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The effects of non-timber forest product cultivation on the plant community structure and composition of a humid tropical forest in southern Mexico

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Abstract

The planting of non-timber forest products (NTFPs) in the understory of tropical forests is promoted in many parts of the world as a strategy to conserve forested lands and meet the economic needs of rural communities. While many studies of NTFP management have focused on the effects of harvesting on wild populations, the impacts of understory NTFP plantations, or enrichment plantings, on forest community composition and structure have not been investigated. We assessed the effects of understory plantations of the palm *Chamaedorea hooperiana* Hodel, on community composition and structure of an old growth tropical rain forest in the Los Tuxtlas Biosphere Reserve in southeastern Mexico. A blocked design consisting of four *C. hooperiana* plantation sites each paired with an adjacent site of unmanaged forest was used to compare the plant species richness and diversity, stem density, basal area and size class structure in plantations versus unmanaged forest. In each site, 12 10 m diameter plots were established for a total of 96 plots (4 blocks × 2 sites × 12 plots). Although the stem density, diversity, richness and basal area of large overstory trees (≥20 cm dbh) were unaffected by the establishment and management of understory palm plantations, the stem density, species richness and basal area of woody species in smaller size classes (<10 cm dbh) were significantly lower in plantation sites than in similar unmanaged forest sites. The density of naturally occurring, economically valuable palm species was unaffected by the *C. hooperiana* plantations, indicating that these understory species are spared when plantations are established and maintained. However, plantation sites showed significant reductions in the density of the midstory palm *Astrocaryum mexicanum*, the most abundant plant in unmanaged forest sites. The removal of vegetation in NTFP plantations may result in the fragmentation and/or elimination of local populations of understory and midstory plant species. In addition, changes to the composition of advanced regeneration due to the removal of canopy tree seedlings and saplings may have implications for future patterns of forest regeneration and composition. Nonetheless, NTFP cultivation offers a promising alternative to more destructive forms of land uses in the tropics and warrants further attention as a forest management strategy.

Keywords: Biosphere Reserve; *Chamaedorea hooperiana*; Community composition; Enrichment planting; Los Tuxtlas; Mexico; Non-timber forest products

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1. Introduction

For as long as people have inhabited forested regions, the management of non-timber forest products (NTFPs) for subsistence use and trade has likely been a major force shaping forest composition and structure (Alcorn, 1981; Gomez-Pompa and Kaus, 1990). Today, the ecological impacts of NTFP management may be even more significant than in the past as the economic role of many NTFPs shifts from subsistence use by rural communities to international commercial markets (e.g., Plotkin and Famolare, 1992; Hedge et al., 1996; Marshall et al., 2003). In many managed forests and buffer zones that surround protected areas such as Biosphere Reserves, forestry programs incorporate NTFP management based on the premise that NTFPs can provide local people with an economic incentive to conserve the habitats from which the products are extracted (e.g., Peters et al., 1989). In response to increasing market values and the depletion of wild populations of many NTFPs, communities have begun enhancement planting of NTFP crops in the understories of primary and secondary forests (Gunatilleke et al., 1993; Sugandhi and Sugandhi, 1995; Ratsirarson et al., 1996; Carpentier et al., 2000; Ticktin et al., 2003). Many studies have assessed effects of NTFP management on the population dynamics of wild harvested species (e.g., Peters, 1990; Salafsky et al., 1993; Murali et al., 1996; Ticktin et al., 2002; Endress et al., 2004). However, despite the expanding practice of NTFP cultivation, no research to date has examined how the management of understory plantations of native NTFPs affects the structure and composition of forest communities (Ticktin, 2004).

1.1. The management of *Chamaedorea* palms

Among the many NTFPs that are managed and exploited in the tropical forests of southern Mexico and Central America, a number of understory palm species in the genus *Chamaedorea* have received much attention due the high demand of their leaves and seeds for use in the floriculture and horticulture industries (Hodel, 1992). The economic potential of these palms has spurred government and non-government programs in Mexico to endorse the cultivation of several species of *Chamaedorea* palms in forested areas surrounding rural communities. Although *Chamaedorea* plantations rely on the larger, native canopy trees for shade, landowners clear many of the smaller trees, shrubs and herbaceous plants in order to increase light availability and reduce competition for cultivated species. This is done both initially—before palms are planted—and periodically after planting, usually once every 6 months to a year.

