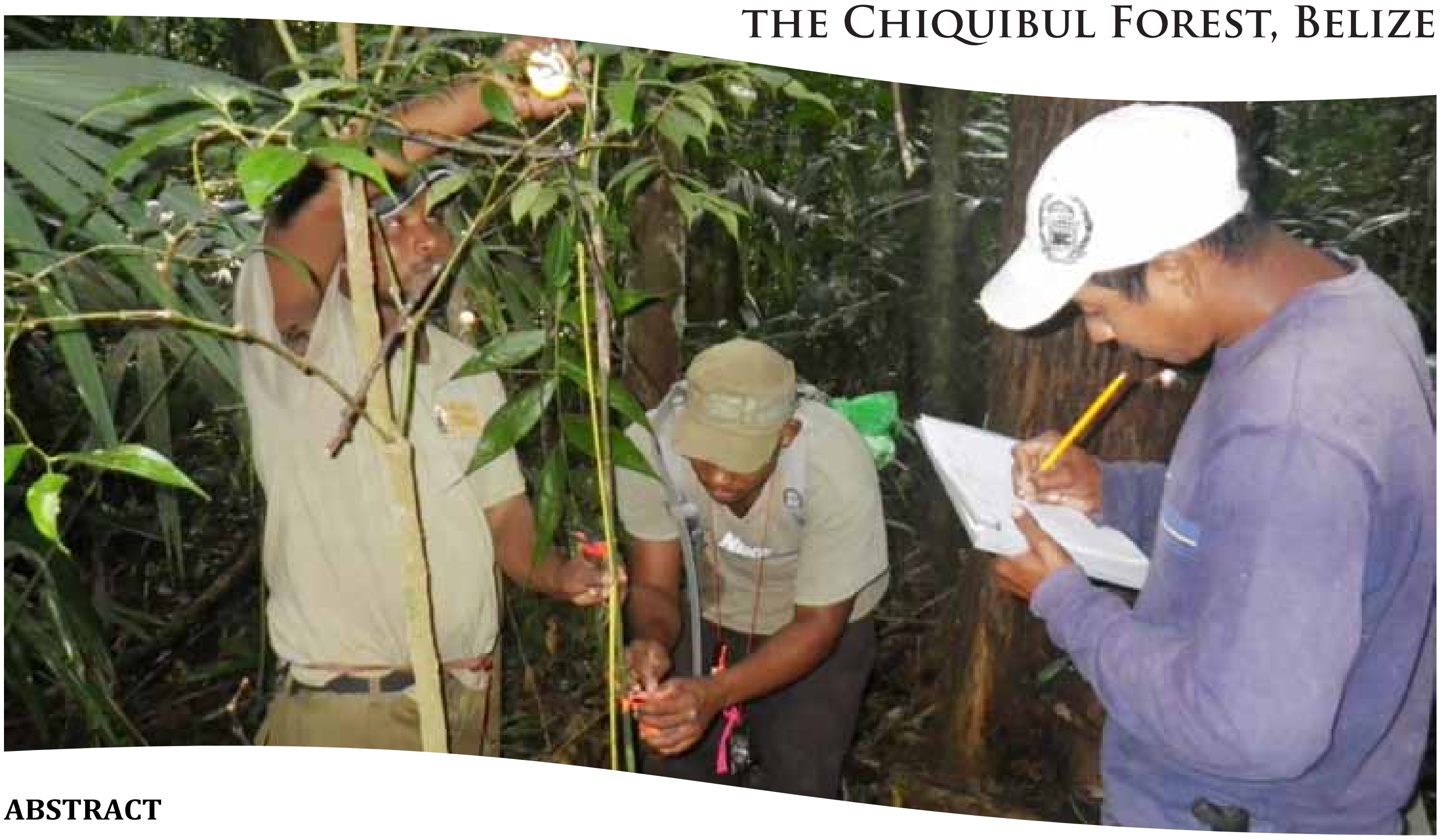
An assessment of Xaté Populations and the Effect of Habitat Complexity on Xaté Stocks in the Chiquibul Forest, Belize



ABSTRACT

Over the years, Xaté (*Chamaedorea spp.*) has gained economic importance as an important Non-Timber Forest Product (NTFP) in Central America. The leaves of these species are harvested and exported into the international floral industry, generating increasingly important revenue. As a result many Guatemalan nationals from the adjacent villages have been illegally harvesting Xaté leaves from the Chiquibul Forest; a region which has the greatest potential economic value of Xaté in Belize. The main objective of this study was to determine the Chamaedorea species density and productive capacity, and to estimate gross economic value of illegally harvested and available Xaté stocks in the Chiquibul Forest. A total of 30,367 individual Chamaedorea plants were measured, representing five (*C. ernesti-augusti, C. oblongata, C. neurochlamys, C. tepejilote, C. schippi*) of the seven recorded species for the Chiquibul Forest; of which, 54.69% (n = 16,609) were categorized as being productive (adult) plants. Of the recorded Chamaedorea species, *C. neurochlamys* showed to have the least global density (94.25 individual/ ha), while *C. oblongata* had the greatest density (703.55 individuals/ ha.) and *C. ernesti-augusti,* showed to be one of the least abundant species (124.55 individuals/ ha.). *C. ernesti-augusti* shows a mean density of 60.5 commercial grade leaves per ha. compared to the 126.3 commercial grade leaves per ha. reported for *C. oblongata*. Of the total available leaves for *C. ernesti-augusti* only 16.34% (n = 1,452) were of commercial quality, while 60.1% showed signs of herbivory. Of the 1,418 available leaves per hectare of *C. oblongata*, only 8.9% were of commercial grade, while 69.7% of the leaves have been affected by herbivores. Illegal harvesters have managed to extract over 14 million leaves of *C. ernesti-augusti* worth US $ 624,592.00, while *C. oblongata* appears to be less favored. Mean productive capacity for *C. ernesti-augusti* was 53.45 leaves per hectare while for C. *oblongata* it was 111.23 leaves per ha, with an accumulated gross economical value of US $ 309,211.00 for the Chiquibul Forest Reserve alone. This study shows evidence that targeted Xaté populations in the Chiquibul Forest are under stress and if adequate management and conservation measures are not set in place, the species may face commercial to local extinction.

