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LOCAL MANGROVE PLANTING IN THE PHILIPPINES: ARE FISHERFOLK AND FISHPOND OWNERS EFFECTIVE RESTORATIONISTS?*

Bradley B. Walters**
Human Ecology Department and
Graduate Program in Ecology & Evolution
Cook College, Rutgers University
New Brunswick, NJ 08901-8520
bbw@rci.rutgers.edu

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** Current address: Department of Geography, Mount Allison University, 144 Main St., Sackville, N.B. Canada. E4L 1A7.

ABSTRACT

Local fisherfolk and fishpond owners have been practicing "restoration" of mangrove forests in some parts of the Philippines for decades, well before governments and NGO's began to promote the activity as a conservation tool. This paper examines ecological characteristics of these mangrove plantations and compares them to natural mangroves in the same areas. Mangrove planters were interviewed and plantation and natural mangrove forests were surveyed to measure forest structure, composition and regeneration. Compared to natural forests, mangrove plantations were characterized by high densities of small stems, shorter and narrower canopies, and fewer species. For both economic and ecological reasons, the vast majority of people dispersed and planted only *Rhizophora mucronata/stylosa* and, furthermore, they often thinned other species out of planted areas. There was remarkably little subsequent recruitment of other, non-planted mangrove species into plantations up to 50 and 60 years of age. This pattern held across a diversity of sites, including plantations that had not been selectively cut or weeded. Important ecological and economic benefits result from local mangrove planting, but "catalyzing diverse forest regeneration" – at least in the short to medium term – is not one of them. The lesson: if you want to restore diverse mangrove forests, you have to plant diverse mangrove forests.

Key Words: mangrove restoration, tree planting, human ecology, recruitment limitation, Philippines.

INTRODUCTION

Vast tracts of mangrove forest throughout the tropics have been cleared for brackish water aquaculture ponds, cut for firewood and timber, and cleared for residential and urban development (e.g., Bailey 1988; Hamilton et al. 1989; Dewalt et al. 1996). The Philippines, in particular, has lost 70% of its original mangrove forests, mostly due to fish pond development (Baconguis et al. 1990; Primavera 1995). Cutting of mangroves for fuel wood and construction materials by coastal residents is also widespread in the Philippines and contributes in many areas to the continued degradation of remaining forests (Eusebio et al. 1986). However, the assumption that people are *always* destroyers of mangroves has been challenged by the discovery of cases where local people are actively planting and managing mangrove and nipa forests entirely on their own initiative (e.g., Yao & Nanagas 1984; Cabahug et al. 1986; Fong 1992; Weinstock 1994; Walters 1995, 1997). The reasons for planting are varied and include the desire to provide a ready supply of construction materials and storm protection for seaside homes (Walters 1997). In this paper, I compare the structural and compositional characteristics of a sample of these local mangrove plantations with natural mangrove forests in the same areas.

Mangrove reforestation is now being promoted enthusiastically by governments, non-government organizations and aid agencies in South and Southeast Asia (Thorhaug 1990; Sukardjo & Yamada 1992; Saenger & Siddiqi 1993; Kaly & Jones 1998) and parts of the Caribbean and Latin America (e.g., Lewis 1990; Thorhaug 1990). Reforestation efforts have met with mixed success in terms of basic estimates of planted tree survival (e.g., Lewis 1990; Saenger & Siddiqi 1993; Calumpong 1994; Pomeroy et al. 1996; Primavera and Agbayani 1996; Erftemeijer & Lewis 1999). However, the degree to which mangrove plantations actually facilitate the restoration of diverse and structurally complex forests akin to their natural predecessors has been little examined, although there is considerable literature on this “catalytic” effect in upland forest plantations (e.g., Lugo 1992; Parrotta & Turnbull 1997).

STUDY AREAS

The field work for this study was conducted in the Philippines between March and December, 1997 in North & South Bais Bay, Negros Oriental (9N/123E) and on Banacon Island, Bohol (10N/124E). The main study area, Bais Bay, is located on the eastern side of Negros Island and fronts a 3km wide alluvial plain which rises into steep hills and mountains (Walters 1995; Calumpong and Luchavez 1997). Mean temperatures in Bais vary from 25 C and 30 C through the year. Annual rainfall along the coast is around 1500mm and mostly falls during a distinct rainy season from July to December. The Bay occupies an area of about 5400 ha and is divided into North and South by Daco Island and a constructed causeway that connects Daco to the mainland (Calumpong & Luchavez, 1997). Three rivers empty into North Bais Bay -- Tamogong, Panambalon and Alangilanan -- while only the Panamangan River empties into South Bais Bay.

Three-quarters of the nearly 1000ha of original mangroves in Bais Bay were cleared and developed into fish ponds between 1930 and 1980, virtually all of which are still in operation (Walters 1995, 2000). Today, much of the perimeter of Bais Bay is fringed by narrow bands of mangrove forest, some natural, and others the result of deliberate planting. Mangrove stands, ranging from about 3ha to 30 ha in size, are also found at the mouths of each river, and a particularly large stand of forest, called *Talabong*, extends as a peninsula across the seaward front of South Bais Bay. The 260 ha *Talabong* was officially designated a marine and wildlife sanctuary by the City of Bais in 1986.

Fifteen different villages ring North and South Bais Bay, ranging in size from a few dozen to nearly one thousand households. A majority of these coastal households derive a substantial portion of their income from fishing, aquaculture, and related activities (Luchavez & Abrenica 1997). Mangrove planting appears to have begun in Bais Bay around 1910, although it was not practiced widely in the area until the 1950s and afterward. Early planting was done to provide a ready source of construction materials, especially for fish traps (called *bunsod)*. As coastal populations grew and mangroves were cleared for fish ponds and housing, increasing numbers of coastal residents also planted to protect their homes and fish pond dykes from storm damage. Mangrove planting today occurs in almost every village in North and South Bais Bay, but the distribution of plantations is extremely patchy because environmental and social factors -- notably waves, oyster infestations, fishing and tenure conflicts -- preclude the successful establishment of plantations at many sites (Walters, 2000). Most of the plantations in Bais fringe shorelines and the seaward sides of fishponds, or in narrow canals between them. There are several hundred plantations in Bais that vary in size from about $10m^2$ - 3ha.