In contrast, actual harvesting practices incur minimal impact both to the palms and surrounding vegetation. Given the relatively long lifespan of *Chamaedorea* palms (15–20 years; Hodel, 1992), plantations are managed for long-term production. Typically, harvesters cut one to two leaves per palm, leaving the newest leaf so as not to damage the meristem and mature palms can produce new fronds once approximately every 3–4 months. Harvesters visit plantations alone and gather the fronds as they are cut, resulting in little damage to other plants and seedlings. In addition, many plantation owners maintain that they spare timber saplings and other economically valuable plant species (e.g., naturally occurring *Chamaedorea* palms) during routine clearings. Thus, beyond their economic importance to landowners, some species may still play an active role in the ecological community of plantations.

1.2. Study objectives

In order to quantify the effects of NTFP plantation management on forest community structure and composition, we conducted a case study of plantations of *Chamaedorea hooperiana* Hodel, an endemic species of the humid tropical forests of the Los Tuxtlas region of southern Mexico. We addressed the following questions: (1) does the management of *Chamaedorea* plantations affect forest community structure and composition (i.e., size class distribution, stem density, basal area and plant diversity)? (2) If so, are specific life history stages and assemblages of plant species differentially affected by plantation management? (3) To what extent are naturally occurring, economically valuable plant species spared when plantations are established? (4) What are the implications of any changes in community structure and composition to forest management and conservation?

2. Materials and methods

2.1. Site description

This research was conducted in the buffer zone of the Los Tuxtlas Biosphere Reserve (LTBR) in southeastern Mexico, in a relatively extensive area of old growth, tropical high evergreen rain forest (Bongers et al., 1988) adjacent to the community of Adolfo Lopez Mateos. Mean annual temperature in the area is approximately 24 °C and mean annual precipitation is between 3000 and 4000 mm with a dry season from December to May (Soto and Gama, 1997). Adolfo Lopez Mateos is located at about 18°24′N, 94°58′W, approximately 18 km east of the city of Catemaco at an elevation of 200 m. To the east of the community the Sierra de Santa Marta, an extinct volcanic crater, rises to an elevation of 1700 m.

2.2. Study design

To assess if plantation management alters forest structure and community composition, we compared NTFP plantations with unmanaged forest. We surveyed all of the *Chamaedorea* plantations in the vicinity of Adolfo Lopez Mateos and selected four plantations of *C. hooperiana* that were most similar in size (0.5–1 ha) and age of palms (1–3 years), and that were adjacent to an area of unaltered forest equally suitable for cultivation. The experimental design consisted of four blocks, each with a plantation site paired with an unmanaged forest site of similar size, slope aspect and inclination (30–45°). The elevation was approximately 300 m at Blocks 1 and 2 and approximately 500 m at Blocks 3 and 4. Block 1 had an easterly slope aspect. Blocks 2–4 had northerly slope aspects. At the time of study, the plantations in Blocks 2–4 were 3 years old and the vegetation in their understories was last cleared 1–3 months before data collection. The plantation in Block 1 was 5 years old and its owner had not cleared the vegetation for over a year before data collection.

In each plantation and forest site, 12 10 m diameter circular plots were established for a total sampling area of 942.4 m^2/site and a total of 96 plots across all blocks (4 blocks × 2 sites × 12 plots). Plot locations were randomly selected using an *x*–*y* coordinate system. In order to avoid confounding effects of plantation edges and existing tree fall gaps, no plot was placed <10 m from a tree fall gap edge or <5 m of a plantation edge. In each plot, we identified and recorded the diameter at breast height (dbh; at rate of 1.3 m) of all woody individuals ≥1 cm dbh. For palms and cycads, we identified and recorded the height of all individuals ≥0.20 m.

2.3. Community structure

Community structure analyses based on size class distributions were performed separately for woody species and palms and cycads. Size classes were assigned based on 10 cm dbh increments for woody species and 1 m height increments for palms and cycads. In order to increase resolution, the first two size classes for both species groups are based on smaller increments. Therefore, 8 dbh size classes were used for woody species: (1) 1–4.9 cm, (2) 5–9.9 cm, (3) 10–19.9 cm, (4) 20–29.9 cm, (5) 30–39.9 cm, (6) 40–49.9 cm, (7) 50–59.9 cm and (8) ≥60 cm. For palms and cycads, seven height size classes were used: (1) 0.2–0.4 m, (2) 0.5–0.9 m, (3) 1.0–1.9 m, (4) 2.0–2.9 m, (5) 3.0–3.9 m, (6) 4.0–4.9 m and (7) ≥5.0 m.

