An Investigation into the Effect of Bamboo on the Surrounding Vegetation in the Arena Forest Reserve

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ABSTRACT

Bambusa vulgaris (Bamboo) is widespread in Trinidad. It occurs at all elevations and in all counties of the island. A study was conducted in the Arena Forest Reserve to determine whether or not *B. vulgaris* had an effect on the vegetation surrounding it, and whether or not it was an invasive species in a closed canopy forest in Trinidad. Species composition, diversity and density of all trees and seedlings within the immediate area of effect of four bamboo clumps in the Reserve were recorded and the parameters compared with an area of natural forest of the same size in the immediate vicinity. The abiotic conditions of dead organic matter (DOM) depth, and canopy closure were also compared between bamboo and natural forest plots. It was found that *B. vulgaris* does not appear to be invasive in the closed canopy areas of the Arena Forest Reserve in Trinidad, but where it exists it modifies its environment to the detriment of some tree species and the apparent benefit of others.

INTRODUCTION

The Present Situation

Bambusa vulgaris Schrad. ex J.C. Wendl (Bamboo) is a widespread introduced plant in Trinidad and Tobago. It is seen mainly in disturbed areas, being an integral part of the early stages of succession of vegetation primarily in agricultural areas. As a result of its growth habit it may deflect or suppress the later successional stage vegetation. It may also be an aggressive invasive species of the natural forests of Trinidad and Tobago with a detrimental effect on the surrounding vegetation and a tendency to form monodominant stands. This study into the effects of bamboo on its surrounding vegetation in a closed canopy rainforest could bring some insight into the situation and useful information will be gleaned to enhance the management strategies concerning this plant.

Invasive Species

B. vulgaris may be considered an invasive species in Trinidad and Tobago. An invasive species is defined by Cronk and Fuller (1995) as "an alien plant spreading naturally (without the direct assistance of people) in natural or semi-natural habitats, to produce a significant change in terms of composition, structure or ecosystem processes"

Invasive species may affect their new environment in a number of ways. These include: -

<u>Category</u>

1. A replacement of diverse ecosystems with single species stands of aliens
2. Invasion that poses a direct threat to native fauna
3. Alteration of soil chemistry
4. Alteration of geomorphological processes
5. Invasion leading to plant extinction
6. Alteration of the fire regime
7. Alteration of hydrology

It is suspected that of these, *Bambusa vulgaris* may to some extent threaten natural forest ecosystems in Trinidad and Tobago at least with a Category 1 effect and possibly with effects in other categories.

The Species

The plant that will be considered in this investigation is of the family Gramineae. Farrelly (1984) has described *Bambusa vulgaris* as the most common bamboo in the world. It is an adaptable plant and very hardy. It has been found at sea level and up to 1219.2 m. It is capable of surviving at most temperatures above 0°C.

B. vulgaris is suspected to have originated in the Madagascar, Java, and Sri-Lanka area by some authors, (Farrelly 1984) and in the East Indies, China, Japan and India by others (Lawson 1968). All authors agree, however, that it originated somewhere in the Far East. By this token it is not native to Trinidad. It is not clear when it was introduced to Trinidad nor the original reasons for its introduction. Uses of *B. vulgaris* in Trinidad today are as a construction material (scaffolding, frames for buildings etc...) and soil stabilisation on slopes and along watercourses.

The ecology of *B. vulgaris* can be inferred from the habitats where it is generally found. It fits the profile of a pioneer or early successional stage plant, the habitats in which it is found are generally disturbed by humans; broken canopies with copious amounts of direct sunlight, adequate moisture and nutrients. Its distribution thus appears to be strongly influenced by humans in Trinidad. It flowers and seeds very infrequently (once every 50 years or so) and so, therefore, spreads over longer distances vegetatively with the aid of humans. However, once established in an area, it is capable of surviving and probably expanding its range slowly without any further assistance. Thus *B. vulgaris* appears to be naturalised because it appears to be surviving in many parts of Trinidad and Tobago without human assistance.

Culms or stalks of *B. vulgaris* can grow up to 20 m tall with an average width of 12 cm. Growth rates have been estimated at 15 - 18 cm per day. Other estimates are a 10 – 30% increase of its height annually. Tree species have a growth rate of a 2 – 5% increase in height per year (Farrelly 1984). The fast growth rate exhibited may result in the overtopping of seedlings and saplings of other species in the vicinity, suppressing their growth by blocking out the sunlight.