INTRODUCTION

Millions of people around the globe depend largely on the harvest of Non-Timber Forest Products (NTFP) for their subsistence needs (Endress *et al.* 2006) leading to a heated debate on the value of NTFP harvest to conservation and improving livelihoods of the rural poor (Marshall *et al.* 2003, Arnold & Ruiz Perez, 2001).

Chamaedorea is the largest palm genus in the Central American Region (Henderson *et al.* 1995) and according to the IUCN, they are among the world's most endangered palms, with an estimated 75% of the species threatened. In Belize, there are 12 reported species of which three are the most favored in the floral industry being *Chamaedorea elegans, C. ernesti-augustii* and *C. oblongata*; of which the latter two species are known to be of high relative abundance in the Chiquibul Forest.

Over the years, Xaté has gained economic importance as an important Non-Timber Forest Product (NTFP) in Central America (Bridgewater *et al.* 2006). The leaves of these species (*C. elegans, C. ernesti-augusti, C. oblongata)*, are harvested and exported to the international floral industry, generating important revenue. The combination of over-harvesting and habitat loss have led to populations in this region becoming progressively more vulnerable (Garwood *et al*. 2006; Porter-Morgan 2005). Other authors such as Cibrian-Jaramillo *et al.* (2009) suggest that demographic bottlenecks decrease local survival in some *Chamaedorea* palms, while Porter-Morgan (2007) indicate that even tree falls and common predation by ground moles increase adult mortality in these species, reducing the number of reproductive individuals and decreasing overall survival at the community level.

If sustainable harvesting is not practiced, target species may face local extinction as research by Wicks (2004) and Morgan (2005) indicate that wild xaté plants are only able to produce 1 to 2 new leaves per year, these findings are also in accord with those of Endress *et al*. (2006, 2004a), suggesting that harvesting frequency and intensity need to be regulated giving time for harvested plants to recuperate. Porter-Morgan (2007), suggests that overharvesting of plants drastically reduce their reproductive capacity, while others may argue that cutting leaves from plants may create stress inducing plants to increase leaf production (Endress *et al*. 2004a, b) but if leaf extraction is frequent and intense it may lead to high plant mortality and reduce plant growth and reproductive capacity (Endress *et al.* 2006).

The Chiquibul Forest shares 45 kilometers of an international border with Petén, Guatemala. Satellite imagery shows that forest cover in Guatemala is highly fragmented while in Belize the Chiquibul forest appears intact. As a result many Guatemalan nationals from the adjacent villages have been illegally harvesting the leaves of *Chamaedorea* (Xaté) palms from the area which has the greatest potential economic value of Xaté in Belize (Bridgewater *et al*. 2006). Illegal Xaté harvesting activities in the Chiquibul Forest were reported there in the 1970's. Since then "xatero" (individuals that harvest Xaté leaves) activity has increased within the area and there is an evident increase in xatero trails and more frequent horse tracks, indicating that illegal Xaté harvesting is an acute problem. The principal objectives of the study were to: i) determine Xaté population abundance and density within the Chiquibul forest, ii) explore relationships between Xaté stock and habitat complexity iii) estimate the gross economic value of illegally harvested Xaté iv) calculate the productive capacity of Xaté populations (by species) within the Chiquibul Forest, and v) provide a baseline data on the status of Xaté populations to compare with later studies on the impact of Xaté extraction in population mortality and reproductive success.

METHODOLOGY

Study site

The Chiquibul Forest, located within the Cayo District, covers an area of 176,999 ha (437,376 acres) comprised of three protected areas being the Chiquibul National Park (106,838 ha), Chiquibul Forest Reserve (59,822 ha) and the Caracol Archeological Reserve (10,339 ha.). Meerman and Sabido (2001) identified 17 different ecosystems within the area, all being variants of Tropical Broadleaf Forests, except for a pine forest and non-mechanized agriculture category (Figure 1, Annex 1). The region has a subtropical climate with a marked dry season between February to June and a rainy season coinciding with the hurricane season which starts from July to November (Salas & Meerman 2008). Cretaceous limestone forms the parent rocks found in the western half of the Chiquibul while Permian meta-sediments are dominant on the east (Cornec 2003). On the extreme south of the Main Divide there are volcanic deposits. The soils are generally derived from limestone and are regarded fertile in comparison to other tropical areas but on the steeper limestone slopes Wright *et al.*(1959) classifies the soils as skeletal where the bedrock tends to protrude out as a consequence of the soil layer being a few centimeters thick.

