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PRINCIPLES OF SUCCESSFUL RESTORATION OF SHRIMP AQUACULTURE PONDS BACK TO MANGROVE FORESTS

Roy R. Lewis III* and Michael J. Marshall

Lewis Environmental Services, Inc.
P.O. Box 20005
Tampa, FL 33622-0005 USA

The basic principles of successful mangrove restoration are: (1) understand the autecology of the mangrove species at the site, in particular the patterns of reproduction, propagule distribution and successful seedling establishment, (2) understand the normal hydrologic patterns that control the distribution and successful establishment and growth of the targeted mangrove species, (3) assess the modifications to the previous mangrove environment that occurred that currently prevent natural secondary succession, (4) design the restoration program to initially restore the appropriate hydrology and utilize natural volunteer mangrove propagule recruitment for plant establishment and (5) only utilize actual planting of propagules, collected seedlings or cultivated seedlings after determining through steps 1-4 that natural recruitment will not provide the quantity of successfully established seedlings, or rate of stabilization by or rate of growth of saplings, established as goals of the restoration project. Failure of natural secondary succession can also occur due to poor soil conditions related to the formation of acid sulfate soils. This condition would need to be rectified prior to determining the success of steps 1-4, or attempting any planting program.

The failure of most mangrove restoration projects can be traced to proceeding in the early planning stages to Step 5 without considering Steps 1-4. We refer to this approach as "gardening", where simply planting mangroves is seen as all that is needed. This ignores the basic principles of mangrove secondary succession, where mangrove forests damaged by natural events, such as hurricanes, have repeatedly been shown to recover on their own without man's intervention.

We use the restoration of four former shrimp aquaculture ponds at a shrimp farm on the Pacific coast of Costa Rica as an example of restoration where planting was not necessary. The four ponds, ranging in size from 4.0 to 25.0 ha in size are undergoing natural secondary succession due to natural breaching of the dikes closest to the Gulf of Nicoya. The managers of the ponds decided to close only one of the three dike breaches when they acquired the ponds in 1989, and the breaches had occurred two years earlier. Thus the natural restoration process has been underway for ten years.

The adjacent undisturbed mangrove forests contain six species of mangroves, *Rhizophora mangle, R. racemosa, Avicennia germinans, A. bicolor, Pellicera rhizophora* and *Laguncularia racemosa*. Quantitative measurements of forest structure taken in the 4.0 ha pond were compared with similar data collected in an adjacent undisturbed forest. Basal area in the pond undergoing restoration (experimental site) was 18.33 m2/ha, while that in the control area was 28.53 m2/ha. Stem counts at the experimental site were 15,200/ha, while in the control area they were 7,000/ha.