2.4. Species richness and diversity

Plant species richness and Brillouin's index of diversity (Krebs, 1999) were determined for each plantation and forest site from the total species counts and abundances pooled from all 12 plots sampled in each site. Comparisons between plantation and forest sites were made for the following species assemblages and life history stages: (1) all species, including all woody plants ≥1 cm dbh and all palms and cycads ≥0.20 m in height, (2) all woody species, (3) woody understory including all individuals <10 cm dbh, (4) woody individuals ≥10 cm dbh, (5) woody individuals ≥20 cm dbh, (6) all fleshy-fruited trees and shrubs, (7) understory tree species, (8) shrub species, (9) all palms and cycads and (10) uncultivated palms and cycads, excluding planted *C. hooperiana* individuals.

2.5. Stem density

Density was calculated as the number of stems per hectare using total counts pooled from all 12 plots in each forest and plantation site. Analyses followed the same life history groups outlined above for species richness and diversity. In order to more closely assess the effects of management on ecologically important, fleshy-fruited trees and shrubs, additional density comparisons for this life history were made for the following size class groups: (1) <10 cm dbh, (2) ≥10 cm dbh and (3) ≥20 cm dbh. To examine the differences between plantation and forest sites for the densities of economic palms, species-specific comparisons were made for the midstory palm, *Astrocaryum mexicanum*, the cultivated species, *C. hooperiana*, and the following naturally occuring economic palm species: *Chamaedorea alternans*, *Chamaedorea elegans*, *Chamaedorea eliator*, *Chamaedorea ernesti-augustii*, *Chamaedorea oblongata*, *Chamaedorea pinnatifrons*, *Chamaedorea tepejilote* and *Reinhardtia gracilis*. For timber saplings (timber species <10 cm dbh), we made comparisons between plantation and forest sites for density and relative abundance (proportion of the no. of timber saplings to total saplings in each site).

2.6. Basal area

Basal area (m^2/ha) was calculated from measurements of stem diameter at breast height (1.3 m) for all woody individuals and was also pooled from the 12 plots from each plantation and forest site. Basal area comparisons between plantation and forest sites were made for all life history groups containing only woody species.

2.7. Statistical analyses

Statistical comparisons between plantation and forest sites for plant community structure were made by testing the independence of size class distributions and management type (plantation versus unmanaged forest) using the log-linear model of goodness of fit (Sokal and Rohlf, 1995). Comparisons of species richness and diversity, stem density and woody plant basal area were made using completely randomized blocks ANOVAs (Sokal and Rohlf, 1995). When data sets did not meet assumptions of normality and homogeneity of variance, we used transformed data or employed the non-parametric Friedman's test (Sokal and Rohlf, 1995, p. 440).

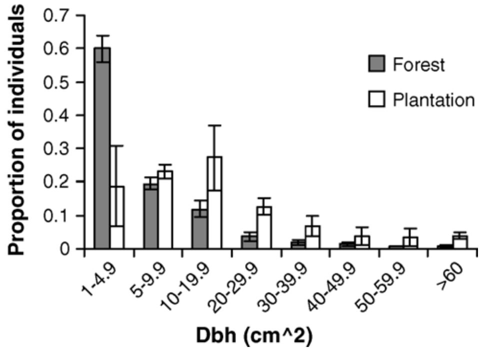

Fig. 1. Size class distribution of woody species for forest vs. plantation sites. Error bars represent standard deviation.

3. Results

The size class distributions of woody species in plantation and forest sites show a reduction in the smaller size classes in plantations (Fig. 1). The log-linear analysis for woody species demonstrated that size class distribution is dependent upon management type (plantation versus forest; $G = 222.6$, $P < 0.0001$, d.f.$_{28}$). In contrast, the community structure of palms and cycads in plantations indicates a scarcity of individuals in larger size classes when compared with forest sites (Fig. 2). Log-linear analysis of palm and cycad community structure also showed that size class distribution is dependent upon management type ($G = 838.7$, $P < 0.0001$, d.f.$_{20}$).

