

MECHANISMS AFFECTING THE COLONIZATION OF AN ARTIFICIAL SUBSTRATE BY MARINE INVERTEBRATES

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Abstract: Understanding the mechanisms regulating the colonization of marine reef organisms aids predictions for how these systems will respond to disturbance. Many marine invertebrates are either completely planktonic, or have complex life cycles which include a planktonic larval stage. The colonization of vacant settling sites and new reef patches by these organisms may be affected by distance from a coral reef source population and by predation. To test for effects of distance from a reef source and predation pressure, we set out artificial colonization sites (bristle brushes) that were exposed to or screened from predators at different distances from a reef. We observed the fish in the vicinity of our study area to assess whether the abundance and diversity of predators changes with distance from reef. We found that both the abundance of marine invertebrate colonizers decreased with distance from reef, and that the abundance and diversity of predators sharply decreased with distance from the reef. We found a significantly higher abundance and diversity of invertebrate colonizers on artificial colonization sites excluded from predators across all distances. Therefore, post-colonization predation pressure may cause high mortality on these colonizing invertebrates, and thus contribute to structuring marine invertebrate communities.

Key Words: invertebrate, coral reef, colonization, predation, artificial colonization site

INTRODUCTION

Understanding the dynamic mechanisms contributing to the vitality of coral reefs is necessary to predict the consequences of habitat destruction and fragmentation on patterns of species diversity (Munday 2004). Reestablishment of coral reef communities is dependent on successful colonization by marine organisms.

Many marine organisms are either entirely planktonic, or have evolved a complex life cycle which includes a planktonic larval stage. These planktonic organisms may exhibit diel vertical migrations during which they seek benthic refuges (settling sites) from predators during the day and move into the water column to feed at night. This may create

invertebrate communities linked by migration and dispersal that differ in their abundance and diversity due to varying local factors. Colonization of vacant settling sites and new reef patches may depend on ocean currents, distance between the settling site and a source population, habitat preference, and invertebrate predators foraging either in the water column (pre-colonization mortality) or on the benthos (post-colonization mortality).

The abundance and diversity of organisms colonizing available substrate will depend on the relative strength of the factors involved (Fig. 1). If the effect of predation is greatest on planktonic individuals that travel the farthest from the reef (thus spending the longest period of time exposed to predators) the abundance and/or diversity of invertebrate colonizers

will decrease with distance from the source (Fig. 1A). An equally likely possibility may be that colonizers are dispersal limited. If the reef is the source, and if dispersal away from the reef is limited, the pattern of colonizer abundance would appear the same as one with dominant pre-colonization predation (Fig. 1A).

If planktivorous fish predators restrict foraging to source areas (Belmaker et al. 2005), predation pressure will be highest closest to the source, and diversity and/or abundance of invertebrate communities will increase with increasing distance from the source (Fig. 1B). However, if pre-colonization and post-colonization predation pressure synchronously, colonizer abundance and diversity would peak at an intermediate distance from the source (Fig. 1C). If planktonic invertebrates have high dispersal abilities, a mixing of planktonic invertebrates from distant sources could result in a dampening of the effect of a single source on colonization rates. Therefore, diversity and abundance of colonizers would not change with distance from any one source.