Another aspect of the growth habit of *B. vulgaris* is its toppling stalks. The culms grow straight up and when they reach their maximum height topple over either from wind-throw, old age, predation, or rotting at the base. This may have the effect of battering down developing saplings in the immediate area. Healthy culms usually sprout at the nodes when lying on the ground causing the clump to increase in size.

B. vulgaris also has copious leaf production and leaf fall. This may have the effect of building up a thick layer of Dead Organic Matter (DOM) which may stifle the seedlings growing in the immediate area of effect of the bamboo clump.

These phenomena were all observed at clumps of *B. vulgaris* in the Arena Forest Reserve, so a quantitative investigation of its effect on the surrounding vegetation was initiated. The study was undertaken to determine if *B. vulgaris* was acting as an invasive plant and caused a Category 1 effect in closed canopy forest in the Arena Forest Reserve.

The specific objectives of this study were the following:

1. To compare species diversity, composition and density of woody vegetation of a relatively undisturbed, closed canopy forest with the woody vegetation in the immediate area of effect of a clump of *Bambusa vulgaris* growing in the same forest;

2. To compare the depth of the DOM and the canopy closure of the two microenvironments.

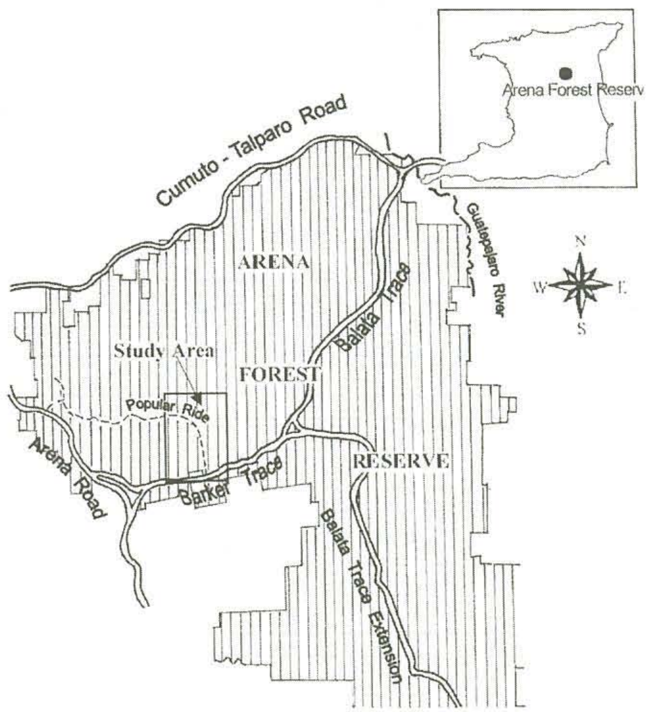

Fig. 1. Location of study area in Arena Forest Reserve

The Study Site

The Arena Forest Reserve lies in the San Raphael forestry range of the Northwest Conservancy, and occupies an area of 1536.6 ha. (Fig. 1)(Bell 1969).

The ground is gently undulating throughout with occasional short steep slopes. Minimum elevations of 22.8 m above sea level are found at the northern boundary of the reserve. Approximately 12.1 ha exceed an elevation of 76.2 m and a maximum elevation of 87.4m above sea level occurs at the southern extreme of the reserve (Bell 1969).

Sands and clays derived from rocks laid down in the lower Pliocene to upper Eocene epochs of the tertiary period constitute the bulk of the Arena Forest Reserve's soil, while in the northwest of the Reserve, sands derived from the deposits of the Pleistocene epoch of the quaternary period are present (Bell 1969). Soils of the Reserve range from the Arena Sand with excessive internal drainage, to clay soils with impeded internal drainage. Soil at the study sites was of two types, the Arena Sand and the Las Lomas Sand and Loam. Both soils drain freely (Bell 1969).

The vegetation of the reserve consists of altered lowland seasonal evergreen forest (Bell 1969). The original composition of the forest was reported in Beard (1946) and was found to be a tall closed forest dominated by commercially important timber trees such as *Carapa guianensis* Aubl. (Crappo) and *Eshwielera subglandulosa* Miers (Guatacare). Over the course of the century the forest was modified by and for timber production but still retained its character as a tall closed forest (Bell 1969). Timber production in Arena Forest Reserve was halted in the late 1980's as it was felt the Reserve no longer contained adequate timber supplies (Vernon Ragbir *pers. comm.*). The practice of harvesting trees for charcoal production was an integral part of the timber production systems in Arena Forest Reserve. However, with the advent of cheap kerosene supplies it became economically marginalised by the middle of the last century (Bell 1969). Charcoal production continued until the 1970's but on a much smaller scale.