Banacon is a small, remote island, located 5km off the northwest corner of Bohol Province and about 30km east of Cebu City (Cabahug et al. 1986). Over 95% of Banacon's roughly 500ha size is mangrove forest. There are currently 550 households crowded onto a 15ha dryland area on the eastern tip of the island. Virtually all of these households derive their principal income from fishing or related activities (e.g., fish processing, marketing, etc.). Many also supplement their income by cutting and selling wood from mangrove plantations.

Mangrove planting began on Banacon in 1957/8 and has continued steadily ever since. Although people on Banacon recognize that mangroves are important for sustaining local fisheries, most planting is done for construction wood and as a contingency investment (i.e., trees are sold if and when extra cash is needed). Most of the planting has been done in natural mangrove areas that were severely degraded by cutting under a commercial firewood lease that was canceled in the late 1970s. The mangroves of Banacon received national Wilderness Area designation in 1981 (DENR 1990), but this has not effectively precluded local people from continuing to plant and cut mangroves there. I estimate there are today 500 or more individual plantation parcels on Banacon Island, ranging in size from about 100 m^2 to 4ha. The plantations are tightly clustered and form a large, contiguous mosaic of different-aged stands, separated only by the occasional narrow walking path and several wide (10-15m) boat paths.

RESEARCH METHODS

I employed the quadrat/census plot method to assess forest characteristics (Cintron & Schaeffer-Novelli 1984; Peters 1996). Each census plot was 10m x 10m, with corners and boundaries marked using a 50m measuring tape. A relatively small plot size was used because trees in most of the stands surveyed were typically small and/or densely crowded as a result of their being young or having been highly disturbed from cutting. I sampled widely in the respective study areas in an attempt to capture some of the variation due to site-specific differences in ecological conditions and human influences. Slightly greater sampling effort was specifically devoted to plantations to ensure representation from a wide range of stand ages.

In summary, I surveyed 52 plots, including 33 in plantations and 19 in natural forests. For plantations, I surveyed one plot in 5 different sites on Banacon Island, and 28 plots in 24 different plantations across 8 geographically distinct sites in North and South Bais Bay. Plantations from 5 to 60 years of age were surveyed (mean = 30.3 years). For natural forests, 13 plots were surveyed across 4 geographically distinct sites in North and South Bais Bay, and 6 plots were surveyed in a large mangrove in Bindoy, 20km north of Bais Bay. The Bindoy site, in particular, was selected because it was the only natural mangrove forest in the region that was not substantially disturbed from cutting and I thought it important to include samples from both cut and uncut natural forests to compare with cut and uncut plantations.

To classify forest canopy structure, I walked transects back and forth over the plot, observing the canopy vertically above me every meter so that 100 observations were made across the area of the plot (i.e. every square meter). These observations were subsequently summarized and converted directly to plot percentages. Canopy structure was classified as either “gap”, “expanded gap”, or “understory” following the criteria employed by Runkle (1982) and Lertzman et al. (1996).

I numbered, mapped and measured every tree (>1.0m tall) and seedling (<1.0m) in each of the 52 forest plots, for a total of 5,926 trees and 1,999 seedlings. Each tree was identified by species (based on Calumpong & Menez 1997) and recorded as either “canopy”, “gap-filler”, “gap”, “expanded gap”, or “understory”(after Lertzman et al. 1996). Dead stems >1.0m tall were classified as “snags”. I measured the diameter at breast height (dbh) of each tree stem following the guidelines of Cintron and Schaeffer-Novelli (1984). I measured the height of the tree and of the lowest live branch using an 8m-tall bamboo pole that was marked off at meter intervals.

I interviewed 215 coastal residents in the study areas, 158 of whom had actually planted mangroves. In the interviews, people were asked about the history of mangrove changes, their motivations to plant mangroves, and their experience planting (e.g., species selectivity, etc.).

Data were analyzed statistically using SPSS (version 9.0). Plot data were log transformed for statistical analysis when they did not meet the test for homogeneity of variances (Zar 1984).

RESULTS

Forest Structure

Most of the planted and natural mangrove forests measured in this study were dense stands of small diameter trees, but plantation forests differed dramatically from natural forests in most of the structural attributes measured (Table 1). The mean density of live stems in plantation forest plots was more than three times the density in natural forests and the density of canopy trees, alone, was almost four times as high. The density of snags was also twice as high in plantations compared to natural forests. By contrast, the mean diameter at breast height and tree height was significantly lower in plantations. Most stems in plantation forests were 1 - 4cm dbh, whereas stems in natural forests were more broadly distributed, with relatively more in intermediate (5 - 10cm) and large (>10cm) size classes (Fig. 1). Basal area was also found to be higher in natural forest plots, but this difference was not statistically significant (Table 1).

Plantations did not differ significantly from natural forests in the abundance of canopy in gap, expanded gap or closed canopy (Table 1). The mean height of the lowest live tree branch was significantly higher in plantations than in natural forests (Table 1). Given that mean canopy tree height in plantations was also significantly lower (Table 1), this indicates that the vertical length of the canopy layer -- i.e., the mean canopy tree height (top of the tree) less the mean height of the lowest live tree branch -- was thinner in plantations than in natural forests (5.1m vs. 7.7m). Seedling densities were slightly, but not significantly lower in plantation plots (Table 1).

