

Effects of epibiota on assemblages of fish associated with urban structures

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ABSTRACT: The increasing number of artificial structures in shallow marine waters has provoked research on the ecological function of artificial habitats. The aim of the present study was to investigate interactions between fish and sessile biota growing on urban structures in coastal waterways. The biota growing on subtidal hard substrata is thought to have a large effect on the composition and distribution of associated fish. Hence, in Sydney Harbour, Australia, experiments were done to test interactions between fish and epibiota sampled on pilings at 4 marinas. The abundance and diversity of fish were strongly positively correlated with the amount of foliose algae, mussels and solitary ascidians on pilings. This correlative evidence was further investigated by experimental manipulations of the amount of conspicuous epibiota on pilings. Removal of these organisms showed a marked decrease in the numbers of many types of fish. Conversely, the addition of mussels to pilings increased the abundance and diversity of associated fish. The cover of complex epibiota on pilings at marinas may strongly affect the abundance of many species of fish and therefore influence the types of fish that recruit to these artificial habitats. Such knowledge on the ecological processes occurring in marinas is an important step in recognising the value of these artificial structures as habitat for marine organisms.

KEY WORDS: Urban structures · Fish · Biogenic habitat · Epibiota

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INTRODUCTION

Artificial structures are becoming common features of urban waterways, but very little is known about their ecology (but see Connell & Glasby 1999, Chapman & Bulleri 2002, Bacchiocchi & Airoidi 2003). For example, in Sydney Harbour, at least 50% of the foreshore is now artificial seawalls (Chapman 2003) and there are about 40 functioning marinas that service 35 000 registered recreational vessels (Widmer et al. 2002). Coastal developments, such as marinas, add novel habitats, such as pontoons, pilings and jetties, to the marine environment. Numerous studies have claimed that the presence of these artificial habitats can contribute to increasing fish biomass (Bohnsack 1989, Fabi et al. 2004). Few studies have, however, documented the patterns of spatial distribution of fish assemblages associated with artificial structures or

identified factors that may contribute to the variation in assemblages of fish among different artificial habitats.

Even at local scales, the composition of assemblages of fish can vary greatly (Choat & Ayling 1987, Holbrook et al. 1994). In recent times, many studies have focused on the relationships between fish assemblages and the biological features of their habitats, at various spatial scales (Schmitt & Holbrook 1985, Holbrook et al. 1990, Levin & Hay 2002). The association of reef fish with particular attributes of microhabitat is common on tropical and temperate reefs (Connell & Jones 1991, Holbrook et al. 2002). Additionally, the effect of habitat at small spatial scales can provide predictive power at large spatial scales for some species of fish (Holbrook et al. 2000, Levin & Hay 2002).

Positive interactions between fish and their habitat often depend on the presence of organisms that either create or alter habitat (Jones 1992, Jenkins & Suther-

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land 1997). Many species of reef fish are positively associated with the density of macro-algae on temperate reefs (Choat & Ayling 1987, Carr 1989). In addition, invertebrates such as sea urchins (Hartney & Grorud 2002), bryozoans (Pederson & Peterson 2002) and corals (Nanami & Nishihira 2002) may provide a form of biogenic structure for fish. In some instances the biota themselves will provide food for fish (e.g. ascidians; Keough 1984). In other cases, the epifauna living in the biota attached to structures may be a source of food (e.g. crustaceans and polychetes living among mussels; Lopez-Jamar et al. 1984). Epifauna and flora may also provide shelter for some fish, particularly small, cryptic species, such as blennies and gobies that live within refuges created by these organisms (Behrens 1987).

Epibiota (the plants and animals that attach to hard surfaces) are a major part of the biotic structure provided by subtidal habitats, including built structures. The composition and amount of the attached biota varies considerably between artificial and natural surfaces (Connell & Glasby 1999, Chapman & Bulleri 2002) and among different types of artificial structures (Glasby 1998). This may influence the numbers and types of fish associated with the different types of habitats (Coleman & Connell 2001) and may, in turn, potentially contribute to the variation of fish assemblages associated with different types of artificial structures.

Few studies have examined the effects of epibiota attached to built structures on the assemblages of fish (Bohnsack 1989). Much of the work has been purely descriptive (e.g. Randell 1963, Hueckel & Stayton 1982) or has only provided correlative evidence. For example, Rooker et al. (1997) found that fish increased in numbers with greater fouling of an offshore oil platform. These studies, however, lack the appropriate experimental manipulations required to determine a direct effect of epibiota. Coleman & Connell (2001), in contrast, experimentally removed epibiota from pier pilings and found that the variation in the amount of epibiota had only minor effects on the abundances of fish around pilings, but they only did the study at 1 marina.

The aim of the present study was to investigate whether or not the spatial variability in composition and amount of epibiota can explain the spatial distribution of fish associated with marinas. Two specific models were evaluated. First, that composition and abundance of epibiota, measured as the percentage cover of sessile organisms such as mussels, foliose algae and solitary ascidians, is associated with the abundance and diversity of fish associated with different marinas. Second, at a smaller spatial scale, that the composition and abundance of epibiota growing on individual pilings in a marina is correlated with the

abundance and diversity of fish associated with different pilings within a marina. The extent to which the amount of epibiota influenced patterns of fish assemblages was determined experimentally by manipulating the natural cover of epibiota on pilings.