B. vulgaris was introduced into the Arena Forest ecosystem by the charcoal producers as posts to brace the sides of the pits in which a tree was burnt for charcoal (Vernon Ragbir *pers. comm.*). After the charcoal was removed the pit was abandoned and the bamboo sprouted from nodes taking advantage of the gap created when the tree was felled for burning and the nutrients in the soil from un-recovered charcoal. The result is clumps of *B. vulgaris* scattered throughout the Reserve today, dating from the abandonment of charcoal burning pits (Vernon Ragbir *pers. comm.*).

METHODS

Site Selection

The Arena Forest reserve was chosen as the preferred site for this investigation, based on its close proximity to the campus of the University of the West Indies in St. Augustine and a known history of human intervention and establishment of *B. vulgaris* clumps. The bamboo clumps investigated at the reserve were established by humans some 30 – 60 years ago (Vernon Ragbir *pers. comm.*).

Four clumps of *B. vulgaris* were chosen within the reserve. One lay obliquely opposite to the eastern end of Popular Ride; two others were situated along Popular Ride; and one other was off Popular Ride surrounded by forest (Fig. 2). These clumps were chosen because of their close proximity to each other, so that they were easily accessible, while being far enough apart so as not to have an effect on each other.

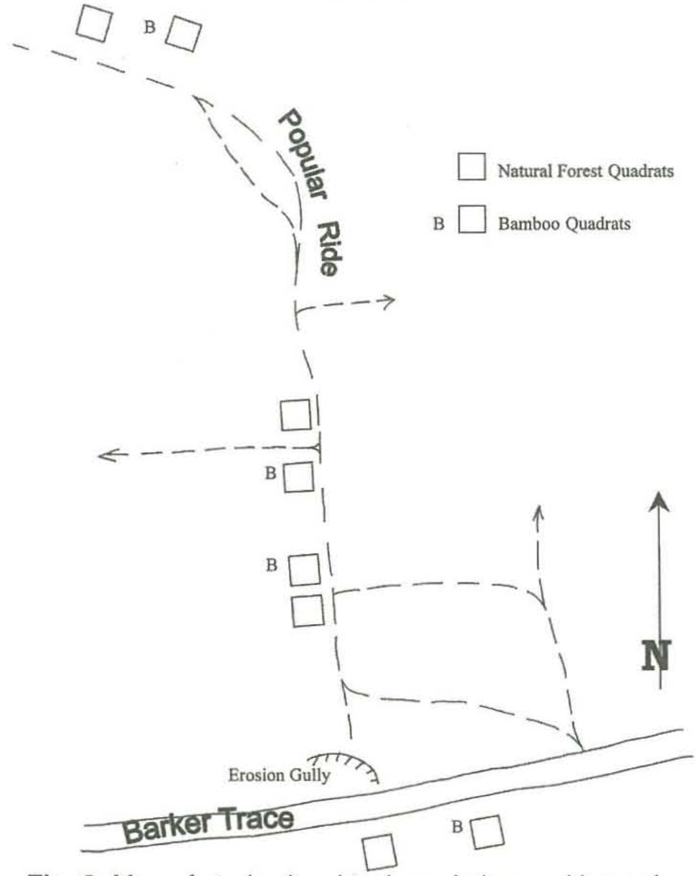

Fig. 2. Map of study site showing relative positions of Bamboo and Natural Forest Quadrats

At each site, woody vegetation was sampled in two main size classes; tree flora (woody vegetation > 1cm Diameter at Breast Height (DBH)) and ground flora (vegetation < 1cm DBH).

Tree Flora

Single 15 m x 15 m quadrats were used to sample trees > 1cm DBH. The size of these quadrats was determined by the qualitative observations of the spread of bamboo leaf litter, and the length of the fallen bamboo stems. With a measuring tape these quadrats were constructed around each bamboo clump, adequately sampling the area of effect. These quadrats were known as the bamboo quadrats.