Structural Comparisons Between Plantations of Different Ages

Many of the structural characteristics measured and discussed above varied with plantation age. The density of all live stems and canopy trees decreased significantly with age ($R=0.521$, $p<0.005$, $F=11.56$, $df=32$, and $R=0.580$, $p<0.001$, $F=15.69$, $df= 32$, respectively). The most dense plot was 15 years old and had 456 live stems (224 canopy stems). By contrast, the oldest plantation (60 years) had only 35 live and 9 canopy trees. The mean dbh increased significantly with age for all live stems ($R=0.565$, $p<0.005$, $F=14.51$, $df=32$; $Y=2.01+0.088X$) and for canopy trees only ($R=0.823$, $p<0.001$, $F=64.97$, $df=32$; $Y=1.63+0.20X$). The mean canopy tree height also increased significantly with plantation age ($R=0.656$, $p<0.001$, $F=23.48$, $df=32$). The relationship suggests that vertical growth is rapid in the first 5 years or so (0.5m - 1.0m/year), but declines thereafter to a mean of about 0.1m/year ($Y=4.64+0.099X$). Neither basal area nor the density of snags varied significantly with age.

Species Composition

Combining surveys done in this study with those done by Calumpong (1992), a total of 21 different mangrove species have been recorded in natural forests across three sites in Bais (Table 2). By contrast, only eight species were observed in plantations in Bais Bay. Plantations are strongly dominated by *R. mucronata/stylosa*, which composes 89.2% of all individuals measured in plantation forest plots (Table 3). Numerically, the only other common species is *A. marina*, which represents 9.1% of individuals. Furthermore, there was no correlation between species richness and plantation age and little compositional variation between structural layers (canopy vs. gap vs. understory), although the relative abundance of *R. mucronata* increased and *A. marina* declined slightly as one moved from the understory to the canopy layer (Table 4).

Plot data were also examined to determine how often an individual of one species was present in a plot in the absence of a canopy member of that same species in that same plot. This analysis was intended to test for further evidence of invasions or colonization into plots of species that were not already established in those plots. It revealed that the incidence of such apparent "invasions" is uncommon, occurring in only 8 of 33 plantation plots (no particular relationship to age or disturbance) and including only 0.8% of all live individuals (39 of 4,769).

According to interviews of mangrove planters (Table 5), virtually everyone (98.7% of 158) has planted *R. mucronata*, whereas few have planted *R. apiculata* (5.7%), *A. marina* (4.4%), *N. fruticans* (4.4%), *Sonneratia* spp. (1.9%), *B. cylindrica* (1.3%), and *C. decandra* (1.3%).

DISCUSSION

Forest Structure

Mangrove plantations in this study were characterized by higher densities of small trees as compared to natural mangrove forests (Table 1). The very high mean density of trees in plantation plots (13,060 live and 5,520 canopy trees per ha) reflects several aspects of the management of these plantations. First, planters typically use only 20 - 60cm spacing when they plant. Second, many deliberately manage their plantations at high densities to produce small, straight stems which are typically cut at 2.5 - 5.0cm dbh for use in fish trap construction (personal observation). Natural forests are also cut heavily, but more so for firewood and thus not as selectively in terms of size classes. The higher density of snags in plantations also reflects the high stocking densities and resultant natural thinning mortality that is common, especially in those plantations that are not selectively cut.

Mangrove plantations also had a thinner canopy layer than natural forests, even if they did not differ significantly in terms of relative canopy openness (% in gaps). The relative absence of lower branches in plantations may reflect the high density of trees since crowded conditions discourage lateral growth and branches lower on the stem would be shaded out early and die (Shepherd 1986). As well, there was significantly more branch cutting in plantations than in natural forests suggesting that the difference may be a pruning effect (personal observation).

Density and basal area measures from this study are summarized in Table 6, where they are compared with published measures from natural and plantation mangroves and upland plantation forests from other regions. Mangrove plantations typically have relatively high tree densities (3270 - 18,000 per ha) and low basal areas (12.7 - 21.8 m^2/ha) compared to natural mangrove forests (1890 - 4210 per ha and 19.4 - 33.2 m^2/ha, respectively; Table 6). The seedling densities found in plantation and natural forests in this study are low, however, compared with several other studies in the Philippines. For example, de Leon et al. (1991) estimated 30,000 seedlings per ha (300 per 100m2) in the Talabong forest in Bais, and Eusebio et al. (1986) estimated 63,840 per ha in a mature, second-growth forest in Zamboanga del Sur. These are an order of magnitude larger than was found in this study.

Tree densities are typically lower and basal areas higher on upland plantations than they are in both natural and plantation mangroves (Table 6). These may, in part, reflect differences in cutting intensity since cutting of mangroves stimulates stem coppicing and reduces basal area significantly and most of the mangroves described in these studies were subject to substantial cutting pressures (personal observation), whereas most of the upland plantations cited were not.

Biomass accumulation also varies depending on the tree species involved and the environmental conditions, especially soil fertility and climate (Lugo et al. 1988). *Rhizophora* spp. are not the fastest-growing of the mangrove trees (Siddiqi & Khan 1990; Devoe & Cole 1998). Mangroves are also subject to very different environmental stressors which influence growth and biomass accumulation and so limit direct comparison with upland sites.

Plantation Age Differences

The mean dbh growth increment for planted *R. mucronata* in this study (0.2 cm/year) is slower than that recorded in natural mangrove forests (0.19 - 0.48cm/year: Devoe & Cole, 1998) or young plantations elsewhere in the Philippines (Brown & Fischer, 1918) and Java (Sukardjo & Yamada, 1992). The slower growth is not surprising in this study given, first, that many plantations are managed at high, crowding densities and, second, that taller trees are often selectively removed through harvesting.

A structural measure that did not show a clear relationship with age, as expected, was basal area. The data suggest, in fact, that the net increase in basal area is initially rapid, but quickly diminishes. In short, 5- and 10-year-old plantations were found to have very low basal area, but variation was high for sites 15 years and older and the two planted sites with the highest recorded basal area were only 15 and 30 years-old (40.0 and 42.0 m^2/ha, respectively).