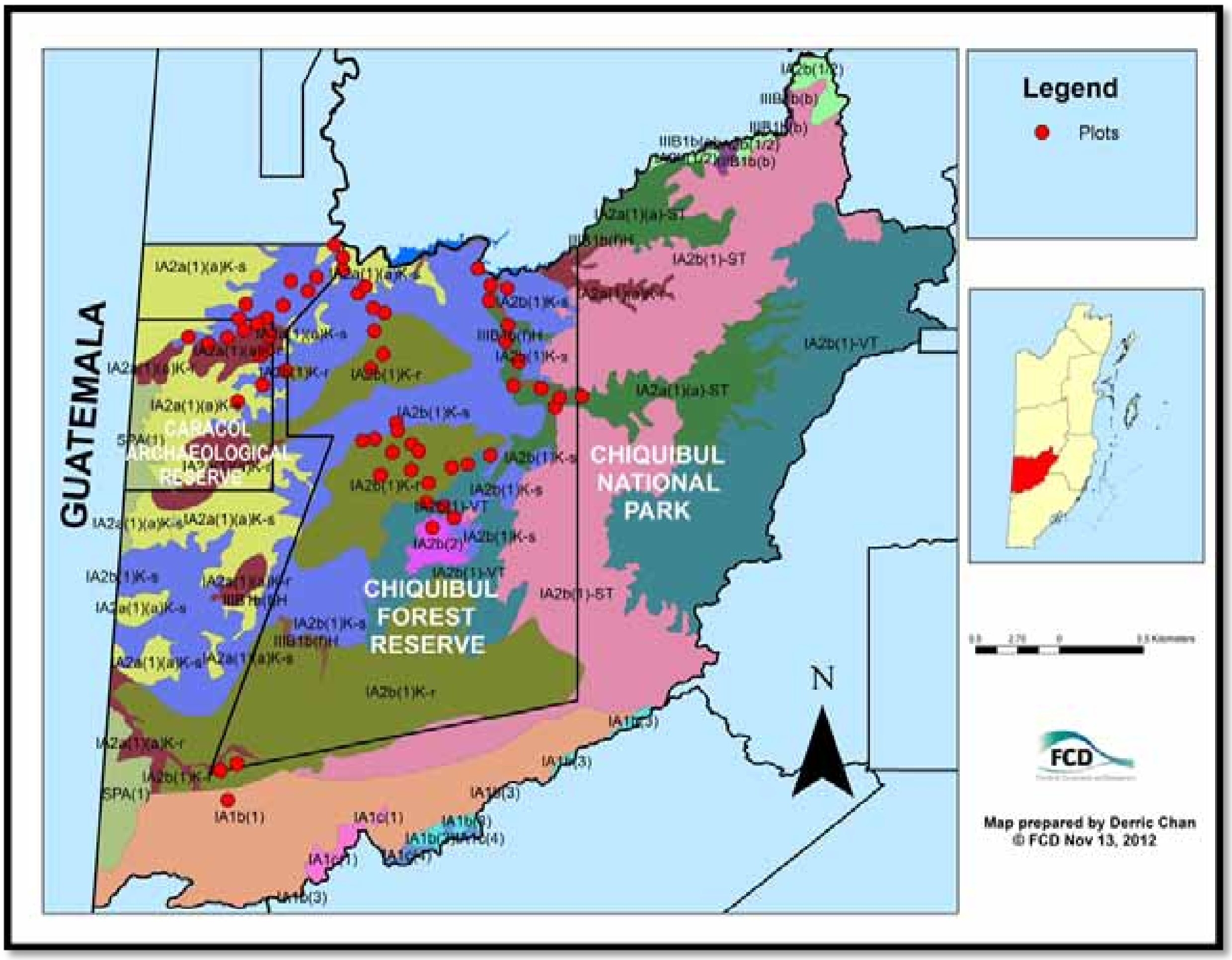


Figure 1: *Ecosystem map of the Chiquibul Forest and spatial distribution of Xaté sampling plots within the study area.*

Xaté stock assessment

To accomplish a representative Xaté stock assessment, 60 plots, each having an area of 0.4 ha. were established following a systematic sampling design distributed throughout the study area, while covering dominant ecosystems (Figure 1). Plots were established based on the methodology provided by Manzanero *et al*. (2009) and Bridgewater *et al*. (2006); each located at least 1 km apart. Existing access routes such as logging roads, tracks, rivers and major xatero trails were employed as transects on which sampling plots were located alternating one another. The central point of each plot was located at least 300 m away from the transect, distance measured using a GPS and following a cardinal direction; making sure that the closest corner of the plot was located at least 100 m from the transect. Access routes used as transects were selected based on degree of accessibility, security issues and ecosystem heterogeneity. Once distancing at least 150 m from the trail, a 300 m transect was established oriented north to south. On this transect the central point of the sampling plot was located at 150 m; from the central point a 150 m transect was cut both towards the west and east. Each sampling plot was composed of 8 sub-parcels measuring 10 × 50 m; 2 oriented towards each cardinal point. The first sub-plots were located 25 m from the central point of the transect. The other 4 sub-plots were located at a distance of 25 m from the finishing end of the first sub-plots and on the opposite side of transects (Figure 2).

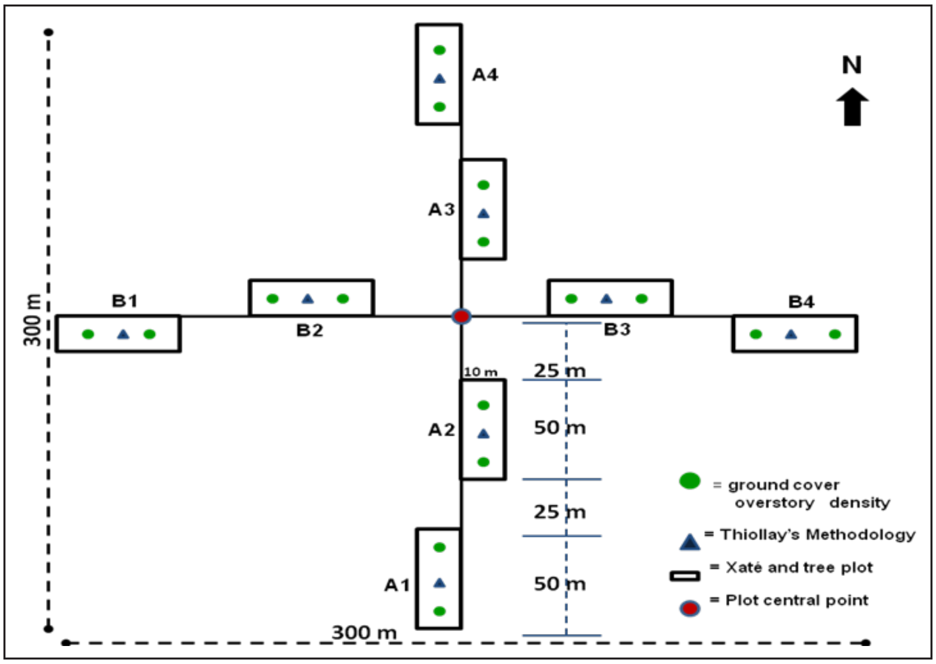


Figure 2: *Xaté sampling plot designed (adapted from Manzanero et al. (2009)).*

Within each of the sub-plots all Xaté plants greater than 10 cm in height were identified to the species level and the following data was collected: height (measured to the base of the meristematic leaf); diameter (measured at 10 cm from ground level); development stage (productive plants= plants that had reached maturity (plants that had produced at least 1 commercial leaf, plants not having commercial leaves but with evidence that leaves had been harvested were considered as productive); regeneration plants (plants that had not reached a productivity stage, meaning that these did not had leaves of harvestable size, for such individuals only the species was recorded); number of leaves (number of harvested leaves ascertained by the amount of cut petioles left on the plant); number of commercial grade leaves; number of leaves with signs of herbivory and reproductive state.