MATERIALS AND METHODS

Quantifying patterns of distribution of epibiota and fish among marinas. To test hypotheses about the relationship between epibiota and the assemblages of fish associated with marinas, fish and epibiota associated with pilings at 4 marinas in Sydney Harbour, Australia (Ferguson's Boatshed, Clontarf, Davis and Point Piper Marinas), were sampled in August 2002 (austral winter) and February 2003 (austral summer). The marinas were between 500 m and 5 km apart and located within 5 km from the mouth of the harbour, and they were built over sand to a depth of approximately 10 m. Within marinas, adjacent pilings were separated by at least 3 m. Pilings were made of either wood or concrete, and were of similar circumference (approximately 2 m). At each time, all locations were sampled within a period of 1 wk.

Epibiota was sampled using a Nikonos underwater camera fitted with a 28 cm lens and strobe. Eight replicate photographs (15 × 23 cm) were taken haphazardly on the vertical sides of pilings at each marina, between a depth of 1 and 2 m below mid-low water of spring tide (MLWS). Each replicate photograph was on a separate piling. The camera was attached to a frame that ensured that each photo-quadrat was the same distance from the substratum and covered the same area. All epibiota in the quadrat were noted in the field, or collected and taken back to the laboratory to aid with the identification of taxa. Percentage covers of sessile organisms were estimated in each photo-quadrat by identifying the taxon under 100 regularly spaced points placed over the entire quadrat. Taxa which were in the quadrat, but not under these points, were recorded as having a cover of 0.5%. There were rarely any large macro-algae to obscure the primary cover, but, if this occurred, the secondary taxa were considered to be the taxa under that point. Organisms were identified to the lowest taxonomic level practical. For example, some algae were sampled as functional groups (i.e. foliose or filamentous), sponges were mostly identified as morpho-species (Oliver & Beattie 1996), and ascidians were classified as either solitary or colonial.

Fish were sampled using stationary point counts, a useful method to estimate the abundance of fish in small areas (Connell et al. 1998). A stationary point count involves counting fish in a defined area for a

defined period of time. Although the small size of the area sampled may reduce the number of fish counted and be biased to more mobile species, it was deemed appropriate to enable a comparison between different habitats within a marina. Replicate counts were done at the surface of 8 different random pilings at each marina. Counts were done over a period of 3 min. The count began when the diver approached the piling and positioned himself/herself 2 m from the piling. Fish were counted 1 m either side of the piling, directly in front of the piling, between the diver and the piling, and to a depth of 2 m. This depth was chosen as visibility was restricted to almost 2 m on some occasions. Small cryptic species were enumerated at the completion of the count by slowly swimming around the structure for approximately 1 min and closely inspecting the substratum.

Quantifying patterns of distribution of epibiota and fish around pilings. Because the previous sampling only allowed for comparisons among marinas, a second study was done in September 2003. This involved sampling fish and epibiota again at 4 marinas in Sydney Harbour (Ferguson's Boatshed, Davis, Point Piper and Northbridge Marinas). At each marina, 8 pilings were sampled. Around each piling, fish were sampled with a 3 min stationary point count. Four photographs were taken on each of the same pilings at depths between 1 and 2 m below MLWS. Abundances of fish were correlated with the mean percentage cover of epibiota per piling.

Manipulation of epibiota. There were positive correlations between the number of species of fish and the abundances of some species of fish and the amount of complex epibiota (see 'Results'). We consequently tested the model that the abundance and diversity of fish associated with pilings was directly related to the amount of complex epibiota growing on the pilings. Two manipulative experiments were done to test 2 alternative hypotheses. The first was done in November 2003 at 2 marinas (Davis Marina and Ferguson's Boatshed), both of which supported a large abundance and diversity of fish at this time of year (austral spring). The relative cover of different types of epibiota differed between the 2 marinas, but both marinas had large amounts of complex epibiota, such as foliose algae or mussels. At these 2 marinas, we tested the hypothesis that the removal of epibiota from pilings would cause a decrease in the abundance of fish. Epibiota were removed from pilings by scraping to a depth of at least 5 m. Fish were sampled around pilings using methods previously described. Pilings were sampled on 8 randomly chosen days: 14, 5 and 1 d before and 5, 10, 20, 29 and 34 d after the removal of epibiota. Sampling was done in this way so that differences between the mean abundances of different treatments

could be calculated for random times of sampling before and again after the removal of epibiota from pilings, so that temporal changes in fish assemblages could be examined. Because removing epibiota from pilings disturbed the pilings, it was necessary to add a procedural treatment of disturbing pilings by cutting, but not removing, epibiota to distinguish changes in the fish assemblage as a result of disturbing (by cutting) the epibiota from changes due to removal of the epibiota. Three treatments were compared ($n = 5$ pilings per treatment): (1) pilings from which epibiota were removed, (2) disturbed pilings and (3) undisturbed pilings. Pilings of each treatment were dispersed within the marina and separated by at least 5 m. The hypothesis tested was that the abundances and diversity of fish associated with cleared pilings would be significantly smaller than abundances and diversity of fish associated with undisturbed pilings. In addition, if there were no artefacts associated with cutting the epibiota, the procedural control and undisturbed pilings would have similar numbers and diversity of fish.