The process of constructing the quadrats and taking their inventory and the DBH of the plants within them was repeated for an area close by each bamboo clump with similar abiotic conditions, but out of the area of effect of the bamboo clump. The positions of these quadrats were determined by a qualitative difference in leaf litter composition and the longest fallen bamboo stalk seen. These quadrats were known as the natural forest quadrats.

Within the 15 m x 15 m quadrats, every tree's DBH was measured with a measuring tape and samples were taken to the National Herbarium of Trinidad and Tobago (TRIN) for identification by herbarium staff when the specific name was not known. Species names followed those in current usage at the time at the National Herbarium (See Appendix 1 for species list). The number of individuals, number of species, Shannon diversity index, average basal area (m^2) and projected percentage cover were calculated and recorded for each 15 m x 15 m quadrat.

The Shannon diversity index is a combined measure of the species richness and the evenness of the distribution of numbers of individuals in the different species according to the formula:

$$H' = [\Sigma p_i(\log_{10} p_i)] \times (-1)$$

Where p_i = the proportion of all individuals in the i^{th} species

The Shannon diversity index increases with increasing species richness and decreasing dominance of any one or few species.

Ground Flora

Within the 15 m x 15 m quadrats, in both bamboo and natural forest quadrats, smaller 2 .m x 2 m quadrats were constructed. This size was determined by the use of a species area curve done in the reserve prior to the investigation. Four of these quadrats were arbitrarily placed within the larger 15 m x 15 m quadrats. Within the 2 m x 2 m quadrats, an inventory of all seedlings (defined here as any plant <1cm DBH) was taken. The number of individuals, number of species, and the Shannon diversity index were recorded for each quadrat and averaged for each site.

Abiotic Data Measurement

In each of the 15 m x 15 m quadrats, the DOM depth was taken at four points with a ruler. Canopy closure measurements were taken with the use of a spherical densiometer (Forest Densiometers, Oklahoma), also within each of the 2 m x 2 m quadrats. Averages of these measurements were taken as representative for their respective quadrats. The averages of abiotic readings for the 2 m x 2 m quadrat were themselves averaged to give a value for the 15 m x 15 m quadrat.

Table 1. Descriptive statistics obtained in the investigation and the probablities that the values obtained for the two microenvironments are the same according a paired t-test (p)

Descriptive Statistic	Microenvironments		p
	Bamboo	Natural Forest	
15m x 15m Quadrats			
Avg. No. of Individuals	46.25	82.00	0.038*
Avg. No. of Species	9.50	8.25	0.120
Shannon Diversity (H')	2.27	2.52	<0.05*
Avg. Basal Area (cm^2)	48.31	39.34	0.368
Canopy Closure (%)	87.00	82.71	0.019*
DOM Depth	4.44	3.94	0.325
2m x 2m Quadrats			
Avg. No. of Individuals	47.50	54.00	0.363
Avg. No. of Species	7.25	8.75	0.248
Shannon Diversity	2.27	2.70	<0.05*

* denotes significant difference

Statistical Analysis

A paired t-test was performed to compare the number of individuals, number of species, average basal area (m^2) and canopy closure between bamboo quadrats and natural forest quadrats (Hayes 1999). An alternative method was used to determine a t statistic for the Shannon Diversity index (H′) (Zar 1984).

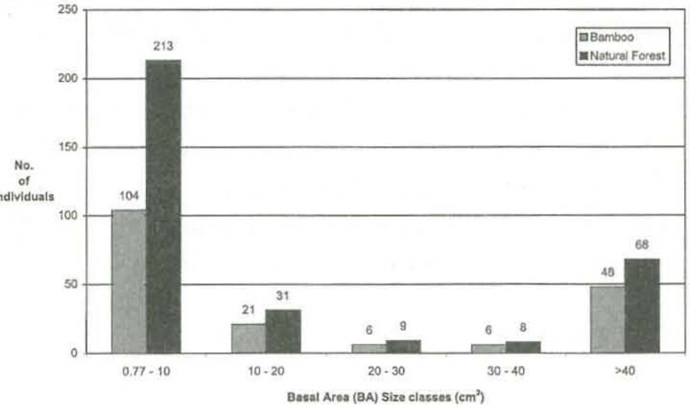

Fig. 3. Histogram of basal area size class vs. no. of individuals for the two microenvironments

RESULTS

Descriptive Statistics

In the 15 m x 15 m quadrats there was a significant difference in the average number of individuals >1 cm DBH (paired t-test, $p = 0.038$), H′ of individuals >1 cm DBH (paired t-test, $p > 0.05$), and percentage cover between the bamboo and the natural forest plots (paired t-test, $p = 0.019$) (Table 1). There were fewer trees in the bamboo quadrats (46.25) compared to the natural quadrats (82.00). This appeared to be accounted for mainly by saplings (Fig. 3). The Shannon Diversity Index was lower around bamboo clumps (H′ = 2.27) than in the natural forest (H′ = 2.52) however the average number of species was not significantly different (paired t-test, $p = 0.120$). Finally, in the 15 m x 15 m quadrats, the canopy closure was lower in the natural forest (82.71%) compared to the bamboo quadrats (87.00%).

