Recolonization of a Restored Red Mangrove Habitat By Fish and Macroinvertebrates

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Abstract

This paper describes the results of the first year's monitoring of a restored mangrove habitat. An adjacent natural mangrove habitat served as a control for these studies. The results indicate that species diversity is a less effective monitoring index than species similarity for gauging the success of restoration projects. Moreover, survival and growth of resident fauna may be the most sensitive indicator of habitat restoration. Future studies will follow long-term changes in the species composition of the restored site, as well as the growth and survival of selected resident fauna. The ultimate goal of these studies is to develop and test techniques which may be used to monitor restored mangrove habitats and to determine the time required for successful habitat restoration.

Introduction

In December, 1990, a red mangrove (Rhizophora mangle) forest which had been leveled and filled in 1973 was restored by removing the fill and planting red mangrove seedlings. The study described in this report was initiated in March of 1991 to document recolonization of the site by macroinvertebrates and fishes. An adjacent natural red mangrove forest was used as a reference site to judge the success of the restoration effort. The purpose of this on-going study is twofold: 1.) to access the success of this mangrove restoration project over time, and 2.) to develop techniques that can be used to monitor future restoration projects. This report summarizes the results of the first year's monitoring effort.

Physical restoration of altered wetland habitats, such as mangrove forests, is quickly becoming a popular alternative to wetland protection. Previous monitoring of wetland restoration has focused primarily on the success of the planted vegetation (Lewis, 1982) and pollution abatement (Hammer, 1992). Fewer studies have monitored the recruitment survival of the fauna of a restored habitat (Moy and Levin, 1991). This is unfortunate since macroinvertebrates and fishes are a crucial link in the mangrove-detritus based food webs of Southwest Florida estuaries (Odum and McIvor, 1990).

In the case of restored mangrove forests, the physiological tolerance and habitat preference of the flora may be less restrictive than that of its resident fauna. This is especially true during early stages of habitat restoration, before canopy closure occurs. In general, forest canopies are known to modify the microclimate of a site thereby protecting sensitive species from extreme temperatures and desiccation (Krebs, 1978). Predation pressure may also change as a restored habitat matures and the denser vegetation provides a better refuge for prey species.

Sediment grain size, compaction and organic content also determine the burrowing success and food availability for benthic fauna (Levinton, 1982). With time these organisms change the chemical and physical characteristics of their habitat (Rhoads and Boyer, 1982; Aller, 1982) which in turn affects the success of secondary recruits and the rate at which the site's species composition approaches that of a natural mangrove forest.

In the present study, the diversity, similarity, relative abundance and size of the resident fauna within a restored site and an adjacent natural mangrove forest are compared. The results describe the first year's monitoring of a long-term project. The purpose of this study is to provide information to guide future restoration efforts and develop monitoring techniques to assess the success of habitat restoration for resident fauna. Understanding the time required for successful recolonization by resident fauna is critical for resource managers to fully access the success of wetland restoration and its potential as an alternative to wetland protection.

Methods

Study Site

The restored habitat site and natural (control) site are located on the southern shore of upper Henderson Creek within the Rookery Bay National Estuarine Research Reserve in Naples, Florida (Figures 1 and 2). The area of the restored site is approximately 7723 m^2. The natural site is adjacent to the restored site and consists predominantly of red mangroves. Historical aerial photographs indicate that the natural site has remained undisturbed for at least 50 years and prior to 1973, was part of a contiguous mangrove forest which extended the length of Henderson Creek (Figure 2).

Physicochemical Data

The maximum tidal height and sediment surface temperature were recorded monthly during the study period (March, 1991 to November, 1992). Sediment grain size (% silt and clay) and organic content were calculated from surface soil samples obtained at the beginning of the study period using standard techniques (Brower et al, 1990).

Biomonitoring

To capture mobile macroinvertebrates and fishes, once a month ten cages (30 x 30 x 15 cm; 2mm^2 wire mesh) were placed along a transect running parallel