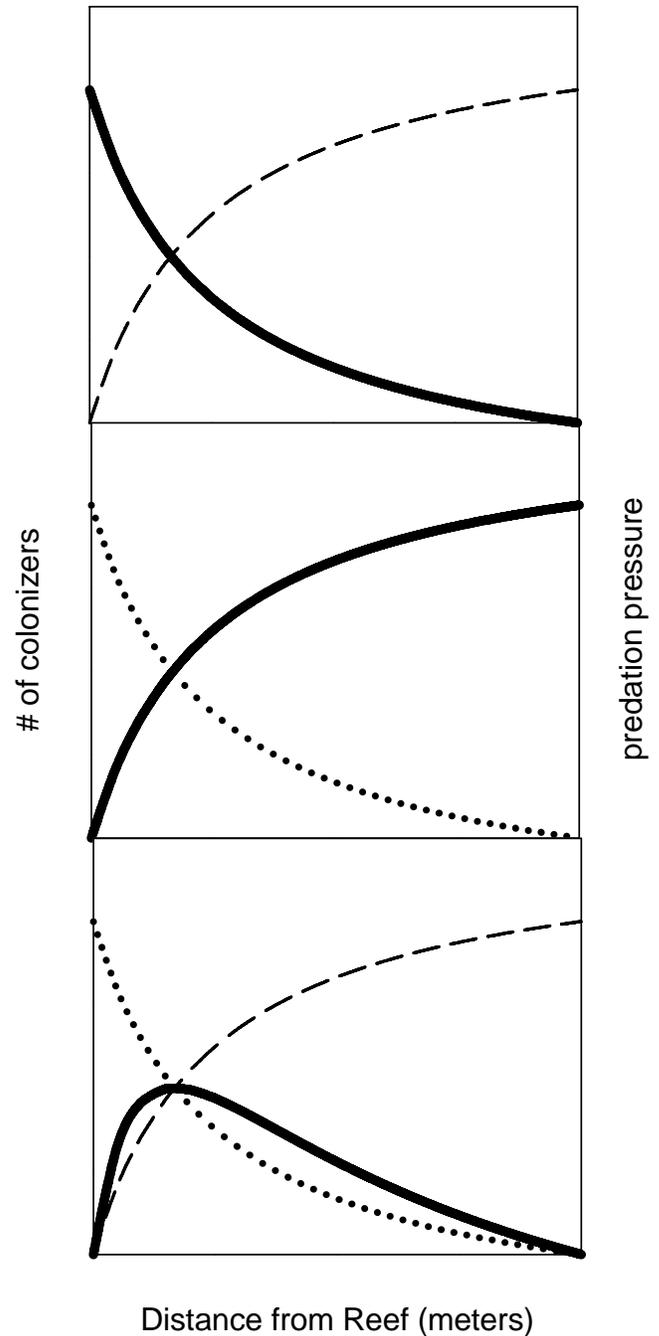


Figure 1. Potential relationship between total invertebrate colonizer abundance (solid line) and A) dominant pre-colonization predation pressure (dashed line) (Note: pattern of colonizer abundance also consistent with dispersal limitation from source), B) dominant post-colonization predation pressure (dotted line), and C) the combination of both pre- and post-colonization pressure, with increasing distance from a coral reef.

We investigated invertebrate colonization of artificial colonization sites and distribution of vertebrate predators at varying distances from a reef source to: 1) determine whether the abundance and diversity of marine invertebrate colonizers on artificial settling sites is affected by distance from a large reef, 2) establish whether the abundance and diversity of potential predators on these invertebrate colonizers changes with distance from the main reef, and 3) determine whether post-settlement predation may affect the abundance and diversity of colonizers and 4) whether post-settlement predation varies with distance from the main reef.

METHODS

Construction of artificial colonization sites (ACS)

We used twenty-four 10 x 3.5 cm cylindrical bristle brushes as artificial colonization sites (henceforth ACS) (Fig. 2). Using 1.25 cm chicken wire, we created cylinders of 10 cm diameter around half of the brushes to serve as predator exclusion cages. These cages were closed at both ends, and the brushes were suspended in the middle using wire. We attached four bolts to the bottom of each bristle brush to anchor the ACS to the benthos. We also used a small foam float attached to the top of each exclusion cage or non-exclusion brush with 25-30 cm of twine to hold the ACS upright under water.

Placement and retrieval of ACS

On 3 March 2006, we used SCUBA to place 24 ACS units in large sandy channels within coral fore reef of Discovery Bay,

Jamaica. We placed two ACS units, one caged and one uncaged, 2 m apart, at each of 0, 5, 10 and 20 m from the reef along three transects running perpendicular to the reef edge in approximately 20 m of deep water. Transect 1 was located at Dancing Lady and the other transects were at Mooring 1. We visually inspected the

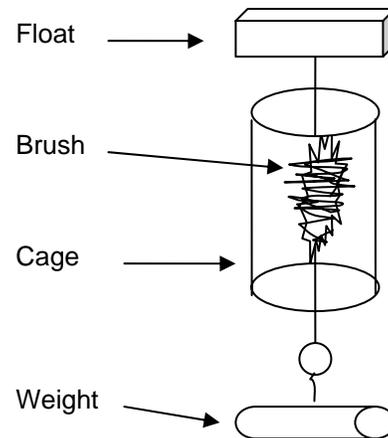


Figure 2. ACS device

transect to ensure that no other coral reef wall or patch was within 20 m.