In the 2 m x 2 m quadrats, the seedlings showed a significantly different Shannon diversity index between the two microenvironments (paired t-test, $p < 0.05$).

Tree Flora

Fourteen species of trees > 1 cm DBH were found at least 5 times in either the natural forest or bamboo quadrats, and were therefore assumed to occur frequently enough for any patterns in their distribution to be of potential significance (Fig. 4). Of the fourteen, four occurred exclusively in the bamboo quadrats, 2 occurred exclusively in the natural forest quadrats and 8 occurred in both quadrats. The species found exclusively in the natural forest plots were *Lacisterma aggregatum* and *Pinzonia coriacea*. In addition *Ryania speciosa* and *Terminalia amazonia* were dras-

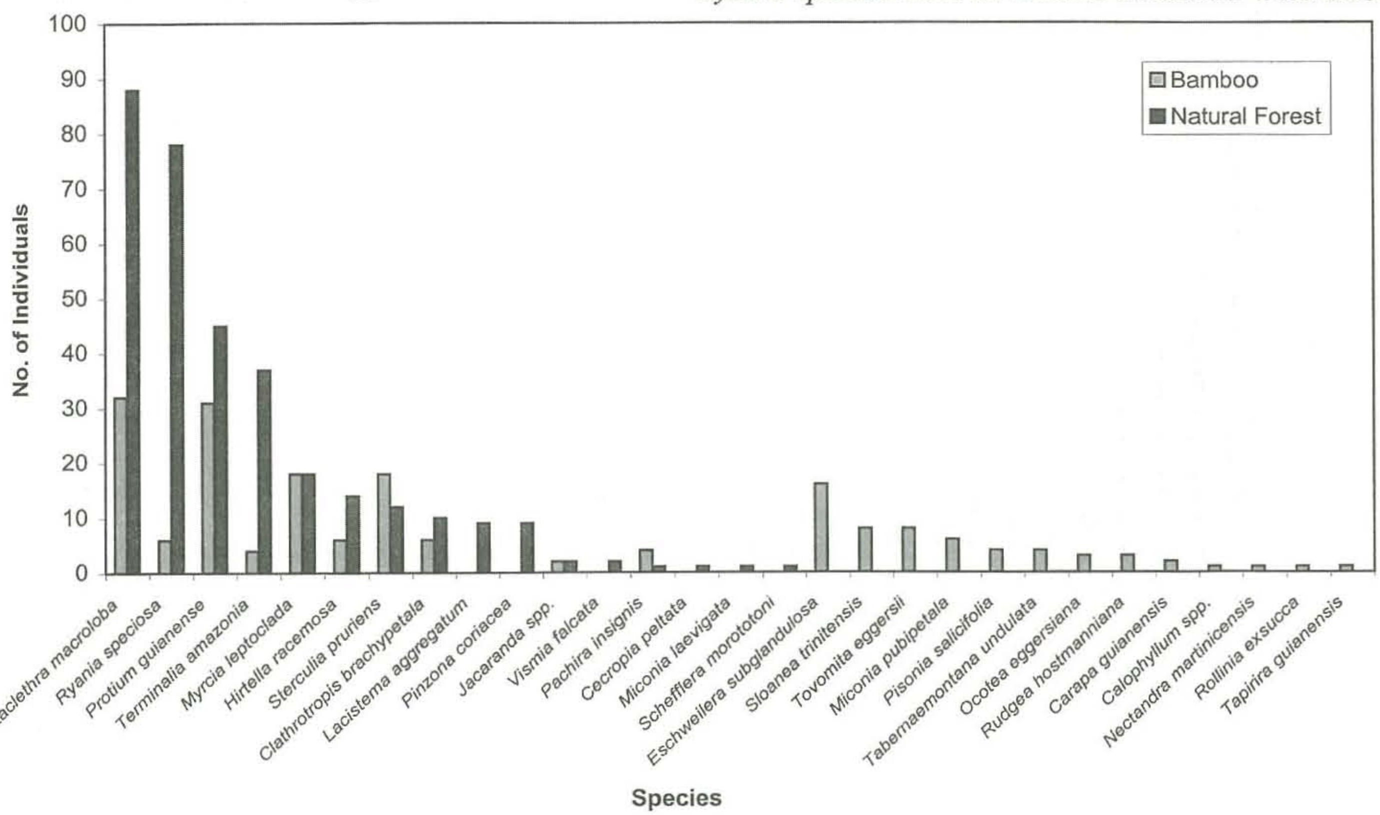

Fig. 4. Species of trees vs. no. of individuals for two microenvironments

tically reduced in numbers in the bamboo plot. The four species found exclusively in the bamboo plots were *Eschweilera subglandulosa*, *Sloanea trinitensis*, *Tovomita eggersi* and *Miconia pubipetala*.

In terms of size class distribution, there were more individuals in the natural forest quadrats in all size classes than there were in the bamboo quadrats (Fig. 3). There were more trees in the larger size class categories in the natural forest quadrats than in the bamboo quadrats. But, generally, greater sapling numbers accounted for the higher numbers of individuals in the natural forest environment.

Ground Flora