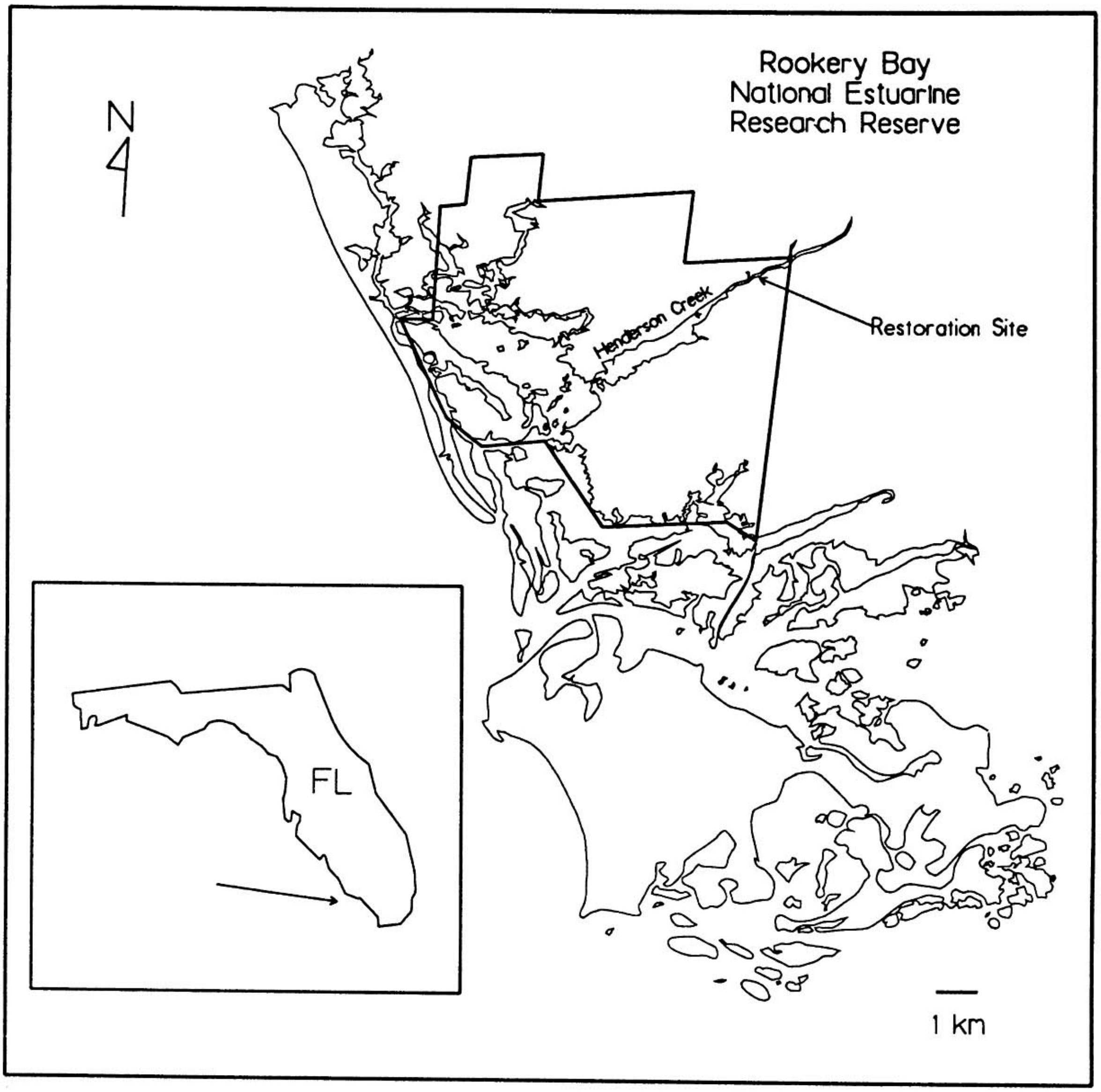

Figure 1. Geographic location of the study site within the Rookery Bay National Estuarine Research, Naples, Florida.