Forest sites were significantly greater in overall species richness than plantation sites. When broken

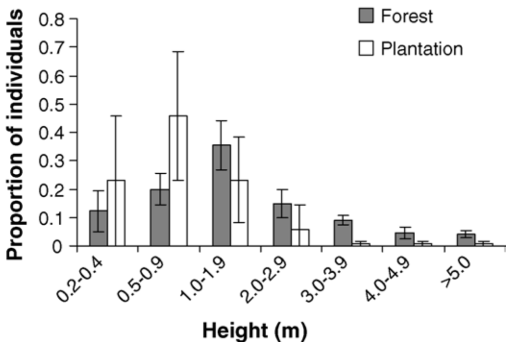

Fig. 2. Size class distribution of palms and cycads for forest vs. plantation sites. Error bars represent standard deviation.

Table 1
Mean values of species richness, diversity, stem density and basal area for plantation (P) vs. unmanaged forest (F) sites for all life history groups and species assemblages

Category	Species richness (no. of spp.)		Brillouin's diversity index		Stem density (stems/ha)		Basal area (m^2/ha)	
	P	F	P	F	P	F	P	F
Overall	**47.00**	**65.50****	**1.91**	**2.82***	**5811.81**	**7870.21***	–	–
All woody spp.	**37.50**	**56.75***	**2.79†**	**3.15***	**920.45**	**3758.71****	39.26	49.30
Woody understory <10 cm dbh	**21.75**	**45.75****	2.19	2.89	**440.33**	**3002.72****	**1.04**	**4.12*****
Woody individuals ≥10 cm dbh	**25.25**	**33.25****	**2.42**	**2.74***	477.46	748.03	38.22	45.18
Woody individuals ≥20 cm dbh	17.75	18.75	0.07	0.17	252.00	310.35	34.51†	38.42
All fleshy-fruited trees and shrubs	**25.25**	**33.25****	2.45	2.70	**578.26**	**1846.20****	30.57	34.86
Understory trees	**6.25**	**9.25***	**1.28**	**1.70***	**252.00**	**1095.52***	4.18	5.81
Shrubs	**2.00**	**9.25***	**0.32**	**1.47***	**55.70**	**1063.69***	–	–
Palms and cycads	9.50	8.75	1.24	1.18	4891.36	4111.50	–	–
Uncultivated palms	8.50	8.75	1.47	1.18	**2021.27**	**4111.50****	–	–

Significant differences indicated by bold type. Analyses made using completely randomized blocks ANOVAs unless otherwise indicated.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.
† Friedman's non-parametric test used.

down into life history groups, richness was greater in forest sites for all woody species, woody understory species, shrubs and woody individuals ≥10 cm dbh (Table 1). In contrast, species richness did not significantly differ between forest and plantation sites for the larger woody individuals ≥20 cm dbh. Forest sites were also found to have a significantly higher richness of understory trees and fleshy-fruited trees and shrubs than plantation sites (Table 1). No differences were found in the richness of all palms and cycads or of uncultivated palms.

According to Brillouin's diversity index, the overall plant diversity in forest sites was greater than plantation sites. Diversity was greater in forest sites for all woody species, woody individuals ≥10 cm and shrubs (Table 1). The Brillouin's indices for the woody understory also indicate that forest sites tended to be more diverse than plantations ($F = 7.99$, $P = 0.0664$, $d.f._{1,3}$). As with species richness, no differences between forest and plantation sites were found for the larger woody individuals ≥20 cm dbh. Forest sites showed a significantly higher diversity of understory trees than plantation sites (Table 1). Forest sites also tended to be more diverse in fleshy-fruited trees and shrubs than plantations sites, though this difference was not significant ($F = 7.11$, $P = 0.0759$, $d.f._{1,3}$). There were no differences between plantation and forest sites in the diversity of all palms and cycads or of uncultivated palms.

The overall density of stems in the forest sites was significantly greater than in plantation sites. Analyses of life history groups showed stem density to be greater in forest sites for all woody species, the woody understory, shrubs, understory trees and all fleshy-fruited shrubs and trees (Table 1). In contrast no significant differences in stem density were found between forest and plantation sites for the larger size class groups including woody individuals ≥10 cm dbh and woody individuals ≥20 cm dbh. While there was no difference between plantation and forest sites in the density of palms and cycads, there was a significant difference in the density of uncultivated palms between these two management types (Table 1).