Economic assessment

The economic assessment of the Xaté resources in the Chiquibul Forest were carried out at two levels; one based on the already extracted amount of Xaté leaves and the other based on potential Xaté harvests under a sustainable regime. The used market price for Xaté (*C. ernesti-augusti* and *C. oblongata*) were based on historical market prices, where Rainforest Alliance (Guatemala) states that under a non certified marketing scheme a bundle of 600 *C. ernesti augusti* will sell at an average of US $ 38.00; while *C. oblongata* will sell at US $ 10.00 per 600 leaves. It is estimated that on average, 30% of uncertified harvest leaves are rejected (Manzanero 2012, pers. comm.); this factor was used when estimating the gross economical value of illegal extracted leaves but not used for the economical assessment of potential harvested leaves under a sustainable regime because in the field leaves regarded as being of commercial grade satisfied international market standards. The rate of leaf production by target species was also considered, which shows that for a harvest to be sustainable one leaf must be cut per year.

In order to extrapolate Xaté abundance in the Chiquibul Forest Reserve (CRF) and the entire Chiquibul Forest (CF) it was necessary to calculate the total area within these two zones that are suitable for Xaté. Based on the ecosystems map, the total area suitable for Xaté in the entire CF is 154,734 ha; while suitable Xaté ecosystems in the CFR have an area of 59,022 ha.

An important factor to consider when estimating the economical value of available commercial grade Xaté leaves was to estimate the xaté population productive capacity: This was calculated based on the amount of harvestable leaves (by specie) by hectare using the following equation:

$$Productive\ Capacity = IL + (X - IL)/\ 2$$

Where: *IL* = inferior limit at a 95% confidence interval
X = mean

Habitat heterogeneity and Xaté stock relationship

An important element in devising down to earth management and conservation strategies is having ample knowledge on the ecology of target populations by linking habitat variables and production. To achieve this, habitat structural and topographical parameters were assessed and then used as regressors in linear regression models where Xaté density and productivity were the dependent variables. These variables include: forest overstorey density, vertical structural heterogeneity (Thiollay's Vegetation Index measured at the "central'' point of each sub-plot), ground cover and slope. Forest overstorey density was assessed in two locations of each sub-plot, using a spherical densitometer (Model A); at each station 4 readings were recorded, each following the cardinal points, from these readings; an average was calculated and used as the overstorey density. Ground cover was visually estimated by randomly placing a 1 × 1 m quadrant at the "central" point of each sub-plot, an average value was reported for each sampling unit. Thiollay's Vegetation Index (Thiollay 1992) was visually estimated in each sub-plot for each of the four main strata (0–2, 2-9, 10–20 and >20 m) using an index of 0 to 3 (where 0 = 0% cover, 1= 1 – 33% cover, 2= 34 – 66% and 3 = 67–100%). The sum of the four indices from all strata in each sub-plot was used as the index of vertical heterogeneity for each site.

RESULTS

Species abundance and density

A total of 30,367 individual Chamaedorea plants were measured, representing five (*C. ernesti-augusti, C. oblongata, C. neurochlamys, C. tepejilote, C. schippi*) of the seven recorded species for the Chiquibul Forest; of which, 54.69% (n = 16,609) were categorized as being productive (adult) plants. The other two species were recorded but outside the sampling plots; *C. elegans* was recorded from South Caracol, while *C. seifrizii* was observed around the Ceibo Chico Area in South Chiquibul. The data indicates that the Chiquibul Forest has a mean abundance of 1,265.3 individual Chamaedorea plants per hectare (Table 1), with an almost 1 to 1 ratio between productive (adult) and regeneration plants. The results also indicate that the most abundant species was *C. oblongata* with a total of 16,885 surveyed individuals (55.6%), followed by *C. tepejilote* (n = 5,034), while the least abundant was *C. neurochlamys* (n = 2262), representing only 7.4% of the total Chamaedoreas recorded (Figure 3).

***Table 1**: Mean abundance of Chamaedorea plants per hectare recorded in the Chiquibul Forest.*

Variable	Mean/ ha.	Minimum	Maximum
Global Abundance	1265.3	0	3747.5
Productive plants	692.05	0	2022.5
Regeneration plant	573.25	0	2717.5

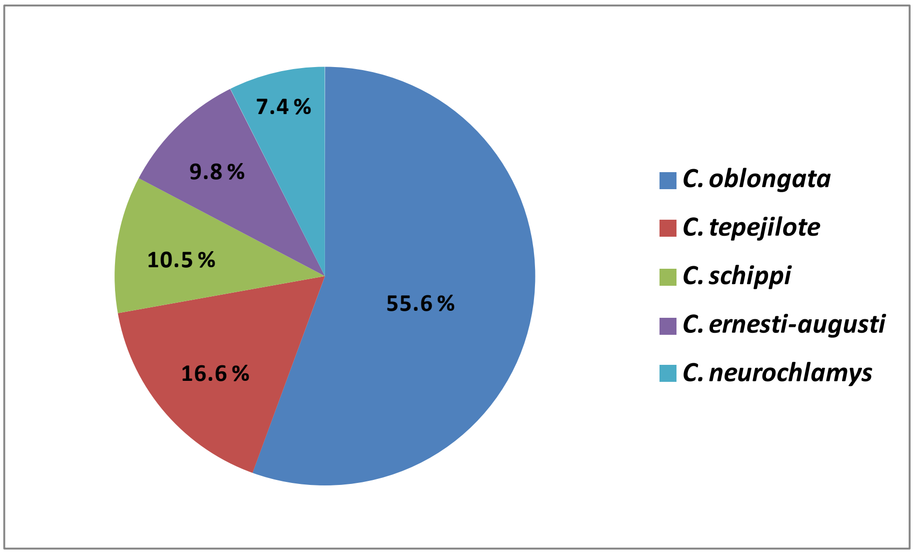


***Figure 3:** Percentile distribution of the 5 Chamaedorea species recorded in the Chiquibul Forest.*

It is evident that the ratio of productive (adult) to regeneration plants varies across recorded species (Figure 4). *C. oblongata* was the only species showing an almost equal distribution in abundance between adult and regeneration plants; *C. schippi* reported 4.4 times more regeneration class individuals than productive; while the other three species had less regeneration plants. *C. ernesti-augusti* reported 3 times more productive plants than regeneration.