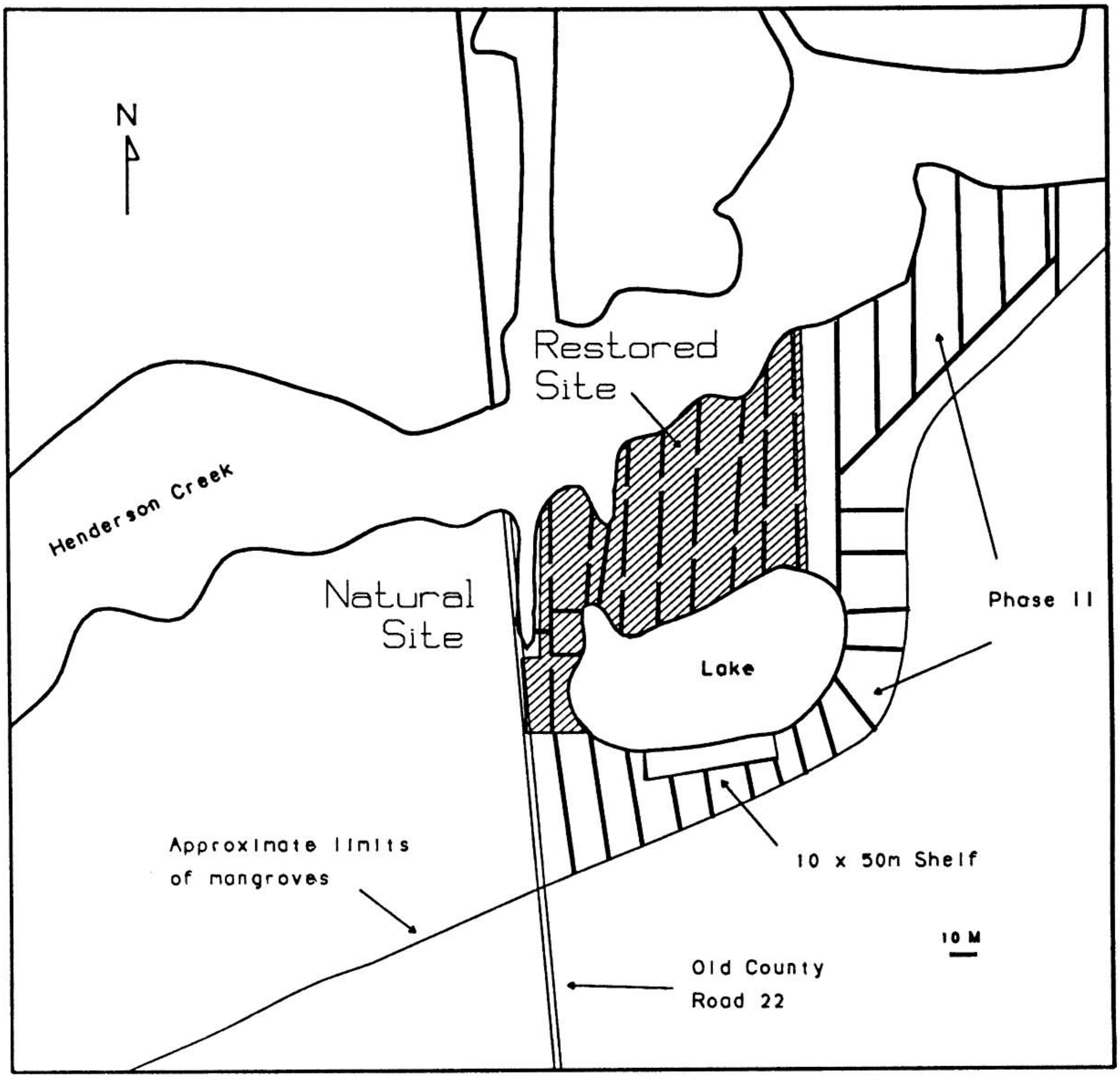

Figure 2. Location of the restored (shaded) and natural (control) study sites.

to and approximately 20 meters from the edge of Henderson Creek at both the natural and the restored sites. Cages were placed ten meters apart and emptied after a 24-hour (two tidal cycles) deployment. Four randomly placed 30 x 30 cm quadrats were also surveyed each month at each site to sample less-mobile species. The data from both the cages and quadrats were combined to estimate the sites' monthly diversity and similarity indices. Diversity was calculated using the Shannon index (H') and similarity was calculated using the Morisita index (Magurran, 1988). The percentage of the captured or observed species which are known to be permanent intertidal residents of red mangrove forests was also calculated for each site.

In addition to these measurements, catch per unit effort (CPUE) and carapace width (mm) of all fiddler crabs caught in the cages were calculated each month at each site. During October and November, 1991, the site-specific size (length of shell in mm) of randomly collected Melampus coffeus, a pulmonate snail, was also recorded.

Statistics

Site-specific comparisons of surface temperatures and maximum tidal heights were analyzed using paired t-tests (Sokal and Rohlf, 1981). The sediment organic content and percent silt and clay of each site were compared using a one-way ANOVA (Sokal and Rohlf, 1981). Monthly Shannon diversity indices were compared by estimating the variance and using a t-test (Magurran, 1988). A Morisita similarity index value of 0.6 was used as the cut-off to indicate similar species composition. The species abundances and percent resident species for each site were compared using log-linear analyses (Sokal and Rohlf, 1981). Catch per unit effort for fiddler crabs at each site was compared using a two-way (site X study) ANOVA on log transformed (log(x+1)) data. Fiddler crab carapace width and Melampus shell length were analyzed using a two-way ANOVA (site X study).

Results

Physicochemical Conditions

The maximum tidal height of the restored site (16.9 $\pm$ 2.5 cm, mean $\pm$ std error) was significantly greater ($p \leq 0.05$, paired t-test) than that of the natural site (14.2 $\pm$ 2.1 cam, mean $\pm$ std error). The daytime surface temperature of the restored site (29.8 $\pm$ 1.4 C, mean $\pm$ std error) was also significantly greater ($p \leq$, paired t-test) than that of the natural site (25.6 $\pm$ 1.1 C, mean $\pm$ std error). In addition, sediment organic content of the restored site (4.22 $\pm$ 0.44%, mean $\pm$ std error) was significantly less ($p \leq 0.05$, ANOVA) than that of the natural site (53.39 $\pm$ 1.16%, mean $\pm$ std error). Likewise, sediment grain size (as % silt and clay) of the restored site (7.74 $\pm$ 12.3%, mean $\pm$ error) was significantly less ($p \leq 0.05$, ANOVA) than that of the natural site (82.54 $\pm$ 1.23%, mean $\pm$ std error).

Biomonitoring

In all, 17 species of macroinvertebrates and fishes were collected during this study (Figure 3). The relative species abundances at each site were significantly different (log-linear analyses, $p \leq 0.05$). The diversity of the two sites remained significantly different (t-test, $p \leq 0.05$) for the first five months after restoration (Figure 4). During August, 1991, the diversity of the restored site exceeded that of the natural site. The species similarity index for the two sites also peaked in the summer, but remained below 0.5 (Figure 5). A closer examination of the species composition of each site reveals that resident species comprise a significantly greater (log-linear analyses, $p \leq 0.05$) proportion of the total community at the natural site than at the restored site (Figure 6).

