Recruitment hotspots around a coral reef: the roles of hydrodynamics and habitats

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Abstract

The patterns and causes of variation in recruitment are widely acknowledged as major determinants of the spatial structure of coral reef communities, both for corals and reef-associated fishes. Atolls and isolated platform reefs often form discrete adult populations and management units for reef organisms. Recruitment to such reefs as a whole and spatial variation at the scale of whole reefs is, however, poorly understood. In addition, concomitant patterns in the recruitment of both corals and fishes have never been investigated. This study examined patterns of variation in coral and fish recruitment around a platform reef on the southern Great Barrier Reef (One Tree Reef) over three years. Using both descriptive and experimental approaches, it examined the roles of hydrodynamic processes and the composition of benthic assemblages as potential causes of recruitment variation across the reef. The aims were to detect persistent "recruitment hotspots" that may be vital to the replenishment and management of reef isolates, and to develop an understanding of why recruitment hotspots occur where they do.

Variation in hydrodynamic regimes in the boundary layer and in the free-stream flow around One Tree Reef was investigated to determine potential differences in larval supply to different areas around the reef. Plaster dissolution was used to assess net water movement on a hierarchy of scales: among locations one to three kilometres apart, among sites within one kilometre of each other and within metres at each site. In the boundary layer, the greatest amount of variation in water movement (69 %) was found within metres at sites, thus precluding comparisons among sites or among locations. In the free-stream, the greatest amount of variation (73 %) was attributable to differences

among sites. Relative ranks of sites according to water movement were consistent when measured at different times, although variability in wind direction affected locations. In the free-stream, mean water movement was 1.5 to 1.8 times greater at some sites compared with others. For flow in the free-stream, variability in water movement among sites could significantly affect cumulative larval supply and subsequent recruitment to assemblages in different areas. When larvae enter the boundary layer they are, however, also likely to be influenced by patterns of flow that are probably determined by small-scale (centimetres to metres) topography.

Patterns of variation in the composition of benthic coral reef assemblages around a reef were investigated to determine whether they persisted over time, and whether they were related to variation in net water movement. Benthic assemblage structure is known to influence recruitment patterns for coral and fish larvae, therefore, significant and predictable variation in the benthic composition among sites, and relationships between assemblages and water movement, could influence spatial patterns of recruitment at this scale. Two different types of sampling units were used to assess the benthic composition of coral reef assemblages: transects sampled the substratum under points spaced along 50 metres of the reef margin, while quadrats sampled the substratum under points located within a 1 m^2 area. The relative compositions of benthic assemblages were variable among sites, but patterns of relative variation persisted over two to three years using both types of sampling unit. The nature of linear relationships between benthic composition and net water flow, however, differed between sampling units. In quadrats the multivariate composition of coral assemblages was significantly linearly correlated with water flow, however, in transects only the percent cover of some particular benthic categories were linearly correlated with water flow. Nevertheless, overall patterns in the

benthic composition of assemblages around One Tree Reef were relatively consistent over the length of the study period, related to patterns of water flow, and together defined stable characteristics of sites likely to be important to the recruitment of reef corals and fishes.

Variation in recruitment of scleractinian corals and potential associations with net water flow, adult abundance and settlement substrata were examined around One Tree Reef. Although overall recruitment rates were very low compared to other studies of recruitment on the Great Barrier Reef, particular sites, both on the reef slope and in the lagoon, had consistently higher recruitment. These 'recruitment hotspots' (two or greater recruits per tile on average for two or more deployment periods) were, however, at different sites for different coral families. Variation in recruitment of pocilloporids and poritids, but not acroporids, was related to the percentage cover of adult colonies at each site. Recruitment hotspots were more common at sites with medium levels of water flow in the lagoon (4.6 cms^{-1}), but there were no clear relationships on the slope. In contrast, in experimental aquaria, *Acropora nasuta* settlement was six to ten times greater under low water flow speeds (2.1 cms^{-1}), compared to medium water flow speeds. This indicated that recruitment hotspots in the field might be more related to larval supply than to larval selection for medium flow sites. Differences in patterns of recruitment among taxa may have also been due to brooding and spawning life history strategies.

Identifying congruent recruitment hotspots for reef corals and fishes and their causes, represents a potentially powerful tool for understanding reef-wide persistence and resilience, and prioritizing management areas within reefs. Spatial variation in

recruitment around a reef was monitored for three species of planktivorous coral-dwelling fishes, *Pomcentrus moluccensis*, *Chromis viridis* and *Dascyllus aruanus* and relationships with net water flow and benthic composition were examined. As for coral taxa, for all species there were 'recruitment hotspots', where recruitment was two to three orders of magnitude (10's to 100's of fish per 100 m^2) greater than at other sites (less than 1 fish per 100 m^2). One site was a recruitment hotspot for all three species, but other sites were recruitment hotspots for just one or two species. Deterministic factors contributing to consistent patterns at this scale included positive relationships with the abundance of recruit microhabitats for *P. moluccensis* and *C. viridis*, and relationships with net water flow, though the nature of relationships with water flow differed between species, and also between the lagoon and slope environments. There was no clear relationship between recruitment and net water flow for *D. aruanus*, and recruitment was greatest at sites in the lagoon where the coral microhabitats to which this species recruited were intermediate in abundance. Relationships between recruiting fish and microhabitats may have been confounded by interactions between net water flow and microhabitats. Flow variation not only affected the abundances of coral taxa but also their morphology. Lower flows produced coral colonies with a wider branching morphology that were preferred by recruits. Nevertheless, recruitment hotspots for coral reef fishes were clear and could be predicted using a combination of hydrodynamic and benthic influences and their synergistic relationships.

In summary, patterns of spatial variability in hydrodynamics and benthic composition around a reef persisted over time and were two factors that influenced recruitment patterns in reef corals and fishes. 'Recruitment hotspots' were identifiable for all three coral families, and all three fish species, although these sites were not the same for all

taxa, reflecting differences in their relationships with hydrodynamics and benthic composition. Interestingly, relationships between patterns of recruitment, hydrodynamics and benthic composition varied not only among taxa, but also between lagoon and slope environments for individual taxa. Sites in the lagoon and on the slope that were recruitment hotspots for more than one taxon were, however, clustered in one area on the leeward side of the reef, and may have related to patterns of larval accumulation at a larger scale. Although there is a general consensus among coral reef ecologists that recruitment is variable, this study adds to the growing body of literature suggesting that predictable and persistent recruitment hotspots occur around coral reefs. This variation should be taken into account in the selection of sites for ecological research and for reef management.

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Declaration

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