A second experiment was done in December 2003 at Point Piper Marina, which supported small numbers of fish and small amounts of epibiota. This experiment tested the hypothesis that the addition of complex epibiota, in this case mussels, to pilings would increase the local abundance and diversity of fish. Mussels were chosen because their densities were highly correlated with several species of fish and they are also relatively easy to transplant. Mussels were collected from a different area in the harbour and brought back to the laboratory, where they were glued to a plastic mesh using Araldite to give 100% cover (presuming that some would be lost whilst being transported). In the field, the mesh with attached mussels was wrapped around pilings. The top of the mesh was positioned at MLWS and extended to a depth of 2 m below MLWS. It was necessary to cover mussels with chicken wire whilst transporting them back to the water. This wire was removed 1 wk after mussels were deployed in the field, by which time mussels had attached themselves firmly to the pilings. Fish were sampled in the manner described above on 7 randomly chosen days: 18, 7 and 4 d before and 8, 16, 23 and 30 d after the addition of epibiota. Sampling was only done on 4 occasions after the addition of mussels as the experiment was stopped after 1 mo, when cover of mussels dropped to approximately 20% on all pilings. The reason for this loss is unknown, but was most likely due to mortality or movement of mussels away from pilings. Again, 3 treatments were compared ($n = 5$ pilings per treatment): (1) pilings to which mussels were added, (2) pilings to which only mesh and glue were added as a procedural control and (3) undisturbed pilings. It was

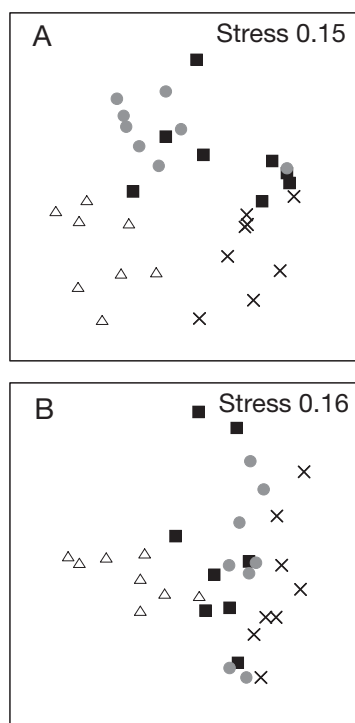


Fig. 1. Non-metric multidimensional scaling ordinations comparing assemblages of (A) fish and (B) epibiota among the 4 marinas in February 2003: Ferguson's Boatshed (■), Clontarf Marina (●), Davis Marina (△) and Point Piper Marina (×); $n = 8$

predicted that the total abundance and diversity of fish would be greater around pilings with added mussels than at the procedural control pilings and those to which no epibiota was added.

RESULTS

Patterns of distribution of epibiota and fish among marinas

The assemblages of fish and epibiota were compared among marinas at each time, using non-parametric MANOVA (Anderson 2001). Data were converted to Bray-Curtis measures of dissimilarity using untransformed data (Bray & Curtis 1957). At each time, there were significant differences in the fish and in the epibiota among marinas ($p < 0.05$, Fig. 1). Despite these differences in the 2 assemblages among marinas, no correlation was detected between the 2 matrices (Relate, $Rho = 0.12$ and 0.18 , $p > 0.05$, August and February, respectively).

Analyses of individual taxa of epibiota tested the hypothesis that percentage cover of these would be associated with the abundance of common fish and number of species at marinas. At each time, the number of spe-

cies of fish at Davis Marina was significantly greater than at all other marinas (Fig. 2A; $F = 5.22$, August, $F = 15.37$; February, $p < 0.01$). The abundances of several common species, including 3 small-bodied species, *Atypichthys strigatus* (mado), *Microcanthus strigatus* (stripey) and *Mecaenichthys immaculatus* (damselfish), and the larger-bodied and highly mobile species *Acanthopagrus australis* (bream), were also significantly greater at Davis Marina in February (Fig. 2D,E,G,H; $F = 11.25, 9.81, 5.81, 4.59$, respectively, $p < 0.01$). Abundances of individual species were not analysed in August (austral winter) due to small numbers (Fig. 2). Correspondingly, there were also greater mean percentage covers of foliose algae, mussels and solitary ascidians at this marina than at the other 3 marinas (Fig. 3A,C,D; $F = 6.91, 8.95, 7.62$; August, $F = 5.66, 38.00, 21.42$, February, $p < 0.05$). In contrast, at each time, the mean percentage cover of bare space was significantly greater at Point Piper Marina, which had the smallest number of species and abundances of fish (Fig. 3H; $F = 4.51$, August, $F = 6.19$; February,