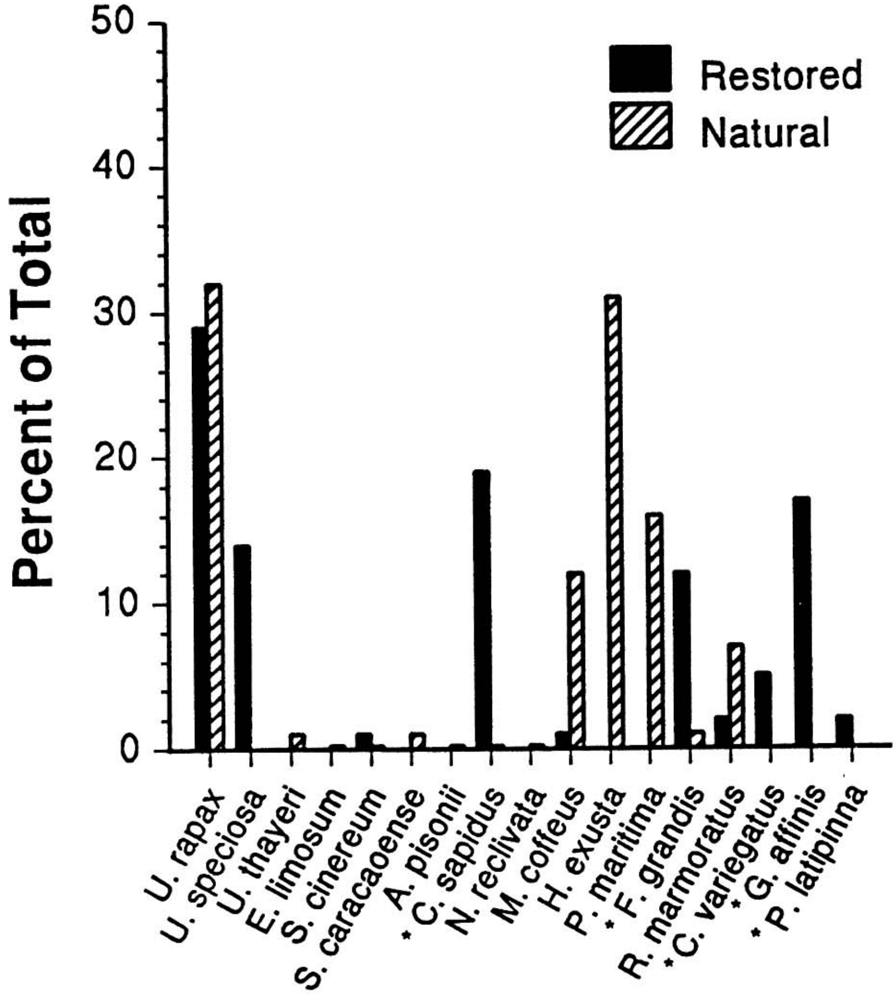

Figure 3. Species abundance for the restored and natural study sites. Asterisks signify those species which inhabit the sites only when inundated.

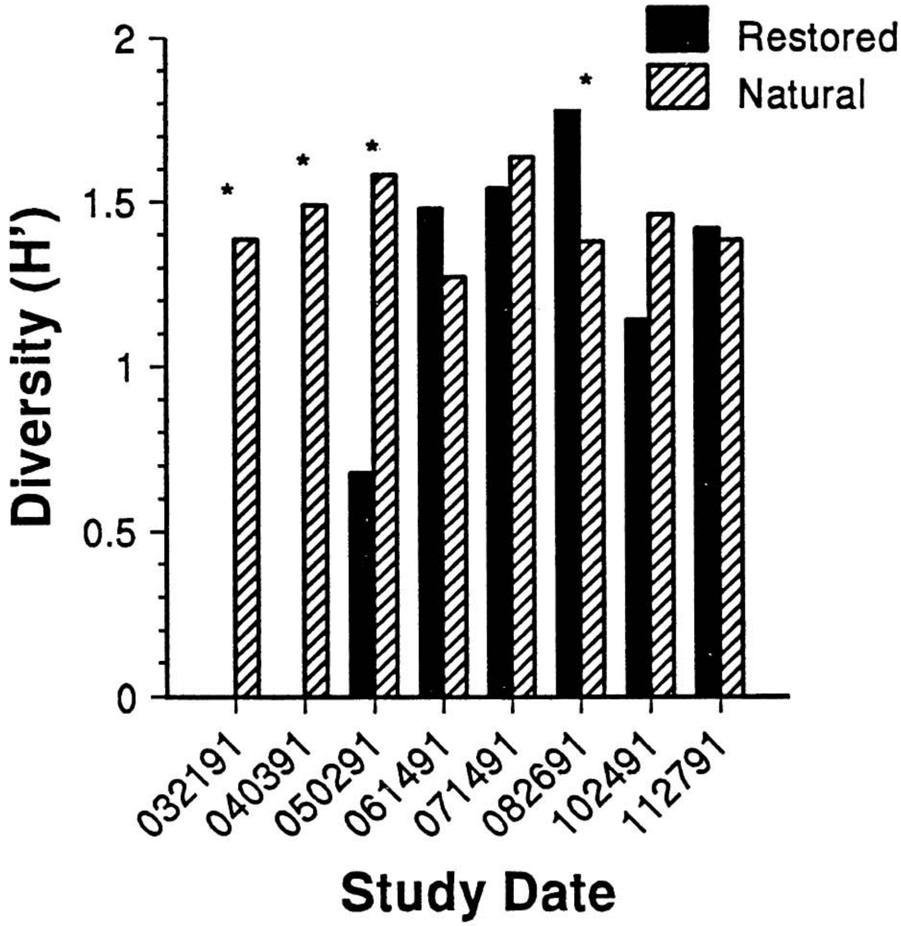

Figure 4. Diversity for the restored and natural study sites. Asterisks denote a significant difference in diversity at each site for a study date.

