Using Facilitation Theory to Enhance Mangrove Restoration

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Comment

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Despite advances in positive interactions and facilitation theory in ecological research (1, 2), the concepts have failed to make a big impact on mangrove restoration ecology. Restoration applications of facilitation include reaping the community benefits of foundation species, positive density dependence, and facilitation cascades (3). In their June 2008 article, "Growth Performance of Planted Mangroves in the Philippines: Revisiting Forest Management Strategies," Samson and Rollon discuss failed mangrove restoration projects in the Philippines and suggest that the poor growth and mortality of *Rhizophora* spp. seedlings were due to inappropriate placement of seedlings in low intertidal mudflat and seagrass habitats, instead of being planted in existing or deforested mangrove areas (many of which are now privately controlled). Planting mangrove seedlings at appropriate elevations to limit abiotic stress on seedlings is a major tenet of recent mangrove restoration work (4), and Samson and Rallon expand on this to say it must be the primary focus of future efforts if restoration is to succeed. This conclusion is overly narrow, whereas incorporating positive interactions into restoration practices will be complementary to ongoing approaches and result in mangrove forest restoration efforts having greater success under a wider range of environmental conditions.

Although positive interactions, such as the planting of foundation species to initiate ecosystem development, are a key component of restorations, other positive interactions are rarely accounted for in marine restoration designs (3). The ability of mangroves to tolerate extremely stressful abiotic conditions is due in part to key adaptations (e.g., salt-excreting glands, aerial or prop roots, and pneumatophores) and to intraspecific positive feedbacks: neighboring trees' leaky roots oxygenate soils and locally ameliorate high sulfide concentrations (5). Yet most mangrove restorations around the world, including the Philippines example, plant mangroves as single seedlings, evenly spaced, in rows. This configuration is based on the assumption that competition among seedlings needs to be minimized to foster establishment and growth. Thus seedlings need to be spaced well away from each other to maximize light availability and minimize competition between neighbors. However, whereas light availability can be a limiting factor at later stages in mangrove forest development, the limiting growth factors at the initial stages of mangrove establishment are edaphic stressors, such as low redox potential and high soil salinity, as recognized by the Samson and Rollon. Because coastal wetland plants engineer the substrate to ameliorate these harmful conditions, an effect that increases with wetland plant density (6), seedlings are likely to exhibit positive, not negative, density dependence because of the facilitative effects of neighbors on ameliorating anoxic soil conditions.

Ecological theory and wetland experiments both predict that mangrove seedlings have a far better chance of survival if they are planted in clusters of several seedlings rather than plantation style. Planting seedlings in clusters will likely allow the necessary positive feedbacks to take root in the absence of adult plant roots or pneumatophores. For example, a black mangrove restoration in Mexico that planted five-seedling clusters resulted in notably high survival of planted seedlings (74%) after 4 years, despite being planted in a mudflat environment (7). Mangrove seedlings frequently suffer high rates of mortality, and clustered or redundant plantings allow surviving seedlings to compensate for lost neighbors. Nurse plants, which can serve the same purpose in a restoration as seedling clusters, promoting the facilitative species interactions that ameliorate abiotic stress, have also been found to improve mangrove restoration success (8). Higher plant densities have also been found to reduce herbivory on susceptible, young plants in other saline wetland environments (9).

Coastal populations depend on mangrove ecosystems for economic products, such as shrimp ponds, fish farms, and timber products, and for the ecosystem services they provide, such as coastal stabilization, wave attenuation, and nursery habitat for fish. These services, from both natural and converted mangrove areas, cannot be minimized, and, as Samson and Rollon suggest, it may not be feasible or prudent in all cases to restore former mangrove areas to mangrove forest. In many cases, the best decision will include a mix of exploitation, conservation, and restoration (10). Whether mangrove restorations proceed in mangrove or nonmangrove habitats, restorations are much more likely to be successful if they assume positive, rather than negative, density dependence during initial ecosystem development and thereby capitalize on advances in facilitation theory. The old paradigm of applying terrestrial forestry nursery theory (minimize competition) to wetland restorations needs to be updated to current ecological theory, showing that positive interactions among plants in more physically harsh wetland systems are integral to plant establishment, survival, and success.

References and Notes

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