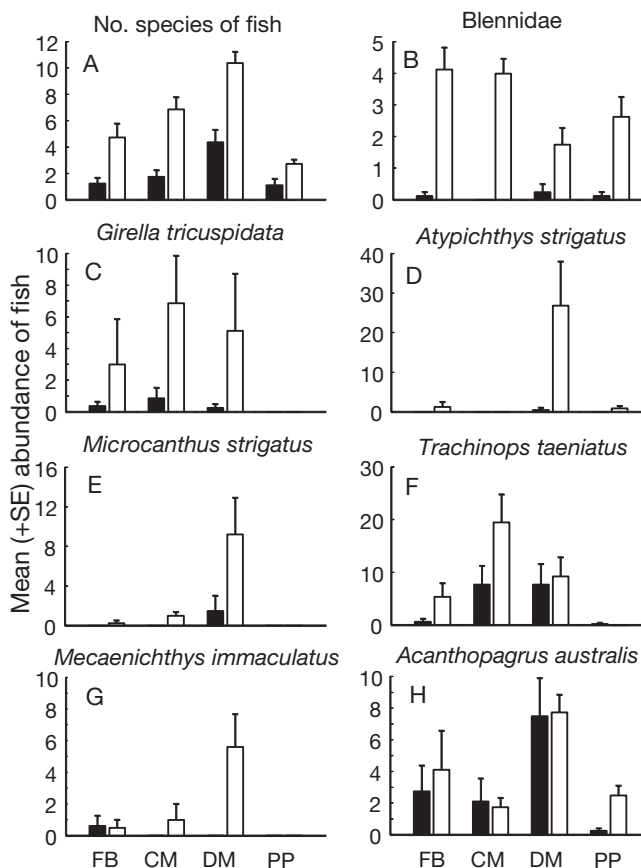


Fig. 2. Mean (+SE, $n = 8$) (A) number of species and (B to H) abundances of common species of fish associated with pilings at the 4 marinas: FB: Ferguson's Boatshed; CM: Clontarf Marina; DM: Davis Marina; PP: Point Piper, in August (empty bars) and February (filled bars)

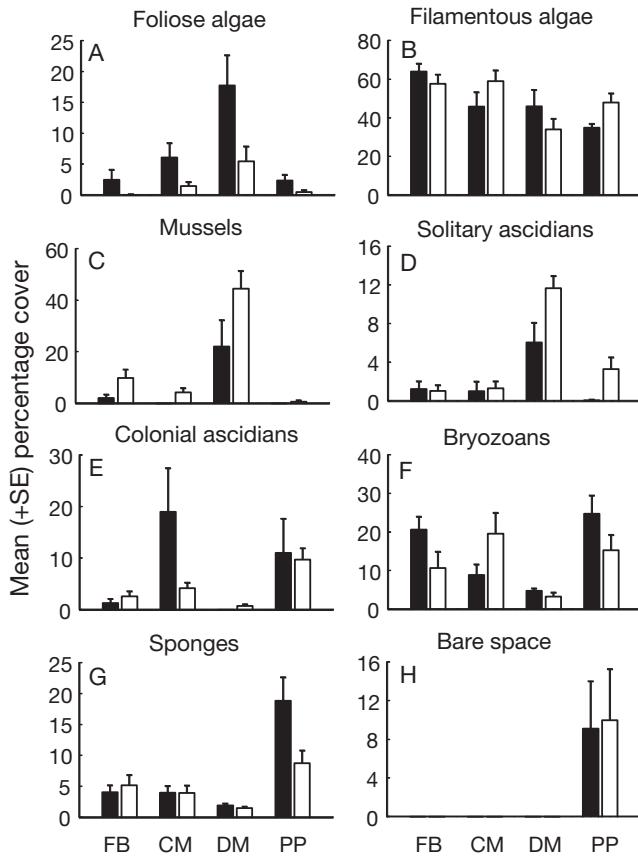


Fig. 3. Mean percentage cover (+SE, $n = 8$) of groups of epibiota growing on pilings at the 4 marinas: FB: Ferguson's Boatshed; CM: Clontarf Marina; DM: Davis Marina; PP: Point Piper, in August (empty bars) and February (filled bars)

$p < 0.01$). In fact, species commonly found at the other 3 marinas were, in general, not present at all or only present in very small numbers at this marina (Fig. 2). The only exception was numbers of Blenniidae, which were similar across all marinas (Fig. 2). At Time 1, at this marina, there was also a significantly greater percentage cover of sponges ($F = 22.98$, $p < 0.001$) and, at Time 2, there was a greater percentage cover of colonial ascidians ($F = 9.68$, $p < 0.001$). These patterns, however, did not persist across times.

Patterns of distribution of epibiota and fish around pilings

As predicted, there were significant ($p < 0.05$) positive correlations between the number of species of fish and the percentage covers of foliose algae, mussels and solitary ascidians ($r = 0.55$, 0.45 , 0.36 , respectively). *Atypichthys strigatus* and *Mecaenichthys immaculatus* were positively correlated with both the

percentage cover of foliose algae and mussels (*A. strigatus*, $r = 0.68$ and 0.45 ; *M. immaculatus*, $r = 0.61$ and 0.43), as was *Acanthopagrus australis* ($r = 0.47$ and 0.35). The planktivore *Trachinops taeniatus* (hulafish) was also correlated with the percentage cover of foliose algae ($r = 0.56$); *Microcanthus strigatus* was correlated with the percentage cover of mussels ($r = 0.35$).