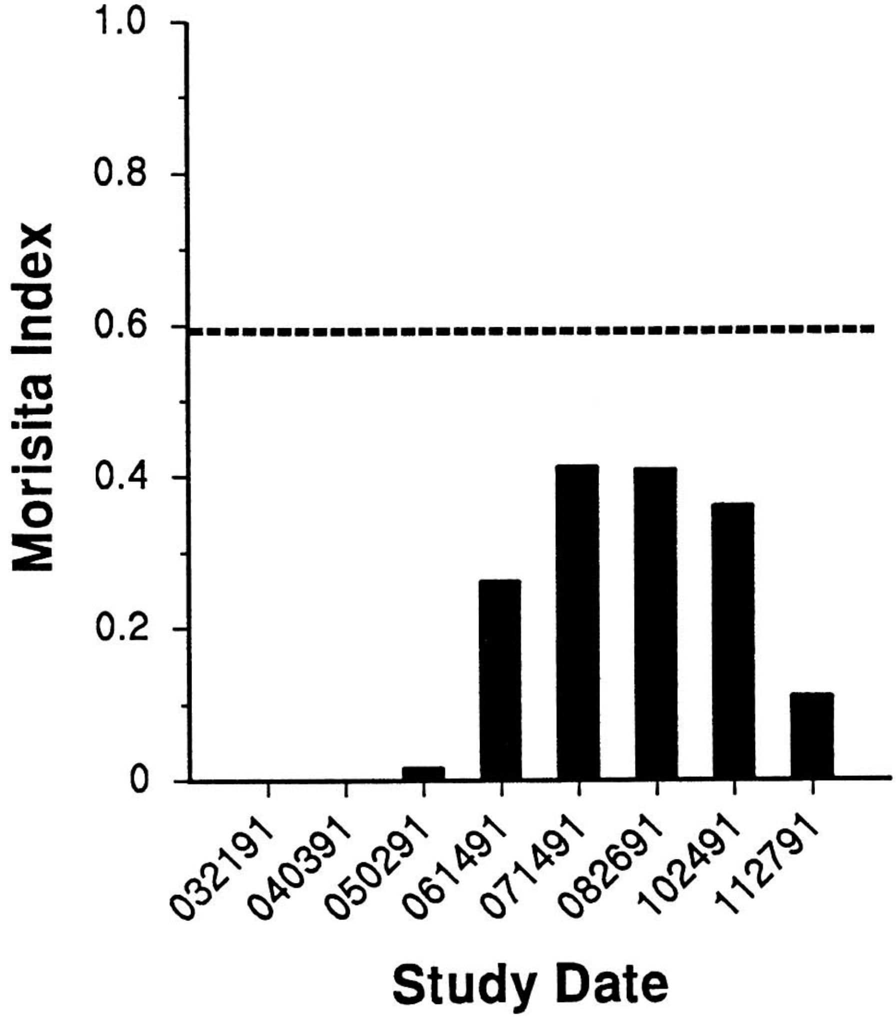

Figure 5. Similarity of the restored and natural sites. The dashed line corresponds to the 0.06 value for similarity as typically required by the State of Florida to indicate successful habitat restoration.