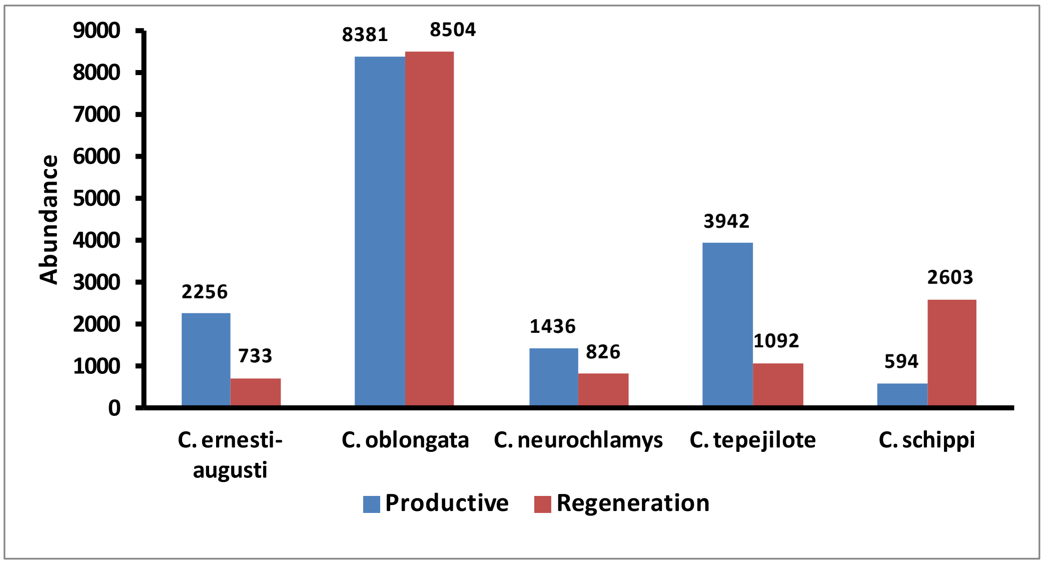


Figure 4: *Abundance of productive and regeneration Chamaedorea plants recorded in the Chiquibul Forest.*

C. ernesti-augusti adult plants had a mean diameter of 1.12 (Minimum = 0.8 cm; maximum = 2.55 cm), and a mean height of 72.72 (minimum = 38.6 cm; maximum = 186 cm). *C. oblongata* had a mean diameter of 1.09 ± 0.11 (minimum = 0.79 cm; maximum = 1.35 cm), with a mean height of 151.76 ± 17.33 (minimum = 99.67; maximum = 215 cm), while *C. neurochlamys* had the greatest diameter and height (Table 2).

Table 2: *Mean diameter and height of adult Chamaedorea plants in the Chiquibul Forest.(SD = Standard Deviation)*

Species	Variable	Mean + SD
C. ernesti-augusti	Diameter	1.12 ± 0.23
	Height	72.72 ± 23.84
C. oblongata	Diameter	1.09 ± 0.11
	Height	151.76 ± 17.33
C. neurochlamys	Diameter	1.22 ± 0.24
	Height	168.07 ± 48.73

Of the five recorded Chamaedorea species, *C. neurochlamys* showed to have the least global density (94.25 individual/ ha), while *C. oblongata* had the greatest density (703.5 individuals/ ha.) (Table 3). *C. ernesti-augusti,* the most favored species by illegal Xaté harvesters, showed the second least global density (124.5 individuals/ ha.), but with a productive plant density of 94 individuals per hectare. Highest productive plant density was recorded for *C. oblongata*, while *C. schippi* recorded lowest productive plant density (Table 3).

Table 3: *Density per hectare of three Chamaedorea species in the Chiquibul Forest*

Species	Variable	Mean/ ha.	Minimum	Maximum
C. oblongata	Global density	703.5	0	3305
	Productive plants	349.2	0	1672.5
	Regeneration plants	354.5	0	2067.5
C. tepejilote	Global density	209.8	0	1937.5
	Productive plants	164.3	0	1827.5
	Regeneration plants	45.5	0	335
C. schippi	Global density	133.2	0	2622.5
	Productive plants	24.8	0	395
	Regeneration plants	108.1	0	2612.5
C. ernesti-augusti	Global density	124.5	0	442.5
	Productive plants	94	0	310
	Regeneration plants	30.5	0	132.5
C. neurochlamys	Global density	94.3	0	652.5
	Productive plants	59.8	0	460
	Regeneration plants	34.4	0	225

Condition and density of Chamaedorea leaves

The data indicates that each productive plant of *C. ernesti-augusti* had an average of 3.9 leaves, with an average of 0.64 commercial grade leaves while illegal Xaté harvesters had extracted an average of 0.96 leaves per plant. In regards to *C. oblongata,* harvesting has been minimal, while results indicate no evidence of harvesters targeting *C. neurochlamys* (Table 4). A major contributing factor to the low availability of commercial grade leaves in both *C. ernesti-augusti* and *C. oblongata* is the high occurrence of leaves showing signs of herbivory (Table 4). Of the three commercially potential Chamaedorea species in the Chiquibul Forest, *C. ernesti-augusti* recorded the highest percentage of commercial grade leaves while *C. oblongata* reported the least (Figure 5). In all three species leaves with herbivory and or other defects composed more than 83%, where the highest percentage was recorded for *C. oblongata* (Figure 5).

Table 4: *Mean abundance of leaves by category per plant for three Chamaedorea species in the Chiquibul Forest.*

Variable	Species		
	C. ernesti-augusti	***C. oblongata***	***C. neurochlamys***
available leaves	3.94	4.1	5.5
harvested leaves	0.97	0.004	0
commercial grade leaves	0.64	0.36	0.53
leaves with herbivory	2.36	2.83	4.1