Similar trends were observed in ground flora as with the mature trees. There were, however, a few additions and contradictions. *R. speciosa,* and *T. amazonia* seedlings had the same preference for natural forest as did stems > 1cm DBH (Fig. 5). The family of vines, Bignoniaceae also appeared to have a preference for a natural forest environment. *E. subglandulosa* seedlings had the same preference for the microenvironment created by bamboo as did the trees > 1cm DBH. *Heliconia psittacorum* was another "seedling" (so classified because it had a DBH < 1cm) to prefer the environment created by bamboo. It should also be noted here that the numbers of individuals of the species associated with the bamboo microenvironment were lower than the species associated with the natural forest environment but not significantly so (paired t-test, p = 0.363,Table 1).

DISCUSSION

Tree Flora

Bambusa vulgaris clearly had an effect on the surrounding vegetation. The most obvious effect was the significantly lower number of trees around the bamboo clump compared to the natural forest. The majority of individuals in both environments were in the sapling size class; however, there were more than double the number of saplings in the natural forest environment than in the bamboo quadrats. This may be as a result of toppling bamboo stems battering down saplings, a phenomenon that was observed in the bamboo quadrats. There was no difference in the average basal area of trees for the two microenvironments. However, it was shown that there were more individuals in all size classes in the natural forest environment. This indicated that the woody vegetation left in the bamboo quadrats was dominated by a few large trees that presumably had grown tall enough to overtop the bamboo and not be harmed by its toppling culms. Another pos-