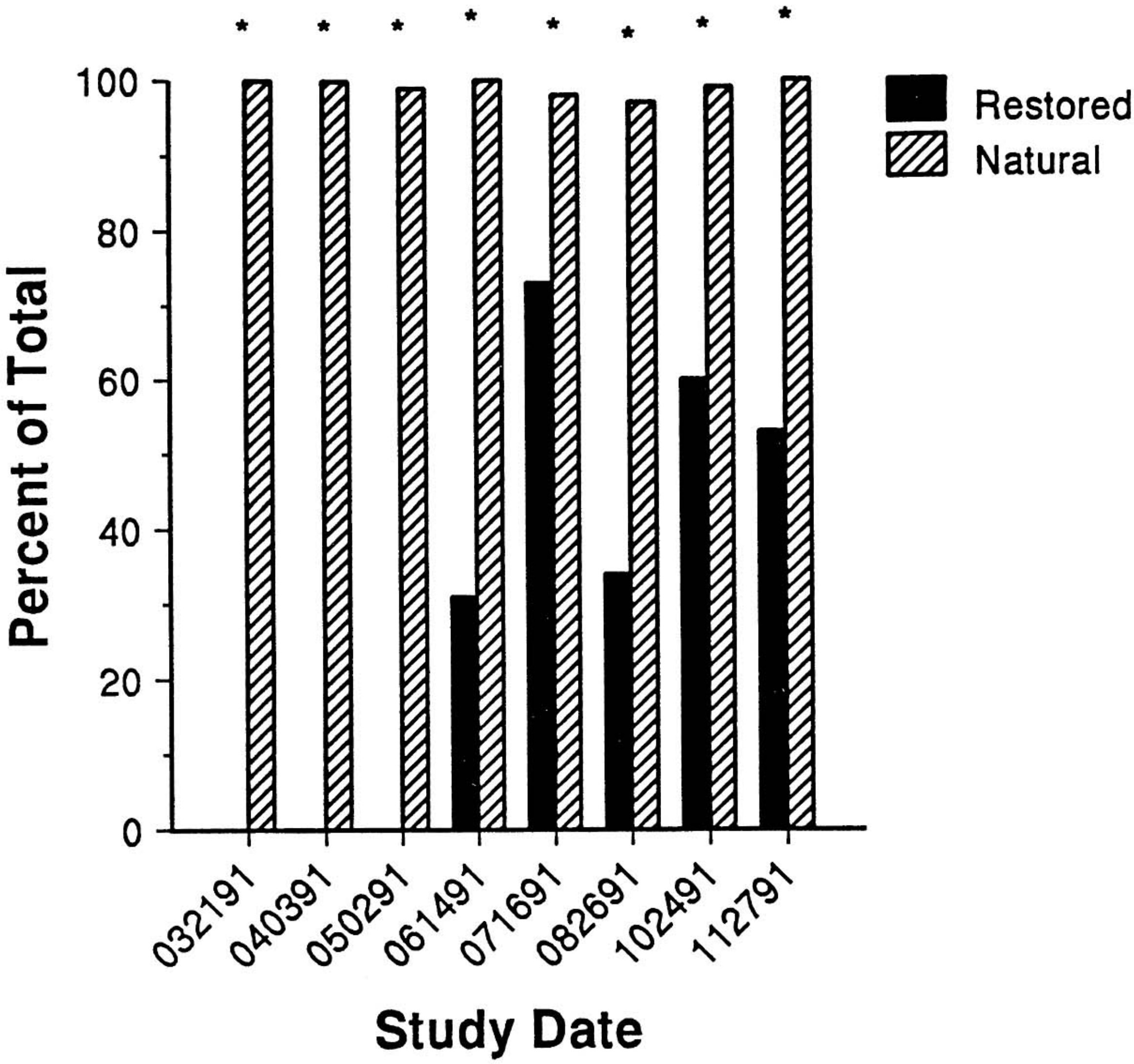

Figure 6. The percent of the total number of individuals representing species which are permanent residents of a natural mangrove forest. Asterisks denote a significant difference between sites for a study date.

Fiddler crabs, one of the earliest taxa to appear at the restored site, became established by the sixth month after planting. The population abundances (CPUE) present a complex pattern (Figure 7) with the crab populations of the restored site being less stable. By July, seven months after planting, the abundance of fiddler crabs was not significantly different from the abundance of the natural site's crab population (ANOVA, $p \leq 0.05$). By August, the fiddler crab abundances of the two sites were again significantly different with higher catch rates occurring at the natural site. In October and November, the abundances of these two adjacent crab populations were again not significantly different.

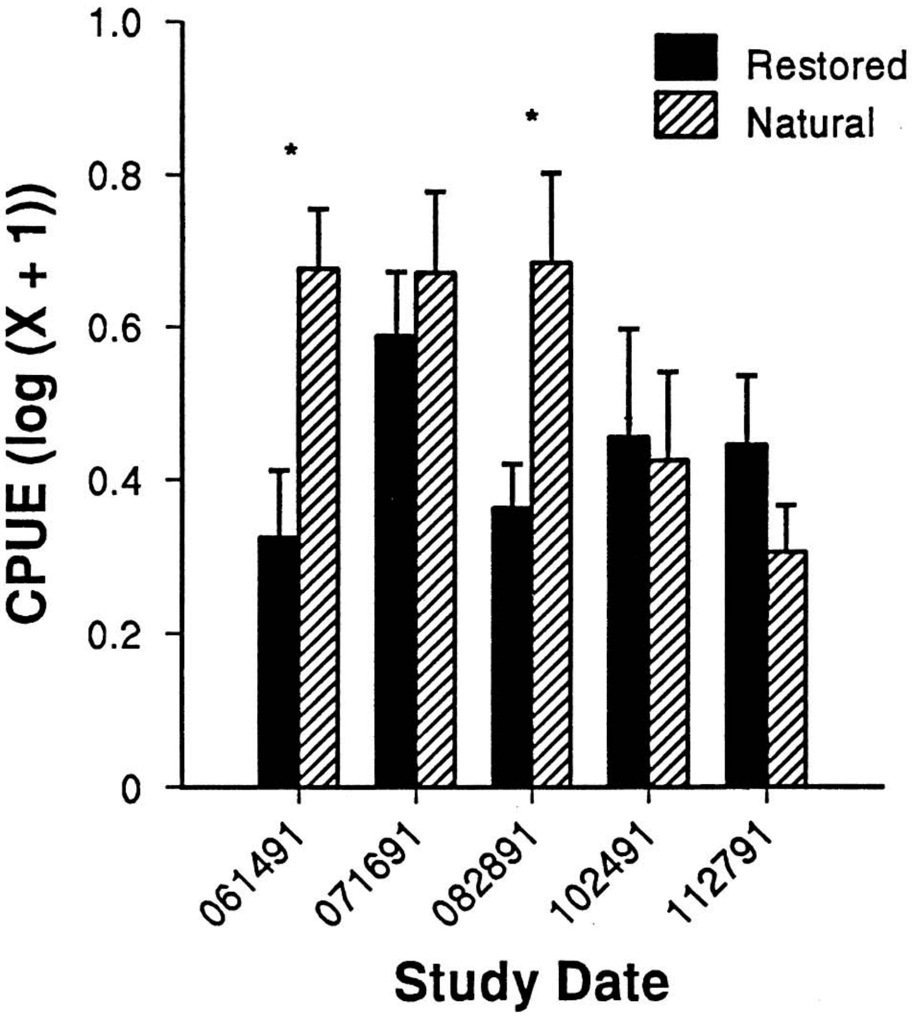

Figure 7. The catch per unit effort (CPUE) for fiddler crabs for the restored and natural sites. Asterisks denote a significant difference in catch in each site for a study date.

The size of individual fiddler crabs inhabiting the natural and restored sites may be indicative of a more subtle difference in habitat suitability. The mean carapace width of captured fiddler crabs remained significantly less at the restored site through August (ANOVA, $p \leq 0.05$, Figure 8). By October, the mean carapace width of the two populations were not significantly different (ANOVA, $p \leq 0.05$). However, this latter change appears to be due to a reduction in the size of the crabs captured at the natural site rather than an increase in the size of the crabs captured at the restored site.