The results of the density analyses for the size classes of fleshy-fruited trees and shrubs were similar to that of woody species in general. Forest sites had a significantly higher density of fleshy-fruited species >10 cm dbh than plantation sites (Table 2). However, no significant differences were found between forest and plantation sites for the larger size class groups, ≥10 and ≥20 cm dbh. Among the fleshy-fruited species recorded, 79% were canopy and subcanopy trees, while 21% were understory and midstory trees and shrubs.

Table 2
Mean values of stem density (no. of stems/ha) for plantation vs. unmanaged forest for three size class groups of fleshy-fruited trees and shrubs

Size class	Plantation	Forest
<10 cm dbh	**252.00**	**1371.39****
≥10 cm dbh	326.27	469.51
≥20 cm dbh	188.33	209.55

Significant differences indicated by bold type. Analyses made using completely randomized blocks ANOVAs.
** $P < 0.01$.

The densities of the naturally occurring economic palm species (*Chamaedorea* spp. and *R. gracilis*) did not significantly differ between forest and plantation sites (Fig. 3). In contrast, large differences in mean densities were found between plantation and forest sites for both *A. mexicanum* and *C. hooperiana*. Whereas the density of *A. mexicanum* was significantly greater in forest sites, the density of *C. hooperiana* was significantly greater in plantation sites (Fig. 4).

For timber saplings (individuals <10 cm dbh), overall density was significantly greater in forest than in plantation sites while the relative abundance (proportion of timber saplings to total saplings) was significantly greater in plantation sites (Fig. 5).

The basal area of the woody understory (<10 cm dbh) was significantly greater in forest sites than in plantation sites (Table 1). However, no significant differences were found for all woody individuals, woody individuals ≥10 cm dbh, woody individuals ≥20 cm dbh, understory trees, or fleshy-fruited trees and shrubs.

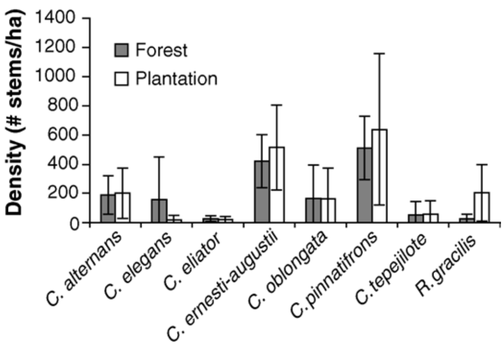

Fig. 3. Mean stem densities for forest vs. plantation sites for the economic palm species not under cultivation. Error bars represent standard deviation.

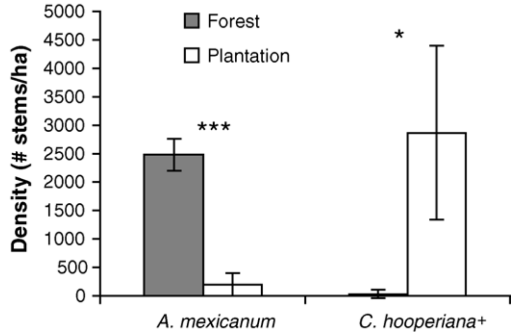

Fig. 4. Mean stem densities for forest vs. plantation sites for the palm species *Astrocaryum mexicanum* and *Chamaedorea hooperiana*. Error bars represent standard deviation ($^{*}P < 0.05$; $^{***}P < 0.0001$; $^{+}$data log transformed).

4. Discussion

In order to integrate the economic objectives of forest management with the conservation of natural resources, it is necessary to minimize the ecological