We retrieved all ACS after 72 hours. Assistants helped cut buoys and bolts and placed each ACS into two Ziploc bags to prevent loss of fauna. In the wet laboratory, we filtered the water in the bags through a 153 μm mesh. We then rinsed each brush with two seawater washes followed by two freshwater washes, and ran these washes through the mesh. We preserved the invertebrates and detritus retained on the mesh filter in 10% formalin. We then we sorted invertebrates by taxon and size class using dissecting microscopes.

Spatial distribution of fish predators

While the ACS units were deployed we observed the abundance and species of

fish present for 10 minutes in 10 m² areas located at 0 to 5 m, 5 to 10 m, and 15 to 20 m intervals along each transect. We determined potential fish predators on invertebrates based on feeding guilds described by Randall (1967).

Analysis

To determine if invertebrate colonization were non-random with respect to distance from reef or predator exclusion, we investigated how distance from reef, ACS type (caged and uncaged), and the interaction between distance and ACS type affected colonizer abundance, taxa richness, taxa diversity, and taxa size by running a two-way ANOVA for each. To calculate taxa diversity of the colonizer community, we used the Gini diversity index:

$$D = 1 - \sum_{i=1}^n p_i^2 \quad [Eq. 1]$$

Where n = taxa p_i = fraction of individuals in the sample that represents taxon i.

To determine the directionality of invertebrate colonization patterns for abundance, we ran an *a priori* linear contrast predicting a linear trend with decreasing abundance of colonizers with distance from reef (JMP 5.0.1).

RESULTS

We counted 848 total invertebrates distributed across 10 taxa: copepod, amphipod, isopod, decapod, mysid, polychaete, medusae, gastropod, nematode, echinoderm.

The abundance of invertebrate colonizers decreased with distance from reef edge (ANOVA; $F_{3,16} = 3.25$, $P = 0.05$: *a priori* linear contrast; $F_{1,16} = 6.92$, $P = 0.02$), and was significantly greater in predator exclosures ($F_{3,16} = 8.63$, $P = 0.01$; Fig. 3). However, the interaction of distance and

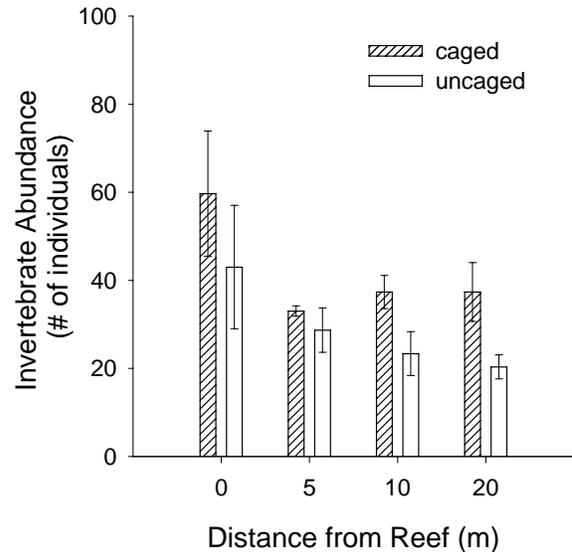


Figure 3. Mean invertebrate abundance (± 1 SE) after 72 hours on caged and uncaged artificial colonization sites placed at 0, 5, 10 and 20 m from large coral reefs in Discover Bay, Jamaica. Abundance decreased significantly with distance from reef ($F_{3,16} = 3.25$ $P = 0.05$) and was significantly higher in sites excluded from predators ($F_{3,16} = 8.63$ $P = 0.01$).

ACS type ($F_{1,16} = 0.41$, $P = 0.74$) did not affect colonizer abundance.