Species Composition

Mangrove planting is highly species-specific for both economic and ecological reasons (Vayda & Walters 1999). *Rhizophora* is the preferred wood for use in the construction of fish traps (called *bunsod*), homes and fences. *Bunsod,* in particular, are abundant in both Bais and Banacon and informal markets exist for the buying and selling of *bunsod* posts. *Rhizophora* is also particularly easy to plant: propagules are abundant and easy to collect from mother trees when ripe; their durability enables them to withstand the physical stresses associated with transport; and no pre-treatment is required to ensure germination (one simply inserts the propagule into mud to a depth of 1/4 - 1/3 its length and, if environmental conditions are suitable, it will likely grow). By contrast, seeds of other common mangrove species, including *Avicennia* spp. and *Sonneratia* spp., require fairly specific conditions or treatments to germinate and are easily damaged during collection and transport (Siddiqi et al. 1993; DENR 1994).

Forest plantations have attracted much attention in recent years from ecologists and policy makers who believe plantations can be used to foster, or "catalyze" the recovery of natural forests and biodiversity on degraded sites by attracting seed-dispersing wildlife and making micro-environmental conditions more favorable for natural tree germination and growth (Lugo 1997; Parrotta & Turnbull 1997; Parrotta et al. 1997a, 1997b). In fact, research from a variety of upland tropical and sub-tropical areas has shown that sites planted with one or a few tree species are subsequently rapidly invaded by many natural forest species and so show increasing species richness with age (Lugo 1992; Guariguata et al. 1995; Fang & Peng 1997; Geldenhuys 1997; Keenan et al. 1997; Loumeto & Huttel 1997; Tucker & Murphy 1997).

Given the abundant evidence showing plantations having a strong catalytic effect on species invasions of upland sites (but see Murcia 1997), it was surprising to find in this study so little evidence of similar post-planting invasion into mangrove plantations. Granted, species richness in mangroves is so much less than in tropical upland forests that one would not expect to find anything like the effects observed there. However, this is not just a matter of degree: 50 mangrove species, representing 26 families, are found in the Philippines (Calumpong 1994), and natural mangrove stands in the area commonly have 10 - 20 or more species (Table 2). Yet, evidence from this study suggests that invasions into plantations up to 50 or 60 years of age are so infrequent as to be almost negligible. In fact, the presence of species other than *Rhizophora* in many plantations reflects not post-planting invasion at all, but rather the common practice of planting in and around existing *A. marina* or *Sonneratia* trees (personal observation).

But why is there so little post-planting invasion? For one, many planters weed and selectively remove non-desirable species, which often means everything but the *Rhizophora* they have planted (personal observation). But, the significance of weeding should not be over-estimated as a factor preventing invasions because many of the plantations were not being systematically weeded -- including several of the oldest ones -- yet these also showed negligible evidence of invasions. In fact, weeding tends to be employed most vigorously in cases where non-desirable species are already present on the site at the time of planting. As such, weeding does not typically involve the elimination of newly invading individuals, but rather the gradual elimination of existing individuals and/or the ongoing removal of seedlings that are sprouting from the stumps, roots and seeds which originate from adult trees already on the site.

A second possible explanation for the absence of invasions in mangrove plantations as compared to upland forests concerns the differences in modes of dispersal between the two. In short, invasions of most species into upland plantations are typically attributed to animal dispersal and, in cases, to growth from residual seed banks in the soil (Parrotta et al. 1997a, 1997b). By contrast, dispersal of mangrove propagules is entirely by water or direct seed fall (Rabinowitz 1978; Van Speybroeck 1992). To my knowledge, with the exception of humans, animals do not disperse mangrove seeds or propagules and neither will remain dormant for long periods in water or soil.

Why water dispersal is not sufficient to cause the rapid invasion of plantations is open to question. Measures of topographic height indicate that plantations facilitate sediment accretion (Walters, 2000; see also Melana 1995; Saenger & Siddiqi 1993). The resulting higher local elevations and dense prop roots typical of *Rhizophora* plantations likely create significant structural barriers to the movement of propagules into these stands.

But even if dispersal into the stands occurs, the likelihood of successful germination and survival from seed is probably low because mangroves are generally shade-intolerant (Snedaker & Lahmann 1988; Smith 1992) and most mangrove plantations in this study – especially those not being cut – were characterized by high stem densities and apparently low understory light levels (personal observation). For plantations that were being cut, the resulting formation of gaps could conceivably foster seedling regeneration, including non-planted species. For example, studies of mangroves elsewhere have found higher seedling recruitment and growth rates in forest gaps compared to neighboring understory (e.g., Smith 1992; Ellison & Farnsworth 1993; Ewel et al. 1998). That such gap-mediated colonization was not occurring much in the plantations in this study can be explained by two factors. First, since planters typically select relatively small trees to cut, the resulting gaps are typically small and presumably short-lived (i.e., rapidly in-filled) and so less significant for understory recruitment. Second, plantations that are most intensively cut are also those most likely to be actively weeded by planters. In short, most successful regeneration in cut and uncut plantations results from either deliberate re-planting or from re-sprouting (root suckers and stem coppice) of already existing adult trees that are able to partially overcome light limitations by drawing upon photosynthetic reserves.

These findings suggest that to an important degree mangrove forests, at least those heavily disturbed by cutting and planting, may be strongly recruitment-limited in the sense that species presence at a given site is more about timing, i.e., getting to that site first when growing conditions are good, than it is about having some kind of inherent competitive advantage for growing at that site (e.g., Hubbell et al. 1999). This is further supported by my observations that natural, colonizing mangroves at the mouth of the Tamogong River in Bais were initially, and remain dominated almost exclusively by, *Avicennia marina* – the seeds of which were effectively dispersed and buried under silt during river floods, -- even though *R. mucronata*, *R. apiculata*, *Nipa fruticans*, *Ceriops tagal*, and *Bruguiera cylindrica* were all subsequently planted in the area and thrive (personal observation).