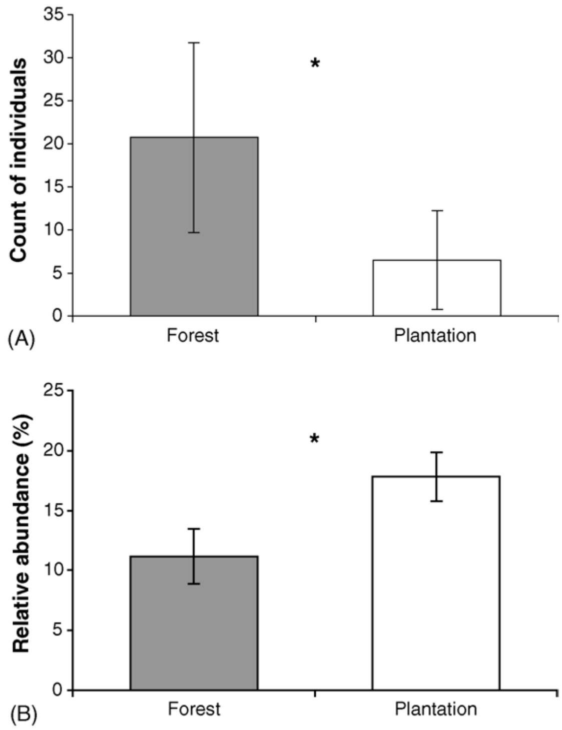

Fig. 5. The (A) mean number and (B) relative abundance (proportion of timber saplings to all saplings) of timber species saplings (<10 cm dbh) in plantation vs. forest sites. Error bars represent standard deviation ($^{*}P < 0.05$).

degradation caused by management practices. Thus, the management of buffer zones and other forested areas that serve the dual purpose of resource conservation and economic development poses a challenging problem. Non-timber forest products offer a promising economic alternative to more destructive forms of land use such as large-scale forest conversion for agriculture and livestock production. However, research on the ecological impacts of NTFP management is largely restricted to wild harvesting, despite the growing practice of NTFP cultivation in forest understories (Ticktin, 2004). In order to effectively manage buffer zones and other forests that contain understory NTFP plantations, it is critical that we understand the impacts of NTFP cultivation on the forest community. This case study illustrates some of the ecological implications of NTFP cultivation by comparing the plant community structure and composition of areas of forest containing understory plantings of the palm *C. hooperiana* with that of unmanaged forest.

4.1. Plant community structure and composition

Our analyses of plant diversity and richness, stem density, basal area and forest structure found consistent differences between plantations and unmanaged forest among the smaller size classes of woody species. Thus, as we expected, management practices are largely directed at removing vegetation in the smaller size classes of woody species, while larger canopy trees appear to be left alone.

In contrast, however, analyses of community structure for palms and cycads showed plantations to have a greater concentration of individuals in the smaller size classes than forest sites, with very few individuals >3 m tall. The difference in the palm community appears to be due entirely to the replacement of *A. mexicanum*, the most abundant palm in forest sites, with *C. hooperiana* (normally restricted to wet montane forests >600 m elevation though one forest site had a wild population at 300 m). Whereas adults of *C. hooperiana* as well as the other *Chamaedorea* species rarely reach heights >3 m (with the exceptions of *C. tepejilote* and *C. eliator*, which were not very abundant), *A. mexicanum* adults normally exceed heights of 5 m. Other differences between *C. hooperiana* and *A. mexicanum* such as crown structure, growth form (e.g., clonal growth in *C. hooperiana*), resource use and species interactions may result in further impacts on both the biotic and abiotic factors affecting the ecological community in *Chamaedorea* plantations.

The decreases in density and species diversity among shrubs and understory trees found in this study suggest a potential problem for the conservation of plant species whose adult sizes rarely exceed 10–20 cm dbh. Since the vegetation in the understories and midstories of plantations is continually removed, populations of shrubs and understory trees may become fragmented or even eliminated locally. For example, in our study, certain species of shrubs (e.g., *Aegiphila costaricensis*, *Daphnopsis americana*, *Mollinedia pallida*) and understory trees (e.g., *Miconia ibarrei*, *Psychotria limonensis*) only occurred at low densities in single sites. Given the patchy distributions of many tropical plant species (e.g., Hubbell, 1998), these species may become a conservation concern in areas of cultivation. The removal of seedlings and saplings is also likely to have serious implications for the recruitment of canopy tree species. The threat to larger tree species may not be as immediate due to the persistence of adults as seed sources in plantations, however, the impact on recruitment in the smaller size classes may lead to problems over the long-term.