Removal of epibiota

Around pilings from which epibiota had been removed, there was an obvious drop in the diversity and the abundances of some individual species of fish (Fig. 4). Abundance and diversity of fish at the procedural control pilings and undisturbed pilings fluctuated over time, but showed no trend of increasing or decreasing numbers of fish (Fig. 4). The abundance of *Trachinops taeniatus* dropped to zero around all cleared pilings at both marinas, although at Davis Marina its abundance was also very low at undisturbed and disturbed pilings (Fig. 4B). At this marina, however, numbers of *Atypichthys strigatus*, *Microcanthus strigatus* and *Mecaenichthys immaculatus* associated with cleared pilings also decreased dramatically (Fig. 5). The latter 3 species were present in very small numbers at Ferguson's Boatshed, which prevented any meaningful comparison among treatments. In contrast, the abundances of *Acanthopagrus australis* fluctuated markedly over time, but did not decrease after the removal of epibiota (Fig. 4C).

Data at each time of sampling were analysed separately to avoid problems of having non-independent data. At Davis Marina, at each of the 3 times before the removal of epibiota, the number of species and abundance of common species (*Atypichthys strigatus*, *Microcanthus strigatus*, *Mecaenichthys immaculatus* and *Acanthopagrus australis*) were similar among pilings of the 3 treatments (Table 1). As predicted, after epibiota were removed, the number of species and numbers of *A. strigatus* and *M. immaculatus* were significantly smaller around experimental pilings without epibiota than around the procedural control pilings or undisturbed pilings (Table 1). Although numbers of *M. strigatus* decreased to zero around pilings from which epibiota was removed, the difference between the 3 treatments was not always significant, due to fluctuating numbers around pilings of the other 2 treatments (Table 1).

At Ferguson's Boatshed, the abundance and diversity of fish were much smaller than at Davis Marina (15 fish and 3 species per piling in contrast to approximately 50 fish and 6 species per piling at Davis Marina) and only *Trachinops taeniatus* were present in large enough numbers to warrant analyses. Again, at each of

the 3 times before the removal of epibiota, the number of species of fish and the abundance of *T. taeniatus* were similar among pilings of the 3 treatments (Table 1). Results from the 4 times after epibiota was removed were inconsistent (Table 1). The number of species of fish was significantly less around cleared pilings 20 and 34 d after the removal of epibiota (Times 6 and 8) and the abundance of *T. taeniatus* was significantly less around cleared pilings at all times, except after 5 d (Time 4; Table 1).

Addition of mussels

There were very few fish at Point Piper Marina (0 to 10 fish per piling) and there were few species (0 to 3 species per piling; Fig. 6). As predicted, when mussels

were added to pilings, there was an immediate increase in the number of species of fish (Fig. 6A) and in the abundance of *Atypichthys strigatus* associated with pilings that had mussels added (Fig. 6C). There was also an increase in the number of *Trachinops taeniatus* (Fig. 6B). This result had not been predicted, however, because there had been no correlation between the abundance of this species and percentage cover of mussels. After several weeks, numbers appeared to drop off again, particularly 23 d after the addition of mussels (Time 6), when there was a sharp decrease in abundance and diversity of fish around pilings to which mussels had been added (Fig. 6).

At each of the 3 times before the addition of mussels, the number of fish species was similar among pilings of the 3 treatments (Table 1). One week after the addition of mussels, the number of fish species was significantly greater around pilings to which mussels had been added, than around either the procedural control or undisturbed pilings (Table 1). There was also a significant difference in the number of species between treatments 1 mo after the addition of mussels (Table 1). The abundance of *Trachinops taeniatus* and *Atypichthys strigatus* was, again, too small to warrant analyses.