If recruitment limitation is important in structuring mangrove communities in general, then the role of humans in dispersal and planting of mangroves is extremely important. More specifically, these findings raise important questions about the supposed ease and value of mangrove reforestation as a tool for ecological restoration (e.g., Thorhaug 1990; Kaly and Jones 1998). Governments and NGOs in the Philippines are planting *Rhizophora* almost exclusively for the same reasons local people do: it is easy to collect, disperse and plant, and it offers many economic benefits. But, the data presented here -- based on surveys of 30 plantations across a dozen sites in 2 different regions of the country -- show remarkably little evidence of post-planting site colonization. The general lesson from this study for restoration is that if you want diverse mangrove forests, you have to plant diverse mangrove forests.

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LITERATURE CITED

Aksornkoae, S., C. Khemnark, and W. H. H. Mellink. 1992. Mangrove for charcoal. Field Document No. 30, Regional Wood Energy Development Program in Asia, Food and Agricultural Organization of the United Nations, Bangkok.

Amarasinghe, M. D., and S. Balasubramaniam. 1992. Structural properties of two types of mangrove stands on the northwestern coast of Sri Lanka. Hydrobiologia 247:17-27.

Atmadja, W.S., and S. Soerojo. 1991. Structure and potential net primary production of mangrove forests at Grjagan and Ujong Kulon, Indonesia. Pages 441-451 in A. C. Alcala, editor. Proceedings of the regional symposium on living resources in coastal areas. Marine Science Institute, University of the Philippines, Quezon City.

Baconguis, S. R., D. M. Cabahug, and S. N. Alonzo-Pasicolon. 1990. Identification and inventory of Philippine forested-wetland resource. Forest Ecology and Management 33/34:21-44.

Bailey, C. 1988. The social consequences of tropical shrimp mariculture development. Ocean and Shoreline Management 11:31-44.

Brown, W. H., and A. F. Fischer. 1918. Philippine mangrove swamps. Bulletin No. 17, Bureau of Forestry, Department of Agriculture and Natural Resources, Manila.

Cabahug, D. M. Jr., F. M. Ambi, S. O. Nisperos, N. C. Truzan Jr. 1986. Impact of community-based mangrove forestation to mangrove dependent families and to nearby coastal areas in Central Visayas: a case example. Pages 441-466 in National Mangrove Committee, editor. Mangroves of Asia and the Pacific: status and management. Natural Resources Management

Center, Ministry of Natural Resources, Quezon City, Philippines.

Calumpong, H. P. 1992. Vegetation of the Talabong Mangrove Forest Reserve: suggestions for rehabilitation. Silliman Journal 36:123-128.

Calumpong, H. P. 1994. Status of mangrove resources in the Philippines. Pages 215-229 in C. Wilkinson, S. Sudara, and C. L. Ming, editors. Proceedings of the Third ASEAN-Australia Symposium on Living Coastal Resources (Bangkok, Thailand, May 16-20, 1994). Volume 1. Australian Agency for International Development (AUSAID) and Australian Institute of Marine Science, Townsville, Australia.

Calumpong, H. P., and J. A. Luchavez. 1997. Profile of the Bais Bay Basin. Silliman Journal 37(3/4):1-27.

Calumpong, H. P., and E. G. Menez. 1997. Field Guide to the Common Mangroves, Seagrasses and Algae of the Philippines. Bookmark, Inc., Makati City, Philippines.

Cintron, G., and Y. Schaeffer-Novelli. 1984. Methods for studying mangrove structure. Pages 91-113 in S. C. Snedaker and J. G. Snedaker, editors. The mangrove ecosystem: research methods. UNESCO, Paris.

Cintron, G., A. E. Lugo, D. J. Pool, and G. Morris. 1978. Mangroves of arid environments in Puerto Rico and adjacent islands. Biotropica 10:110-121.

De Leon, R. O. D., A. C. Alcala, and R. J. Raymundo. 1991. Potential levels of primary production and community structure of the Talabong Mangrove Forest, Negros Oriental, Philippines. Pages 453-458 in A. C. Alcala, editor. Proceedings of the regional symposium on living resources in coastal areas. Marine Science Institute, University of the Philippines, Quezon

City.

Department of Environment and Natural Resources (DENR). 1990. Compilation of mangrove regulations. Coastal Resources Management Committee, Department of Environment and Natural Resources, Quezon City, Philippines.

Department of Environment and Natural Resources (DENR). 1994. Mangrove regeneration and management. Mangrove Technical Review Committee, Fisheries Sector Program, Department of Environment and Natural Resources, Quezon City, Philippines.

Devoe, N. N., and T. G. Cole. 1998. Growth and yield in mangrove forests of the Federated States of Micronesia. Forest Ecology and Management 103:33-48.

Dewalt, B. R., P. Vergne, and M. Hardin. 1996. Shrimp aquaculture development and the environment: people, mangroves and fisheries on the Gulf of Fonseca, Honduras. World Development 24:1193-1208.

Ellison, A. M., and E. J. Farnsworth. 1993. Seedling survivorship, growth, and response to disturbance in Belizean mangal. American Journal of Botany 80:1137-1145.

Erftemeijer, L. A., and R. R. Lewis III. 1999. Planting mangroves on intertidal mudflats: habitat restoration or habitat conversion? Paper presented at the ECOTONE-VIII Seminar, “Enhancing Coastal Ecosystem Restoration for the 21st Century”, Ranong & Phuket, Thailand, May 23-28.

Eusebio, M. A., F. O. Tesoro, and D. M. Cabahug. 1986. Environmental impact of timber harvesting on mangrove ecosystem in the Philippines. Pages 337-354 in National Mangrove Committee, editor. Mangroves of Asia and the Pacific: status and management. Natural

Resources Management Center, Ministry of Natural Resources, Quezon City, Philippines.

Ewel, K. C., S. Zheng, Z. Pinzon, and J. A. Bourgeois. 1998. Environmental effects of canopy gap formation in high-rainfall mangrove forests. Biotropica 30:510-518.