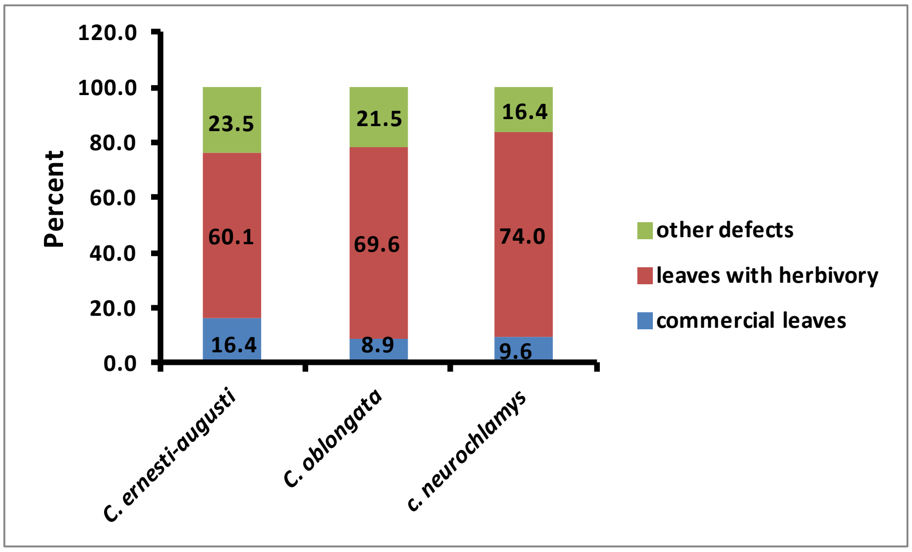


Figure 5: *Percentage distribution by leaf category of three Chamaedorea species assessed in the Chiquibul Forest.*

Results indicate that the density of available *C. oblongata* leaves was 3.8 times greater than that of *C. ernesti-augusti*, while *C. neurochlamys* reported the least density of available leaves with an average density of 329.3 leaves per ha. (Table 5). *C. ernesti-augusti* shows a mean density of 60.5 commercial grade leaves per ha. compared to the 126.3 commercial grade leaves per ha. reported for *C. oblongata*. Of the total available leaves for *C. ernesti-augusti* only 16.34% (n = 1452) were of commercial quality, while 60.1% show signs of herbivory. Of the 1417.9 available leaves per hectare of *C. oblongata*, only 8.9% were of commercial grade, while 69.7% of the leaves have been affected by herbivores (Figure 5).

Table 5: *Mean abundance of Chamaedorea sp. leaves per hectare.*

Species	Variable	Mean/ ha.	Minimum	Maximum
C. ernesti-augusti	Available leaves	370.175	0	1250
	Harvested leaves	91.05	0	382.5
	Commercial grade leaves	60.5	0	232.5
	Leaves with herbivory	221.7	0	765
C. oblongata	Available leaves	1417.9	0	6995
	Harvested leaves	1.5	0	22.5
	Commercial grade leaves	126.3	0	417.5
	Leaves with herbivory	988.2	0	4645
C. neurochlamys	Available leaves	329.3	0	2762.5
	Harvested leaves	0	0	0
	Commercial grade leaves	31.5	0	395
	Leaves with herbivory	243.8	0	2055

Most of the productive Chamaedorea plants assessed showed high occurrence of herbivory as shown in Figure 6, whereby 98.7% of all adult *C. neurochlamys* plants had suffered from herbivory while *C. ernesti-augusti* showed the least.

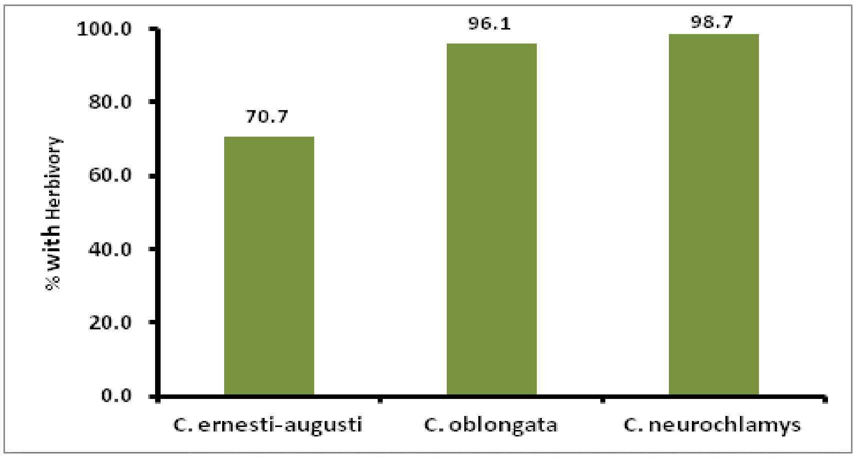


Figure 6: *Percentage of adult (productive) plants for three Chamaedorea species having leaves with herbivory.*

Of all adult *C. ernesti-augusti* only 2.4% were fertile having either flowers or fruits, while 47.9% and 30.8% of all adult *C. oblongata* and *C. neurochlamys* plants respectively were fertile. Of the absolute abundance of harvested *C. ernesti-augusti* adult plants, 5.1% were fertile while only 16.4% of harvested *C. oblongata* were fertile (Figure 7).

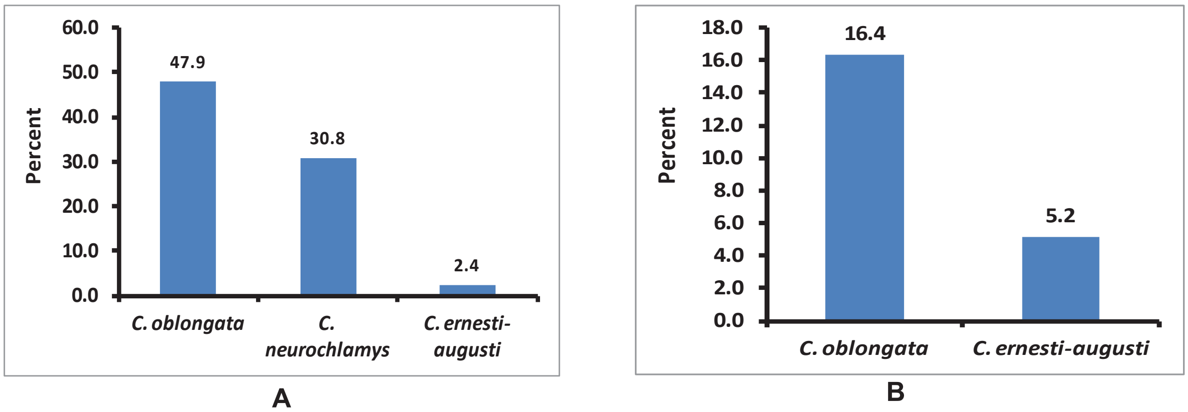


Figure 7: *Percentage of fertile plants (A) and percentage of fertile plants which have been harvested for each of three Chamaedorea species recorded in the Chiquibul Forest*

Quantity and gross economic value of illegally harvested Xaté

The most illegally harvested species in the Chiquibul Forest is *C. ernesti-augusti*, where illegal harvesters have managed to extract over 14 million leaves worth US $ 624,592.00, while *C. oblongata* appears to be less favored (Table 6).