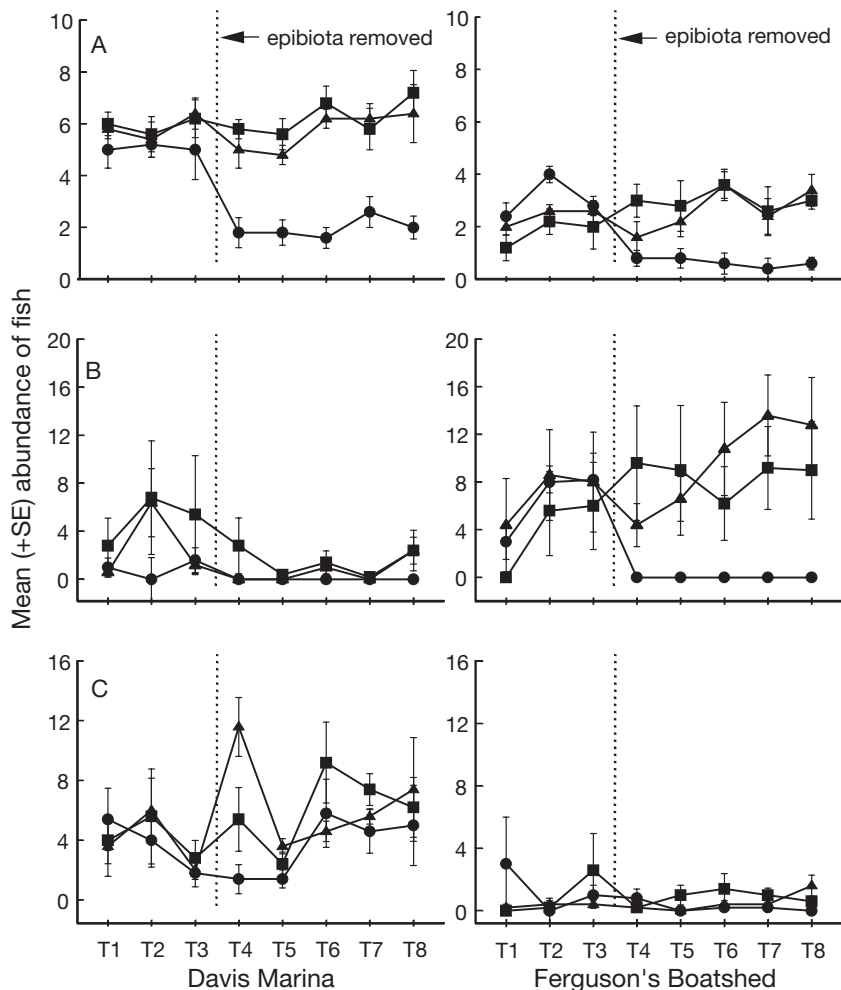


Fig. 4. Mean (\pm SE, $n = 5$) number of (A) species, (B) *Trachinops taeniatus* and (C) *Acanthopagrus australis* associated with pilings at Davis Marina and Ferguson's Boatshed, before (Times 1 to 3) and after (Times 4 to 8) the removal of epibiota from pilings (at the time shown by the dotted line). ●: removal; ■: disturbance control; ▲: undisturbed

DISCUSSION

Epibiota had strong effects on the abundance of fish associated with marinas. Patterns of diversity and abundances of common species at the scale of marinas appeared to relate to the percentage cover of conspicuous epibiota, particularly the foliose algae, solitary ascidians and mussels. Furthermore, the number of species and the abundances of common species associated with different pilings was positively correlated with the percentage cover of foliose algae, mussels and solitary ascidians. Biogenic habitat has been documented as playing an important role in structuring fish assemblages associated with natural habitats (Holbrook et al. 1990, Jenkins & Sutherland 1997). Whether or not similar associations occur in artificial habitats is largely unknown. A few studies have provided correlative evidence that suggest fish are associated with epibiota on built structures (e.g. Hueckel & Stayton

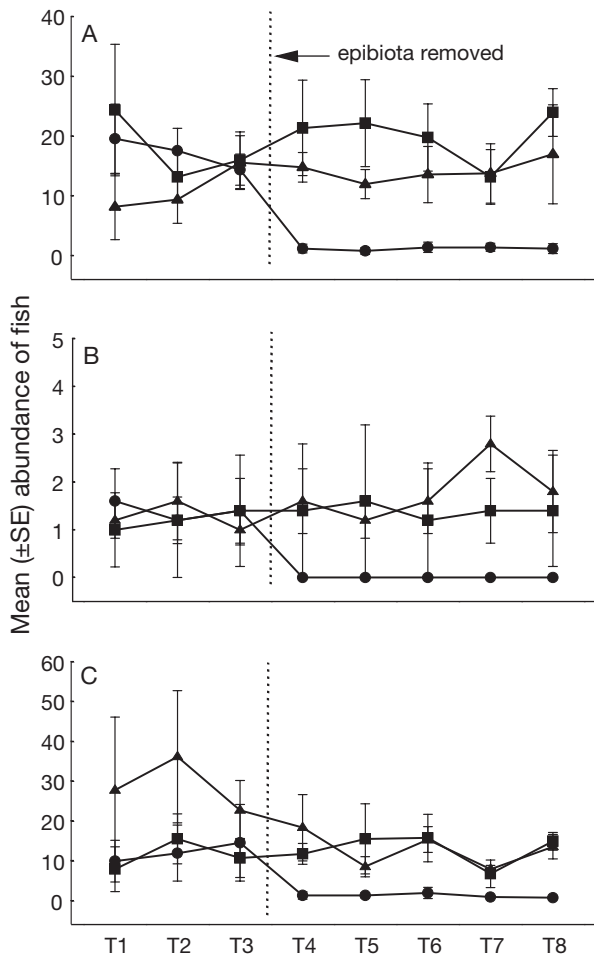


Fig. 5. Mean (\pm SE, $n = 5$) number of (A) *Atypichthys strigatus*, (B) *Microcanthus strigatus* and (C) *Mecaenichthys immaculatus* associated with pilings at Davis Marina, before (Times 1 to 3) and after (Times 4 to 8) the removal of epibiota from pilings (at the time shown by the dotted line). ●: removal; ■: disturbance control; ▲: undisturbed