Fang, W., and S. L. Peng. 1997. Development of species diversity in the restoration process of establishing a tropical man-made forest ecosystem in China. Forest Ecology and Management 99:185-196.

Fong, F. W. 1992. Perspectives for sustainable resource utilization and management of nipa vegetation. Economic Botany 46:45-54.

Fromard, F., H. Puig, E. Mougin, G. Marty, J. L. Betoulle, and L. Cadamuro. 1998. Structure, above-ground biomass and dynamics of mangrove ecosystems: new data from French Guiana. Oecologia 115:39-53.

Geldenhuys, C. J. 1997. Native forest regeneration in pine and eucalyptic plantations in Northern Province, South Africa. Forest Ecology and Management 99:101-116.

Guariguata, M. R., R. Rheingans, and F. Montagnini. 1995. Early woody invasion under tree plantations in Costa Rica: implications for forest restoration. Restoration Ecology 3:252-260.

Hamilton, L. S., J. A. Dixon, and G. O. Miller. 1989. Mangrove forests: an undervalued resource of the land and of the sea. Pages 254-288 in E. M Borgese, N. Ginsburg and J. R. Morgan, editors. Ocean Yearbook 8. University of Chicago Press, Chicago.

Hubbell, S. P., R. B. Foster, S. T. O’Brien, K. E. Harms, R. Condit, B. Wechsler, S. J. Wright, and S. Loo de Lao. 1999. Light-gap disturbances, recruitment limitation, and tree diversity in a neotropical forest. Science 283:554-557.

Jimenez, J. A., A. E. Lugo, and G. Cintron. 1985. Tree mortality in mangrove forests. Biotropica 17:177-185.

Kaly, U. L., and G. P. Jones. 1998. Mangrove restoration: a potential tool for coastal management in tropical developing countries. Ambio 27:656-661.

Keenan, R., D. Lamb, O. Woldring, T. Irvine, and R. Jensen. 1997. Restoration of plant biodiversity beneath tropical tree plantations in Northern Australia. Forest Ecology and Management 99:117-132.

Lertzman, K. P., G. D. Sutherland, A. Inselberg, and S. C. Saunders. 1996. Canopy gaps and the landscape mosaic in a coastal temperate rain forest. Ecology 77:1254-1270.

Lewis, R. R. 1990. Creation and restoration of coastal plain wetlands in Florida. Pages 73-101 in J. A. Kusler and M. E. Kentula, editors. Wetland creation and restoration: the status of the science. Island Press, Washington, D.C.

Loumeto, J. J., and C. Huttel. 1997. Understory vegetation in fast-growing tree plantations on savanna soils in Congo. Forest Ecology and Management 99:65-82.

Luchavez, J. A., and B. T. Abrenica. 1997. Fisheries profile of Bais Bay, Negros Oriental. Silliman Journal 37(3/4):93-171.

Lugo, A. E. 1992. Comparison of tropical tree plantations with secondary forests of similar age. Ecological Monographs 62:1-41.

Lugo, A. E. 1997. The apparent paradox of reestablishing species richness on degraded lands with tree monocultures. Forest Ecology and Management 99:9-19.

Lugo, A. E., S. Brown, and J. Chapman. 1988. An analytical review of production rates and stemwood biomass of tropical forest plantations. Forest Ecology and Management 23:179-200.

Melana, E. E. 1995. Productivity and soil deposition/movement in the mangrove plantations of Banacon Is., Bohol, Philippines. Pages 27-32 in T. Kikuchi, editor. Rapid sea level rise and mangrove habitat. Man and the Biosphere and the Institute for Basin Ecosystem Studies, Gifu University, Japan.

Murcia, C. 1997. Evaluation of Andean alders as a catalyst for the recovery of tropical cloud forests in Columbia. Forest Ecology and Management 99:163-170.

Parrotta, J. A., and J. W. Turnbull (editors). 1997. Catalyzing native forest regeneration on degraded tropical lands. Special Issue, Forest Ecology and Management 99:1-290.

Parrotta, J. A., O. H. Knowles, and J. M. Wunderle. 1997a. Development of floristic diversity in 10-year-old restoration forests on a bauxite mined site in Amazonia. Forest Ecology and Management 99:21-42.

Parrotta, J. A., J. W. Turnbull, and N. Jones. 1997b. Catalyzing native forest regeneration on degraded tropical lands. Forest Ecology and Management 99:1-8.

Peters, C. M. 1996. Beyond nomenclature and use: a review of ecological methods for ethnobotanists. Pages 241-276 in M. N. Alexiades, editor. Selected guidelines for ethnobotanical research: a field manual. The New York Botanical Garden, Bronx, New York.

Pomeroy, R. S., R. B. Pollnac, C. D. Predo, and B. M. Katon. 1996. Impact evaluation of community-based coastal resource management projects in the Philippines. International Center for Living Aquatic Resources Management (ICLARM), Makati City, Philippines.

Primavera, J. H. 1995. Mangroves and brackish water pond culture in the Philippines. Hydrobiologia 295:303-309.

Primavera, J. H., and R. F. Agbayani. 1996. Comparative strategies in community-based mangrove rehabilitation programs in the Philippines. Paper presented at the ECOTONE V: community participation in conservation, sustainable use and rehabilitation of mangroves in Southeast Asia. Ho Chi Minh City, Vietnam, January 8-12.

Rabinowitz, D. 1978. Dispersal properties of mangrove propagules. Biotropica 10:47-57.

Runkle, J. R. 1982. Patterns of disturbance in some old-growth mesic forests of eastern North America. Ecology 63:1533-1546.

Saenger, P., and N. A. Siddiqi. 1993. Land from the sea: the mangrove afforestation program in Bangladesh. Ocean and Coastal Management 20:23-39.

Shepherd, K. R. 1986. Plantation silviculture. Martinus Nijhoff Publishers (Klewer Academic Publishers), Boston.