Table 6: *Quantity of illegally extracted leaves and economical value. (CF = Chiquibul Forest)*

Species	Illegally extracted leaves		US $ Value
	Mean/ ha	CF	
C. ernesti-augusti	91.05	14,088,531	624,592.00
C. oblongata	1.5	232,101	2,708.00

Productive capacity and economic value of Xaté populations

Results indicate that mean productive capacity for *C. ernesti-augusti* was 53.5 leaves per hectare while for C*. oblongata* it was111.2 leaves per ha, a productive capacity which is two times greater than the former species. The accumulated gross economical value of Xaté for the Chiquibul Forest Reserve was estimated at US $ 309,211.00 but if extracted from the entire Chiquibul Forest its aggregated value was estimated at US $ 810,638.00 (Table 7).

Table 7: *Productive capacity and gross economical value of the two commercial Chamaedorea species in the Chiquibul Forest*. (CF = Chiquibul Forest, CFR = Chiquibul Forest Reserve)

Species	Productive capacity (leaves)				Economic value	
	plot	Ha	CFR	CF	US $ CFR	US $ CF
C. ernesti-augusti	21.4	53.5	3,154,726	8,270,532	199,799.00	523,800.00
C. oblongata	44.5	111.2	6,564,722	17,210,289	109,412.00	286,838.00

Habitat complexity and Xaté density and productivity

The study was unable to identify strong relationships between Xaté density and productivity with habitat complexity and topographical variables.

DISCUSSION

The results clearly indicate that Chamaedorea species are widely spread in the Chiquibul Forest forming a major component of the understory flora but densities vary greatly across species, such uneven distributions are also reported in other studies (Bridgewater *et al.* 2006; Radachowsky *et al*. 2004). Similar to the results obtained by Bridgewater *et al*. (2006) *C. oblongata* was most dominant, being 3.3 times more common than *C. tepejilote* (second most common species). Interesting to note is that Bridgewater *et al.* (2006) reports that *C. ernesti-augusti* was the second most common species but in this study it is one of the least common being 5.6 times less common than *C. oblongata,* equivalent to only 9.8% of absolute abundance of individuals recorded, while Bridgewater *et al*. (2006) reports that *C. ernesti-augusti* accounted for 22% of the absolute abundance recorded in their study. Two important factors that may help account for the high relative abundance of *C. tepejilote* and *C. schippi* is their clustering growth habit tending to be recorded in high abundance when encountered. The other factor is more topographically related where both species tend to prefer slopes and hill tops dominated by rock outcrops, common features in the Chiquibul Forest, even though such topographical variables were not found to be statistically significant in explaining such abundance and density.

Even though habitat structural heterogeneity and topographical data collected was found not to be significantly correlated to Xaté densities and production capacity, similar to the results obtained by Penn *et a*l (2009) it is still believed that soil characteristics and fertility plus floristic composition may play a vital role in determining Xaté species densities but more detailed studies are needed in order to prove such assumptions. Habitat and Xaté densities and productivity relationship is important to be indentified or investigated as it will shed important light in how to efficiently manage and conserve the species both in natural forests and plantations.

Based on the results obtained, it is evident that only *C. ernesti-augusti* is being targeted for its leaves by Xaté harvesters, where 34.3% of all adult plants showed signs of extraction much less than the 86% reported by Bridgewater *et al.* (2004), while the harvested *C. oblongata* plants represented less than 1% of all recorded adult individuals for that species. These two contrasting results may indicate that roughly after 2006, rate of extraction has decreased as indicated by the mean harvested leaves per plant (0.97 leaves/ plant) in this study as compared to the mean harvested leaves of 2.8 per plant as reported by Bridgewater *et al.* (2006). This finding sheds light on the assumption that illegal Xaté extraction in the CF has been unsustainable and if no adequate and urgent conservation measures are set in place the targeted Chamaedorea populations may face local extinction. The low density of harvested *C. oblongata* leaves (1.5 leaves per ha.) may suggest that such leaves may have been cut for different purposes other than for commercialization. Even though this study did not found evidence of illegal extraction of leaves from *C. neruochlamys*, abundance and density data of both plants and leaves were collected due to plant and leaf architecture similarity with *C. oblongata*, which may have a potential to be extracted; although at this moment there are no records that it is or has been commercialized.

A major limiting factor affecting the productive capacity of both *C. ernesti-augusti* and *C. oblongata* is the high occurrence of leaves with herbivory. This study indicates that the frequency of *C. ernesti-augusti* leaves with evidence of herbivory was 3.7 times greater than that of commercial grade leaves; while for *C. oblongata* commercial grade leaves were 7.8 times less abundant than those with herbivory. By analyzing these results it is safe to conclude that Xaté harvesting in the CF is on the verge of a collapse if no management and conservation measures are set in place, since 83.5% of all *C. ernesti-augusti* leaves are defected.

Even though this study provides limited information on the effect of leaf extraction on plant fertility it shows that *C. ernesti-augusti* had the lowest percentage (2.4%) of fertile plants in respect to *C. oblongata* and *C. neurochlamys* but most interesting is the fact that only 5.2% of harvested plants were fertile. Since *C. ernesti-augusti* is targeted by Xaté harvesters this result may indicate that the population is under stress due to over harvesting of leaves limiting its reproductive potential and also reflected by showing the second lowest regeneration abundance which represented 32% of total individuals assessed for that species. The low regeneration density of *C. tepejilote* may be attributed to the fact that illegal harvesters target this species for its inflorescence directly impacting its seed production rates. No information was able to be collected regarding the extraction rate of *C. tepejilote* inflorescences because its harvesting does not leave any evidence on harvested plants but reports indicated that large quantities of *C. tepejilote* inflorescences have been confiscated from within the Chiquibul Forest.

