloor (Glasby, 1999b) where pontoons are moored. This could explain why in the present study solitary ascidians (primary *Styela plicata*) were many times more abundant on pontoons than on the reef.

Understanding the ecology of urban structures is not just about solving ecological riddles. Epibiotic assemblages are food and shelter for many types of organisms (e.g. Bell and Pollard, 1989; Connell and Anderson, 1999; Minchinton and Ross, 1999) and are important components of the biogenic structure of coastal habitats (Underwood et al., 1991). These habitats are being rapidly destroyed and urbanised with little appraisal of the ecological consequences. While it has been relatively simple to record and document loss of coastal habitats (Gray, 1997), little is known about the consequences of introducing new habitats as urban structures (Glasby and Connell, 1999).
Interpreting and managing urbanisation not only requires understanding the consequences of destroying natural habitat, but also that of creating new habitat, particularly in the form of urban structures. Ultimately, this knowledge may aid programmes of restoration or rehabilitation of damaged habitats. Estuaries pose particular problems globally since there is conflict between the interests of industrial development, shipping, harbour development, fishing, recreation and the needs for conservation (Gray, 1997). Solutions to some of these competing demands require an understanding of the factors that enhance the conservation value of structures that continue to result from these activities.

In conclusion, these results demonstrate that pontoons constitute novel habitats for epibiota. This highlights a need for determining how current understanding of the ecology of epibiota, which is primarily based on studies of urban structures (pilings and pontoons), relates to natural reef. Fundamental differences in the ecology of different taxa appear to have important consequences for their relative abundances on pontoons and rocky reef. Future tests of hypotheses about the nature of these differences will not only contribute to better ecological understanding of epibiota and their use of urban structures as habitats, but also to better predictions of future changes to the ecology of coastal habitats.

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References