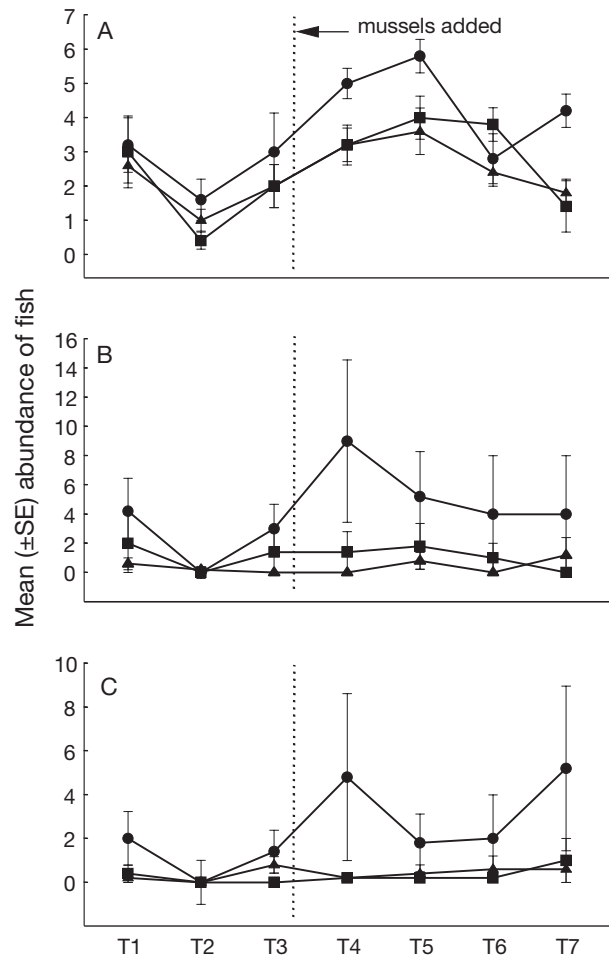


Fig. 6. Mean (\pm SE, $n = 5$) number of (A) species, (B) *Trachinops taeniatus* and (C) *Atypichthys strigatus* associated with pilings at Point Piper before (Times 1 to 3) and after (Times 4 to 7) the addition of mussels to pilings (at the time shown by the dotted line). ●: mussels added; ■: mesh control; ▲: undisturbed

Table 1. Summary of analyses of the number of species and the abundance of common species around pilings at Davis Marina and Ferguson's Boatshed at each time before and after the removal of epibiota (at Time 3) and Point Piper Marina each time before and after the addition of mussels (at Time 3). C: control; D: disturbed; R: removal; Me: mesh; Mu: mussel treatments; ns: not significant. All data were transformed to $\ln(x + 1)$, and results of all Cochran's tests were non-significant ($n = 5$)

	Time 1	Time 2	Time 3	Time 4	Time 5	Time 6	Time 7	Time 8
Davis Marina								
No. of species	ns	ns	ns	C = D > R	C = D > R	C = D > R	C = D > R	C = D > R
<i>Atypichthys strigatus</i>	ns	ns	ns	C = D > R	C = D > R	C = D > R	C = D > R	C = D > R
<i>Microcanthus strigatus</i>	ns	ns	ns	ns	ns	ns	C = D > R	ns
<i>Mecaenichthys immaculatus</i>	ns	ns	ns	C = D > R	ns	C = D > R	C = D > R	C = D > R
<i>Acanthopagrus australis</i>	ns	ns	ns	D > C = R	ns	ns	ns	ns
Ferguson's Boatshed								
No. of species	ns	R > D = C	ns	-	ns	C = D > R	ns	C = D > R
<i>Trachinops taeniatus</i>	ns	ns	ns	-	C = D > R	C = D > R	C = D > R	C = D > R
Point Piper Marina								
No. of species	ns	ns	ns	Mu > Me = C	ns	ns	Mu > Me = C	

1982, Rooker et al. 1997), but they lacked manipulative experiments to demonstrate that the relationship between the two is causal (e.g. Hartney & Grorud 2002, Levin & Hay 2002).

When the amount of epibiota on pilings was experimentally reduced, the abundance of several common small-bodied fish (*Trachinops taeniatus*, *Atypichthys strigatus*, *Mecaenichthys immaculatus* and *Microcanthus strigatus*) decreased dramatically within days, as did the overall diversity of fish associated with cleared pilings. Similarly, when the amount of epibiota was experimentally increased, in this case by the addition of mussels, the abundances of 2 species common to other marinas, *A. strigatus* and *T. taeniatus*, and the number of species of fish associated with these pilings increased within several days. Manipulating the amount of epibiota on pilings altered the local complexity and the amount of potential food. It may be that the amount of shelter and/or the amount of food provided by these complex epibiota create differences in fish assemblages among marinas.

Few studies have investigated whether small fish feed on biota associated with reef habitats, or simply shelter there (Gillanders & Kingsford 1998). In natural habitats, benthic organisms, such as macro-algae (Ruitton et al. 2000), ascidians (Keough 1984) and urchins (Sala 1997a), are thought to be important food sources for fish, as are the smaller animals, such as crustaceans, that live amongst these organisms (Caine 1987, Sala 1997b). For example, Bell et al. (1978) examined the feeding ecology of 3 species of leatherjackets in a seagrass habitat. All 3 species were found to be highly dependent on the seagrass and on the encrusting fauna and epiphytic algae in the seagrass. Choat & Ayling (1987) argued that differences in the availability of food may explain differences in the distribution of fish among different types of temperate reefs. During the present experiment, some of the species that were in numbers correlated with the percentage cover of algae and mussels, including *Acanthopagrus australis* and *Atypichthys strigatus*, were observed foraging on invertebrates associated with algae and mussels on pier pilings. Therefore, if different marinas and/or different pilings provide different amounts of potential food for these species, this could maintain differences in their distribution among marinas and pilings within marinas.