The estimated value of the extracted *C. ernesti-augusti* leaves from the Chiquibul Forest is U.S. $ 624,592.00, of which at least 50% of total revenue will go directly to the harvesters (Manzanero 2012, pers. Comm.). The economical benefits of the extracted NTFP is certainly contributing to improving the livelihoods of Guatemalan nationals found in communities buffering the CF but the true economic impact at the family level is not clear as the number of individuals involved in illegal Xaté extraction is unknown.

To sustainably harvest *C. ernesti-augusti* and *C. oblongata* leaves it is important to take into account the productive capacity of both species. The findings indicate that *C. oblongata* has a productive capacity, two times greater than that of *C. ernesti-augusti* mainly due to the its high density and not due to the mean number of commercial grade leaves per plant as it is 1.8 times less than that of *C. ernesti-augusti*.

Anyone venturing into establishing a Xaté industry based on the densities found in the Chiquibul Forest needs to take into account the protective status of the forest. It is estimated that within the Chiquibul Forest Reserve - the only area in the Chiquibul Forest where extractive activities can be legally undertaken - Xaté has an estimated gross value of U.S. $ 0.3 million, similar to that estimated by Bridgewater *et al.* (2006), even though at present the density of commercial grade leaves is less than that reported by the said authors but the export price for the product is more promising. Although only *C. ernesti-augusti* has been targeted in the Chiquibul Forest due to its high market value, it is possible that the scenario shifts to *C. oblongata* if demand and price for this species changes or if *C. ernesti-augusti* densities are depleted from the region.

CONCLUSION AND RECOMMENDATIONS

Illegal harvesting of Xaté within the Chiquibul Forest has centered on *C. ernesti-agusti* due to its high market price and demand but evidence exists, although impossible to quantify in the field, that *C. tepejilote* is also being harvested not for its leaves as is the case with the former species but for its inflorescence. The extraction of *C. tepejilote* inflorescence if not controlled will lead to a drastic decline in density and will directly impact its recruitment rates, but such impact is likely to be noticed in the medium term.

Of the five recorded Chamaedorea species, *C. neurochlamys* showed to have the least global density, while *C. oblongata* had greatest density. *C. ernesti-augusti,* shows an intermediate global density, but with a productive plant density of 94 individuals per hectare. The density of available *C. oblongata* leaves was 3.8 times greater than that of *C. ernesti-augusti*, while *C. neurochlamys* reported the least density of available leaves with an average density of 329.3 leaves per ha. *C. ernesti-augusti* shows a mean density of 60.5 commercial grade leaves per ha. compared to the 126.3 commercial grade leaves per ha. reported for *C. oblongata*. A major contributing factor to the low availability of commercial grade leaves in both *C. ernesti-augusti* and *C. oblongata* is the high occurrence of leaves showing signs of herbivory. Of the three commercially potential Chamaedorea species in the Chiquibul Forest, *C. ernesti-augusti* recorded the highest percentage of commercial grade leaves while *C. oblongata* reported the least (Figure 5). In all three species, leaves with herbivory and or other defects composed more than 83%, where the highest percentage was recorded for *C. oblongata*

It is clear that *C. ernesti-augusti* populations are being stressed by the illegal and unsustainable harvesting of leaves which may lead to a reduction in plant density that will eventually lead to a commercial and possible local extinction of the species. Although data from this study does not allow to investigate the impacts of leaf harvesting on reproductive capacity some evidence was gathered that this is being affected by showing a low regeneration plant density and low fertile plant frequency. By cutting leaves, plants' photosynthetic capacity is reduced due to a direct reduction in photosynthetic tissue but to my knowledge no study has been executed to explore this relationship.

This is the second study within the Chiquibul Forest that quantifies the degree of Xaté extraction and plant densities in the area and both studies present highly different results and the assumption is not solely based due to slight differences in methodology but due to a change in Chamaedorea species densities; however; to prove this more long term studies are needed.

Based on the findings the following is recommended:

- Conduct a long term study to determine the impact of Xaté leaves extraction rates and frequencies on plant reproductive capacity, mortality rates, and growth rates.

- Continue to conduct biological monitoring on the Xaté populations of the Chiquibul forest at least every two years.
- Study the germination and growth rate of Xaté in natural environments.
- Continue to investigate for potential relationships between Xaté densities and productive capacity with habitat floristic and topographical variables (especially looking at soil characteristics and fertility).
- Design a sound and practical conservation strategy to lessen and control illegal harvesting of Xaté within the Chiquibul Forest.

ANNEX

Annex 1: *Ecosystem found within the Chiquibul Forest*

UNESCO Code	UNESCO Ecosystem Type
IA1b(1)	Tropical evergreen broad-leaved submontane forest
IA1b(3)	Tropical evergreen broad-leaved submontane palm forest
IA1c(1)	Tropical evergreen broad-leaved lower-montane forest
IA1c(4)	Tropical evergreen broad-leaved lower montane palm forest
IA2a(1)(a)-ST	Tropical evergreen seasonal broad-leaved lowland hill forest, Simarouba-Terminalia variant
IA2a(1)(a)K-r	Tropical evergreen seasonal broad-leaved lowland hill forest, on rolling karstic terrain
IA2a(1)(a)K-s	Tropical evergreen seasonal broad-leaved lowland hill forest on steep karstic terrain
IA2b(1)-ST	Tropical evergreen seasonal broad-leaved submontane forest, Simarouba-Terminalia variant
IA2b(1)-VT	Tropical evergreen seasonal broad-leaved submontane forest: Virola-Terminalia variant
IA2b(1)K-r	Tropical evergreen seasonal broad-leaved submontane forest on rolling karstic hills
IA2b(1)K-s	Tropical evergreen seasonal broad-leaved submontane forest on steep karstic hills
IA2b(1/2)	Tropical evergreen seasonal mixed submontane forest
IA2b(2)	Tropical evergreen seasonal needle-leaved submontane forest
IIIB1b(a)	Deciduous broad-leaved lowland shrubland, well-drained, over poor soils
IIIB1b(b)	Deciduous mixed submontane shrubland over poor soils
IIIB1b(f)H	Deciduous broad-leaved lowland riparian shrubland in hills
SPA(1)	Agriculture: non mechanized agriculture including unimproved pasture

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