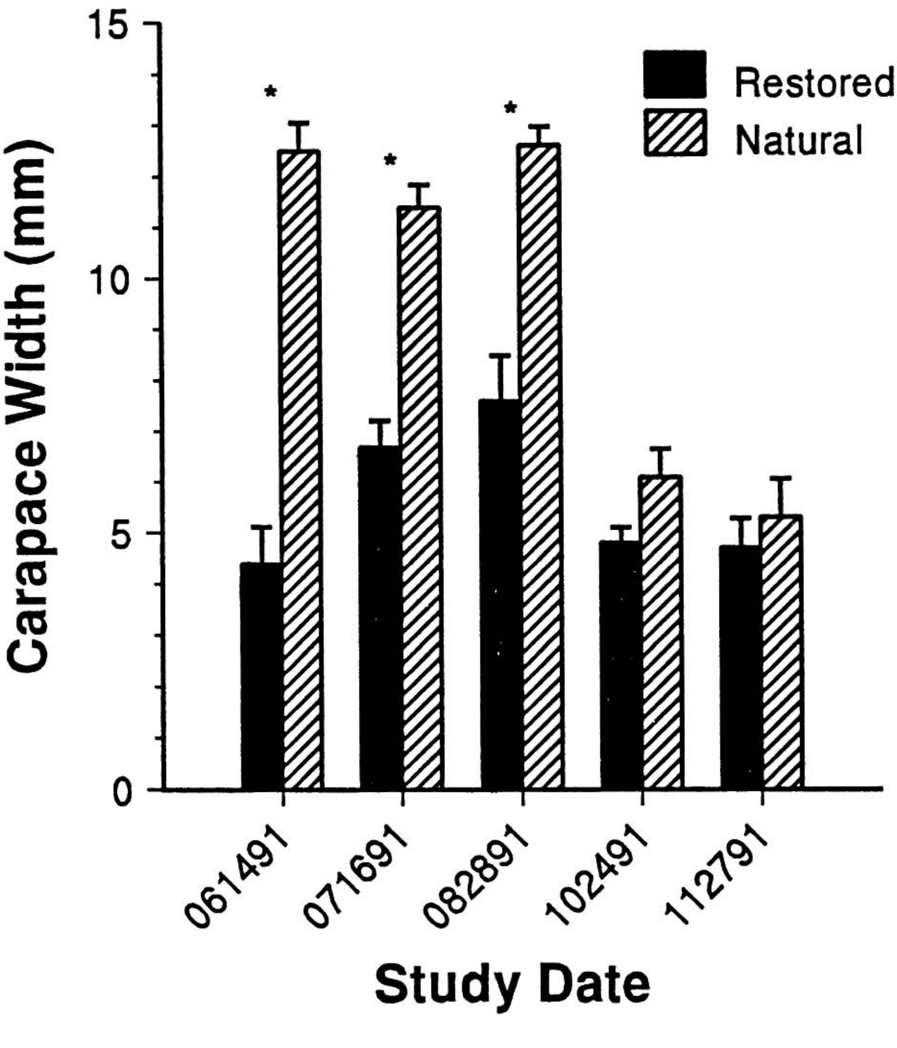

Figure 8. The mean carapace width (mm) for fiddler crabs captured at the restored and natural sites. Asterisks denote a significant difference in mean size and crabs caught at each site during a study date.

The pulmonate snail, Melampus coffeus, was a late recruit to the restored site not appearing until September. During October and November, the mean shell length of M. coffeus from the restored site was significantly less (ANOVA, $p \leq 0.05$) than that of snails collected from the natural site (Figure 9).