The number of *Trachinops taeniatus* was also positively correlated with the percentage cover of foliose algae, and this species responded to the decrease in epibiota and increase in cover of mussels, although this latter result was not predicted. *T. taeniatus* is a planktivore (Kuitert 2000), and does not feed directly on the epibiota. It may, however, feed on floating organic matter associated with mussel beds. Epibiota may also

be an important source of shelter for these small fish. Hence, in the absence of other complex epibiota, such as foliose algae, mussels may provide a refuge for this species.

Several groups of epibiota, e.g. encrusting sponges and colonial ascidians, showed no correlation with the abundance and diversity of fish. In contrast to organisms whose cover was positively correlated with the abundance of fish, i.e. mussels, algae and solitary ascidians, these types of epibiota had little to add in the way of complexity and heterogeneity to pilings. This indicates that the structure provided by complex epibiota may play a role in affecting the distribution of fish. Habitat complexity can modify the effects of predation on fish by providing refuges (Connell & Jones 1991, Hixon & Beets 1993), and the amount of shelter available influences the distribution and abundance of fish (Behrens 1987, Connell & Jones 1991). It is unlikely that epibiota associated with pilings provide shelter for larger fish, such as *Acanthopagrus australis* and *Girella tricuspidata*. Small species, such as *Trachinops taeniatus* and *Mecaenichthys immaculatus*, may respond to the presence of algae, mussels and ascidians as a form of shelter; therefore, differences in the cover of such epibiota may influence the distribution of these species around pilings.

The response of organisms to habitat is largely dependent on scale (Levin 1992). Fish assemblages may vary at spatial scales from metres to 1000s of kilometres along-shore (Choat & Ayling 1987, Connell & Kingsford 1998). Nevertheless, the degree to which the distribution of fish at large spatial scales, e.g. among reefs, is influenced by patterns of use of habitat at the scale of metres is largely unknown (but see Tolimieri 1995, Levin & Hay 2002). In the present study, associations between abundances and diversity of fish and percentage cover of conspicuous epibiota were apparent at the scale of marinas, and positive correlations were evident at the smaller spatial scale of pilings within marinas. The results of the small-scale manipulative experiments at the 3 marinas demonstrated that the abundance of most species and the total abundance and diversity of fish associated with pilings were strongly influenced by the amount of epibiota on pilings. Therefore, it can be predicted that use of habitat at this small spatial scale may affect the distribution of fish at larger scales, i.e. among different marinas. This agrees with the study done by Levin & Hay (2002), who showed that the response of the common wrasse *Halichoeres bivittatus* to the manipulation of algal biomass at small scales (1.5 m² plots) predicted large-scale patterns of abundance on reefs in the South Atlantic Bight.

The number of *Acanthopagrus australis*, in contrast, appeared to be associated with the amounts of epibiota at the scale of marinas. When the amount of growth on

individual pilings was manipulated, however, this species showed little response. *A. australis* is a highly mobile species that can move over distances of 100s of metres. Therefore, it may only respond to the removal of epibiota at larger spatial scales, i.e. groups of pilings or whole marinas. Testing this model would require manipulations at a much larger scale, which are difficult to do.

In this experiment, blennies did not appear to respond to the presence of epibiota. This was unexpected because these are small, very cryptic fish that rely heavily on the presence of holes and crevices in which to hide (Connell & Jones 1991). The results were probably due to a sampling error associated with using visual census to sample such cryptic species. More fish were probably seen on pilings that provided less shelter, i.e. pilings that had a smaller percentage cover of mussels and algae. Lincoln-Smith (1988) compared visual counts of sedentary species of fish to samples collected using rotenone and found that cryptic species are largely overlooked during visual census, regardless of the amount of time the observer takes to search the substratum. Therefore, it is not possible to draw any reliable conclusions about the effect of epibiota on these small sedentary fish.

The addition of complex structure, in this case mussels, to pilings with little or no biotic structure only had weak influences on the abundance and diversity of fish. The number of fish associated with pilings with added mussels did not increase to anywhere near the number of fish that was associated with pilings with natural large covers of mussels. Interestingly though, the increase in diversity around pilings where epibiota was added was roughly equivalent to the decrease in diversity of fish that was observed around pilings from which epibiota was removed. The experiment would have been greatly aided by being able to sample on more occasions over a longer period. We had planned to sample over several months, but most mussels died after 1 mo. It is not yet clear whether these inconsistent results could be attributed to the fact that the experiment was not run for long enough for the fish to redistribute themselves among pilings or for more fish to recruit to these added habitats from elsewhere. Alternatively, it could simply be that other factors, such as water quality, position in the estuary and the absence of other conspicuous epibiota (e.g. foliose algae), contribute to the small numbers of fish associated with this marina.

The abundance of reef fish is often correlated with the amount of hard substrata in the habitat in which they live. In the present study, the percentage cover of complex epibiota growing on pilings at marinas influenced the abundance of many species of fish. We suggest that fish may depend on these organisms as a

source of food or shelter. Furthermore, results showed that differences in the amount of epibiota, namely foliose algae, mussels and solitary ascidians, among different marinas in the harbour may explain some of the variation in the fish assemblages associated with these marinas.

It is still unclear whether artificial structures have the potential to sustain viable populations of fish and other associated organisms. Knowledge on the ecological processes that create and maintain patterns of distribution of fish in artificial habitats is, however, an important step in evaluating the role that artificial structures play as habitat for fish.

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