The result of these changes in the community composition of woody species and palms is a simplification of the vegetative structure in plantations in terms of plant richness and diversity, stem density and basal area. These effects on the plant community may in turn affect the diversity of other organisms. For instance, several studies of other agroforestry systems note that plantations with more complex vegetative structure tend to support a greater diversity of bird species than simplified systems (Thiollay, 1995; Greenberg et al., 1997a,b; Calvo and Blake, 1998). In addition, reductions in the structural complexity of the vegetation in coffee plantations have been associated with reductions in mammal diversity (Gallina et al., 1996) and even arthropod diversity (Perfecto et al., 1997; Perfecto and Vandermeer, 2002).

Other studies have related the abundance of frugivorous animals directly to the availability of food resources (e.g., Moegenburg and Levey, 2003; Saracco et al., 2004). A reduction in the density of fleshy-fruited species in plantations does not directly relate to reductions in fruit availability, especially since management affects mostly the smaller size classes (i.e., <10 cm dbh). Thus, the reproductive, fruiting individuals of many larger tree species may persist in *Chamaedorea* plantations. However, 21% of the fleshy-fruited species recorded were understory trees and shrubs whose reproductive adults fall within the size class most affected by plantation clearing. The loss of these species may explain the lower species richness of fleshy-fruited species in plantation sites. These changes may have important implications for patterns of seed dispersal and the assemblages of frugivorous animals moving within and between managed and unmanaged areas of forest.

4.2. Management of economic species

The results from this study indicate that economically valuable NTFPs, namely the naturally occurring *Chamaedorea* species and *R. gracilis*, were spared during the establishment and maintenance of plantations. In contrast were the large reductions of *A. mexicanum* in plantations. Although *A. mexicanum* is generally valued as a food source (both the flowers and meristems are eaten), plantation owners consider it a nuisance due to its spine-encrusted trunk and large leaves that can fall and cover planted seedlings.

For timber species, although plantations had a higher proportion of timber saplings relative to total saplings than forest sites, this must be interpreted with caution due to the overall reduction of timber sapling density in plantations. Further long-term research would be required in order to determine whether selection for timber species within NTFP plantations at this small of a scale has the potential to sustain populations of economically valuable tree species or alter future forest composition.

4.3. Implications for forest management

This study reveals some consistent trends in the structural and compositional changes associated with the establishment and maintenance of *Chamaedorea* plantations. However, it must be noted that these results refer to a single study site, making extrapolations to other systems of NTFP cultivation difficult. Conclusions about human-managed systems are further complicated by differences in land use histories, and especially, the variation among NTFP management practices (Ticktin, 2004).

The most direct and immediate effect of *Chamaedorea* plantation management is the fragmentation and/or elimination of local populations of certain species of palms, such as small trees and shrubs that are not considered useful. These include species such as *A. mexicanum*, *Bactris* spp., *Psychotria* spp., *Faramea occidentalis* and *Myriocarpa longipes*. Variation in topography, such as very steep slopes and ravines, may provide refugia for understory and midstory plant species. However, in areas where NTFP cultivation is extensive, maintaining a matrix of unmanaged forest understory amid NTFP plantations may be necessary to sustain the populations of these smaller plant species. In relation to our knowledge of the ecology of larger canopy tree species in tropical forests (e.g., Clark and Clark, 1992; Lieberman et al., 1995; Hubbell, 1998), our understanding of the ecology and the extent of habitat required for the persistence of understory and midstory plant species is limited.

It is more difficult to surmise the long-term ecological consequences of plantation management because of the limited temporal scope of this study and the fact that NTFP cultivation has only been extensively practiced over the past 10 years. Although the larger canopy and subcanopy trees are left standing, plantation management is likely to affect the population dynamics of these species due to the continual removal of seedlings and saplings. Given the long and complex life histories of many tropical canopy tree species (Clark and Clark, 1992), it is difficult both to assess how plantation management impacts these species and how their populations should be managed appropriately. One possibility is to have plantation owners spare the advanced regeneration of canopy tree seedlings and saplings (e.g., Viana, 1990; Mesquita, 2000), as they already do with economically valuable plant species. Another alternative may be to establish understory NTFP plantations in strips similar to the system proposed by Hartshorn, (1989) for tropical timber harvesting so that areas of natural regeneration are maintained between managed areas. With further long-term research on the ecological impacts of NTFP cultivation in the context of community dynamics and forest regeneration, it should be possible to develop comprehensive forest management strategies that can optimize the potential of NTFPs for both economic development and resource conservation in buffer zone forests and elsewhere.

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