Neither distance ($F_{3,16} = 0.65$, $P = 0.59$), ACS type ($F_{1,16} = 2.23$, $P = 0.16$) nor the interaction ($F_{3,16} = 0.77$ $P = 0.53$) between distance and ACS type affected invertebrate taxa richness. Colonizer diversity was greater in caged than uncaged ACS ($F_{1,16} = 12.38$, $P = 0.003$), but distance from reef edge ($F_{3,16} = 0.32$, $P = 0.81$), and the interaction between distance and ACS type ($F_{3,16} = 1.05$, $P = 0.40$) did not affect diversity of the colonizing community. These trends were consistent across all size classes for

the most abundant taxa (copepod, amphipod, and polychaete) (all $P < 0.04$).

We observed 406 total fish visitors among 34 species at our transects, with 354 individuals identified as potential invertebrate predators. Predation pressure was concentrated at the reef, with a sharp decrease in abundance and diversity of predators with increasing distance from the reef (Table 1).

DISCUSSION

Our results indicate that the abundance of marine invertebrate colonizers on ACS decreases with distance from the coral reef, which may serve as the source population for dispersing planktonic organisms. This trend follows the one predicted by colonizer abundance if pre-colonization predation pressure increases with distance from a source reef (Fig. 1A). However, it is the same trend predicted if invertebrate colonizers are dispersal limited (Fig. 1A). Thus, our results cannot distinguish between these two mechanisms.

Our two methods of examining predation pressure provided contrasting results. The sharp decline in observed

potential predators with distance from the reef suggests that predatory fish have a preference for three dimensional structure provided by a coral reef, and that distance from a reef may be a major factor affecting marine reef fish distribution. This may lead to predation pressure decreasing with increasing distance from edge. Yet, colonizer abundance also decreased with distance from the reef, and we found a similarly higher abundance and diversity of invertebrate colonizers on predator-excluded ACS across all distances. Therefore, though it appears that post-colonization predation pressure (as measured with predator-exclusion cages) strongly influences invertebrate populations after colonization, we found no variation in post-colonization predation with distance from the reef. This result is in contrast with our observations on spatial distribution of predators. However, it is possible that our exclusion cages may have led to artifacts (effects due not only to predator exclusion but other factors), for example cages may create a more hospitable microclimate for colonization (Sale 1991). Our study does not distinguish effects of predation versus caging artifacts.

TABLE 1. Observations of potential predators on invertebrate colonizers (fish predators were observed during 10 minute intervals) with increasing distance from the reef source at three transects in two sites (Dancing Lady, Mooring 1) in Discovery Bay, Jamaica.

Site	Transect	Distance from reef	# of fish observed	# of fish species observed
Dancing Lady	1	0	61	15
Dancing Lady	1	5	7	2
Dancing Lady	1	15	0	0
Mooring 1	2	0	158	21
Mooring 1	2	5	0	0
Mooring 1	2	15	5	1
Mooring 1	3	0	123	23
Mooring 1	3	5	0	0
Mooring 1	3	15	0	0

The results of our study suggest that both distance from a source reef and predation, both pre- and post-colonization, may serve as important underlying regulatory mechanisms affecting the colonization and survival of populations of marine invertebrates. Based on our conclusion that abundance of invertebrate colonizers is affected by distance from the coral reef or source, it may be useful to pursue the application of island biogeography theory (Belmaker et al. 2005) to understand the effect of distance on the recruitment of marine invertebrates to potential settling sites. It will be important to consider the effects of these mechanisms on successful re-establishment of coral reef communities after disturbance.

Iwamoto, K.A. and N.L. Salant. 2003. The effect of depth on invertebrate colonization patterns on a Caribbean reef. *Dartmouth Studies in Tropical Ecology*, p. 163-365.

Randall, J.E. 1967. Food habits of reef fishes of the West Indies. *Studies in Tropical Oceanography* 5: 665-847.

Sale, F.P. 1991. *The Ecology of Fishes on Coral Reefs*. San Diego: Academic Press.

LITERATURE CITED

Belmaker, J., N. Shashar and Z. Yaron. 2005. Effects of small-scale isolation and predation on fish diversity on experimental reefs. *Marine Ecology Progress Series* 289: 273-283.

Munday, P.L. 2004. Competitive coexistence of coral-dwelling fishes: the lottery hypothesis revisited. *Ecology* 85(3): 623-628.