Siddiqi, N. A., M. R. Islam, M. A. S. Khan, and M. Shahidullah. 1993. Mangrove nurseries in Bangladesh. Mangrove Ecosystems Occasional Papers No. 1, International Society for Mangrove Ecosystems.

Siddiqi, N. A., and M. A. S. Khan. 1990. Growth performance of mangrove trees along the coastal belt of Bangladesh. Mangrove Ecosystems Occasional Papers No. 8, UNESCO/UNDP/COMAR.

Smith, T. J.III. 1992. Forest structure. Pages 101-136 in A. I. Robertson, and D. M. Alongi, editors. Tropical mangrove ecosystems. American Geophysical Union, Washington, D.C.

Snedaker, S. C., and E. J. Lahmann. 1988. Mangrove understory absence: a consequence of evolution? Journal of Tropical Ecology 4:311-314.

Sukardjo, S., and I. Yamada. 1992. Biomass and productivity of a *Rhizophora mucronata* Lamarck plantation in Tritih, Central Java, Indonesia. Forest Ecology and Management 49:195-209.

Thorhaug, A. 1990. Restoration of mangroves and seagrasses – economic benefits for fisheries and mariculture. Pages 265-281 in J. J. Berger, editor. Environmental restoration: science and strategies for restoring the earth. Island Press, Washington, D.C.

Tucker, N. I. J., and T. M. Murphy. 1997. The effects of ecological rehabilitation on vegetation recruitment: some observations from the wet tropics of north Queensland. Forest Ecology and Management 99:133-152.

Van Speybroeck, D. 1992. Regeneration strategy of mangroves along the Kenya coast: a first approach. Hydrobiologia 247:243-251.

Vayda, A. P., and B. B. Walters. 1999. Against political ecology. Human Ecology 27:167-179.

Walters, B. B. 1995. People, policies and resources: mangrove restoration and conservation in the Bais Bay Basin, Negros Oriental and wider Philippine context. Pages 151-165 in M. A. Juinio-Menez and G. F. Newkirk, editors. Philippine coastal resources under stress. Coastal Resources Research Network, Halifax, Canada and Marine Science Institute, Quezon City, Philippines.

Walters, B. B. 1997. Human ecological questions for tropical restoration: experiences from planting native upland forest and coastal mangrove trees in the Philippines. Forest Ecology and Management 99:275-290.

Walters, B. B. 2000. Event ecology in the Philippines: explaining mangrove tree cutting and planting and their environmental effects. Dissertation, Rutgers, the State University of New Jersey, New Brunswick, New Jersey.

Weinstock, J. A. 1994. *Rhizophora* mangrove agroforestry. Economic Botany 48:210-213.

Yao, C. E., and F. Nanagas. 1984. Banacon Island: biggest bakauan plantations in Central Visayas. Canopy International 10(5):1,4,5,9.

Zar, J. H. 1984. Biostatistical analysis. 2nd. Edition. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Table 1. Summary of select ecological characteristics of mangrove forest census plots, comparing mean values (and standard deviations) between natural and plantation plots.

Characteristic	Natural Forest Plots (n=19)	Plantation Forest Plots (n=33)	F - Values (df = 1,51)
No. Tree Species	3.3 (1.5)	2.0 (1.0)	12.49****
Density of Live Stems (/100m^2)	42.1 (32.8)	130.6 (99.4)	24.39****
DBH of Live Stems (cm)	9.3 (6.8)	4.7 (2.2)	14.98****
Density of Canopy Trees (/100m^2)	14.3 (11.3)	55.2 (49.9)	30.83****
DBH of Canopy Trees (cm)	17.3 (13.1)	7.6 (3.5)	26.32****
Basal Area (m^2/ha)	33.2 (28.9)	21.8 (9.1)	3.44
Snag density (/100m^2)	2.2 (4.4)	4.2 (5.5)	4.06*
Seedling Density (/100m^2)	44.6 (44.6)	35.8 (38.1)	0.57
Canopy Tree Height (m)	9.4 (2.3)	7.7 (2.2)	7.76**
Lowest Branch Height (m)	1.7 (1.0)	2.6 (1.2)	8.28**
Canopy Gap (%)	6.9 (6.1)	10.6 (8.5)	1.82
Expanded Gap (%)	43.3 (31.0)	30.5 (19.0)	0.60
Closed Canopy (%)	49.8 (34.0)	59.0 (25.8)	1.20

* $p < 0.05$
** $p < 0.01$
*** $p < 0.005$
**** $p < 0.001$

Table 2. Summary of mangrove species observed (with relative abundance) in natural forest sites and in all plantations sites combined: +++ abundant; ++ common; + rare; - not confirmed/recorded. These observations are based on the systematic plot surveys plus non-systematic, general area surveys.

	Natural Forest Sites				
Species Name	Dauis, Bais[1]	Talabong, Bais[2]	San Isidro, Bais[3]	Bindoy[4]	All Plantations
Rhizophora mucronata /stylosa	+++	+++	++	+++	+++
R. apiculata	+++	+++	+	+++	+
Bruguiera gymnorhiza	-	+	-	+++	-
B. cylindrica	-	-	-	+	+
B. sexangula	-	++	-	-	-
Ceriops decandra	++	++	++	++	+
C. tagal	+	-	+	-	-
Avicennia marina	+++	+++	+++	+++	+++
A. alba	-	++	-	-	-
A. officinalis	+	-	+	-	-
A. lanata	++	-	++	++	+
S. alba/caseolaris	+++	+++	+++	+++	++
Osbornia octodonta	++	++	-	-	-
Aegiceras corniculatum	-	+	-	-	-
Acanthus ilicifolius	-	++	-	-	-
Pemphis acidula	-	++	+	-	-
Lumnitzera racemosa	-	++	++	++	-
Excoecaria agallocha	-	-	++	++	-
Scyphiphora hydrophyllacea	+	+	+		-
Pongamia pinnata	-	++	-	+	-
Xylocarpus spp.	+	-	+	+	-
Nypa fruticans	++	-	+		+
Total Species Recorded	12	15	14	12	8

[1] The area surveyed includes about 3 ha of forest located seaward (eastward) of fish ponds north of the mouth of the Panamangan River.