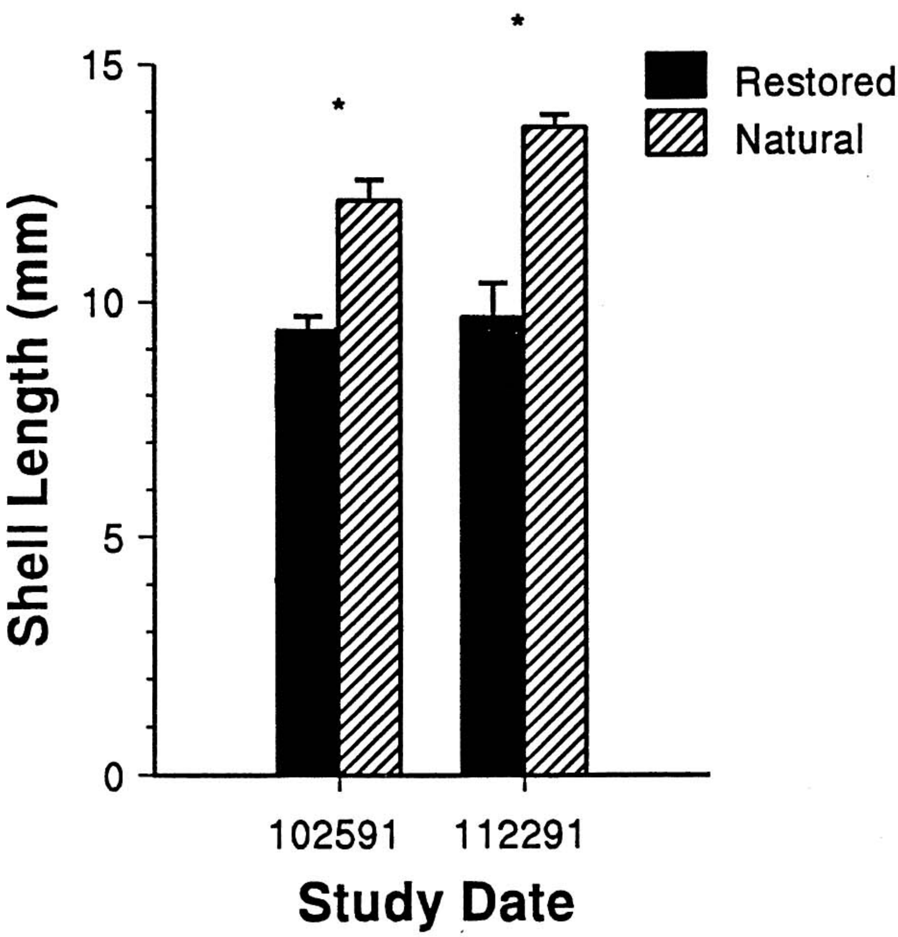

Figure 9. The mean shell length (mm) of Melampus snails collected from the restored and natural sites. Asterisks denote a significant difference in the size of snails at each site for a study date.

Discussion

After one year, the physicochemical conditions at the restored site and natural site remain different. Of potential physiological significance is the low organic content and high surface temperatures of the restored site. Both of these conditions may be ameliorated with canopy closure through subsequent shading and litter accumulation. Long-term studies are planned to record changes in species composition as the restored site matures. The sediments of the restored site are chiefly sand and shell hash, whereas the sediments of the natural site are predominately silts and clay. These differences in substrates may adversely affect the burrowing activity of fauna at the restored site. Future studies will examine faunal recruitment to a second, adjacent, newly restored habitat that has a sediment composition, relative to organic content, similar to the natural habitat (Figure 2, Phase II).

The effects of the site-specific difference in physicochemical conditions on the recruitment of resident macroinvertebrates and fishes is apparent. At least eight species normally found in a natural mangrove site have yet to establish stable populations at the restored site. These species are the snail, Melampus coffeus, the marsh clam, Pseudocyrena maritima, the scorched mussel, (Hormomya exusta, the fish, Rivulus marmoratus and the crabs Uca thayeri, Eurytium limosum, Aratus pisonii, and Sesarma caracaoense.

Due to their limited mobility, mollusks depend mostly on larval transport to disperse long distances. Since few juvenile or adult mollusks are observed at the restored site the constraints to recolonization by these species may occur during larval recruitment. Recolonization of the restored site by crustaceans and teleosts may occur either by larval recruitment or adult migration. Studies are being initiated to address the suitability of the restored habitats to adults to determine if the restored habitat is capable of sustaining an adult population.

After seven months, the diversity of the restored habitat was not different from the adjacent natural mangrove forest. However, as noted above, the species composition of the two sites remain different. This result clearly demonstrates the limits of using diversity measurements alone to estimate the success of habitat restoration. A more conclusive technique may be to determine the proportion of the individuals at a restored site that are permanent residents of a natural mangrove habitat. Many of the species captured at the restored habitat during the first year were subtidal transients such as blue crabs, Callinectes sapidus, Gulf killifish, Fundulus grandis, and mosquito fish, Gambusia affinis. It is uncertain whether this result reflects actual site-specific habitat utilization patterns, or that the lack of structure at the restored site which enhanced the cages' efficiencies at that site. Future plans include studies in which cages will be placed in areas with various levels of structural complexity to address this question.

An alternative approach to using species abundance estimates to gauge the success of habitat restoration is to monitor the growth and survival of individual "diagnostic" species. Of the species collected, fiddler crabs appeared to be the only successful permanent faunal residents of the restored site. Crab population abundances of the restored site reached natural site abundances by the seventh month after planting. Lack of interspecific competition, or perhaps reduced cannibalism of settling magalopae, may have aided this recruitment. However, the stability of the crab populations at the restored site was less than adjacent natural populations. In addition, mean carapace width of the fiddler crabs at the restored site was less than that of crabs at the natural site during most of the first year. Only during the winter months, when the mean carapace widths of the fiddler crabs captured at the natural site were reduced, were no differences found in the site-specific size of the fiddler crabs. Studies are continuing to monitor the carapace size of fiddler crabs at each site. Further longer-term study is needed to fully evaluate the success of the restored site's crab population.

The pulmonate snail, Melampus coffeus, also appears to be a promising candidate for further monitoring. The snails are abundant in the adjacent natural mangrove forest, but rarely found at the restored site. Differential predation rates, food availability, and physicochemical conditions are likely to be responsible for this observation. After one year, the mean shell length of Melampus at the restored site is significantly less than that of those inhabiting the natural site. Initial studies also indicate that the survival of Melampus that are protected from predators is also less at the restored site. Future studies are planned to continue monitoring the site-specific growth rates and survival for Melampus at these two sites.

In summary, after one year, the restored habitat is not supporting a community similar to a natural mangrove forest. However, recruitment of some resident fauna such as fiddler crabs has occurred. Monitoring of species' similarity and individual size distributions were found to be useful bioindicators of habitat convergence. Diversity and relative abundance of fiddler crabs were less useful indicators of successful habitat restoration. Future studies will continue to monitor species composition with more attention being focused on site-specific differences in survival and growth of species which are natural residents of a mangrove forest such as Melampus snails.

Acknowledgements

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