[2] Based on surveys done by H.P. Calumpong and colleagues from Silliman University (Calumpong 1992).

[3] The area surveyed includes about 2 ha of remnant, natural forests found around the perimeter of the fish ponds in Barangay San Isidro, including narrow stands on the eastern (seaward) edge of the pond dykes and in the canals running along the southern (San Isidro-Talungon border) and northern (San Isidro-Tanculogan border) sides.

[4] This is based on mostly unsystematic observations of Bindoy forests on the south-central side of the area

Table 3. Species composition (% abundance) of live mangrove trees in natural and plantation forest plots.

	Percent (%) Abundance	
Species	Natural Forests (n = 799)	Plantation Forests (n = 4310)
R. mucronata	4.9	89.2
R. apiculata	8.9	0.5
A. marina	54.3	9.1
S. alba	11.9	0.2
S. caseolaris	4.9	0
C. decandra	7.6	0.3
O. octodonta	5.6	0
B. cylindrica	0	0.6
B. gymnorrhiza	0.9	0
X. granatum	0.6	0
Other Species	0.4	0.1
Total	100.0	100.0

Table 4. Species composition (% abundance) of mangrove trees by canopy status in plantation forests (sample size in brackets).

Species	Canopy Status					
	Canopy (1823)	Gap-filler (402)	Gap (240)	Expanded Gap (777)	Understory (1068)	Stump (464)
R. mucronata	93.4	97.0	91.3	86.4	80.4	85.6
R. apiculata	0.7	0	0	0.3	0.7	0.6
A. marina	5.1	2.5	8.7	11.8	16.5	11.5
S. alba	0.3	0	0	0	0.4	0.6
B. cylindrica	0.4	0.5	0	0.4	1.1	0.2
C. decandra	0	0	0	0.9	0.7	1.5
Other species	0.1	0	0	0.2	0.2	0
Total	100.0	100.0	100.0	100.0	100.0	100.0

Table 5. Summary of the number and percentage of planters in Bais who claim to have planted the different mangrove species.

Species Planted	Number of Planters (n= 158)	Percentage of Planters
R. mucronata	156	98.7
R. apiculata	9	5.7
A. marina	7	4.4
N. fruticans	7	4.4
Sonneratia spp.	3	1.9
B. cylindrica	2	1.3
C. decandra	2	1.3

Table 6. Summary of age, basal area and tree density (means and ranges) from sample plantation and natural mangrove forests and tropical upland plantations.

Dominant Tree Species	Location	Age (yrs.)	Tree Density (stems/ha)	Basal Area (m^2/ha)	Management /Status	Reference
Mangrove Plantations						
R. mucronata	Philippines	28 (5-60)	13,060 (1900-45,600)	21.8 (7.0-42.6)	selectively cut	This study
R. apiculata	Thailand	1-15	18,100 (10,300- 23,800)	-	not cut	Aksornkoae et al. 1992
R. mucronata	Indonesia	7	3270 (3200-3400)	12.7 (8.5-17.7)	not cut	Sukardjo & Yamada 1992
Natural Mangroves						
*Rh/Av/Sn**	Philippines	N/A	4210 (800-11,200)	33.2 (9.6-137.9)	selectively cut	This study
Rh/Av/Sn	Philippines	N/A	3547	19.4	selectively cut	De leon et al. 1991
Rh/Av/Sn/Br	Philippines	N/A	91-6558	-	selectively cut to mature	Calumpong 1994
Rh/Av/Sn/Br	Indonesia	N/A	2349 382-10,015	30.3 13.0-57.0	young to mature	Atmadja & Soerojo 1991
Rh/Av	Sri Lanka	N/A	1890 (450-3600)	25.4 (11.4-43.8)	?	Amarasinge & Balasubramaniam 1992
Av/Rh/La	French Guiana	N/A	2044 (780-3310)	25.0 (17.8-33.6)	mature forest	Fromard et al. 1998
Rh/La/Av	Puerto Rico	N/A	-	20.3 (13.5-27.3)	highly saline	Cintron et al. 1978
Rh/La/Av	Caribbean	N/A	3460 (473-9050)	23.3 (7.6-45.0)	various sites	Jimenez et al. 1985
Upland Plantations						
Pinus caribaea	Puerto Rico	11 (4-18)	1518** (1330-1705)	39.6 (21.3-57.8)	not cut	Lugo 1992

Swietenia macrophylla	Puerto Rico	33 (17-49)	1108** (974-1242)	33.9 (33.1-34.7)	not cut	Lugo 1992
P. caribaea	Australia	15.7 (5-31)	-	50.2 (20.2-94.9)	thinning & weeding	Keenan et al. 1997
Araucaria cunninghamii	Australia	38.5 (6-63)	-	62.3 (14.3-94.0)	thinning & weeding	Keenan et al. 1997
Eucalyptus spp.	Congo	12.8 (6-20)	721 (380-1080)	13.9 (8.5-31.5)	savanna, some cutting	Loumeto & Huttel 1997
Alnus acuminata	Columbia	30	2658	31.5	not cut	Murcia 1997
Pinus spp.	South Africa	29.8 (7-90)	479 (263-1275)	41.6 (14.7-90.7)	dry, sub-tropical	Geldenhuys 1997

* *Rh* = *Rhizophora* spp., *Av* = *Avicennia* spp., *Sn* = *Sonneratia* spp., *Br* = *Bruguiera* spp., *La* = *Laguncularia racemosa*.
** Density of "overstory" stems only.

FIGURE LEGENDS

Figure 1. Size distribution (dbh) of all live trees found in natural and plantation mangrove forest plots (values expressed per ha).