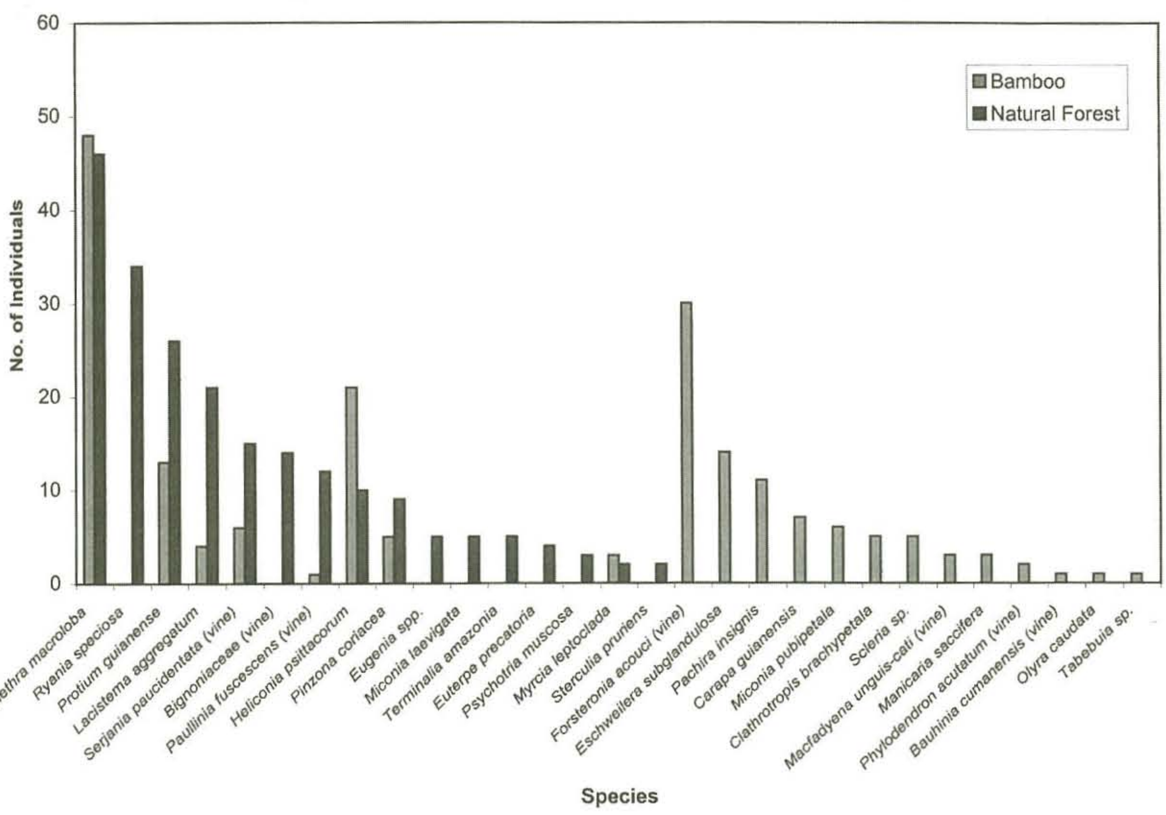

Fig. 5. Species of seedlings vs. no. of individuals for two microenvironments

sible reason for the lower numbers of saplings in the bamboo quadrats could also have been the higher canopy closure cover found in the bamboo quadrats. This indicated that bamboo shaded the plants beneath it more than the trees in the natural forest do, probably resulting in poorer vegetative growth around the bamboo clumps. The higher canopy closure in the bamboo plots is a result of the high density of culms creating a more closed canopy than the adjacent natural forest. Below, ground root competition may have also had a part to play in the lower numbers of saplings in the bamboo plots but this was not investigated in this study.

There was no difference in the number of species of trees in the two microenvironments. There was however, a difference in the Shannon diversity index (H′). This indicated that although the species count was similar for both microenvironments, the evenness of representation of the species was greater in the natural forest environment than in the immediate vicinity of the bamboo clumps. This indicated that some species are able to survive the bamboo microenvironment better than others and dominate the tree species community. The species that favoured the bamboo quadrats (*Eschweilera subglandulosa*, *Sloanea trinitensis*, *Tovomita eggersi* and *Miconia pubipetala*) were better able to survive and grow in the altered microenvironment under the bamboo. These species may have favoured the bamboo quadrats, however, they probably occur in the natural forest as well, albeit probably at a lower density. The reasons and mechanisms for their higher density in the bamboo plots were not determined in this project and need further study.

Of the common species that occurred in numbers having >20 individuals in at least one of the microenvironments, the main difference between the natural forest and bamboo quadrats was the large reduction in the numbers of *Ryania speciosa* and *Terminalia amazonia* in the bamboo. In particular, the reduction in *Ryania speciosa* would emphasize the dominance of *Pentaclethra macroloba* and *Protium guianense* in the bamboo quadrats. This appears likely to be the cause of the difference in H′ between the two microenvironments. The reasons for the reduction in numbers of *R. speciosa* and *T. amazonia* are not clear and need further work.

Ground Flora

In the ground flora quadrats there appeared to be no difference in either the average number of individuals or average number of species in the natural forest and bamboo quadrats (Table 1). There was, however, a significant difference in H′ between the two microenvironments. This indicated that the ground flora in the bamboo quadrats tended to be dominated by particular species that had disproportionally high numbers compared to the natural forest plots (for example *Pentaclethra macroloba*, *Forsteronia accoui* and *Heliconia psittacorum*). Like the 15 m x 15 m tree quadrats, the dominance of the above species is emphasized by the absence of species common in the natural forest (for example *Ryania speciosa*, *Protium guianense* and *Lacistema aggregatum*). The difference in the species composition may have been due to such factors as nearby seed trees affecting the frequency of seedlings in any plot, or differences in soil nutrient status in the plots.

For the most part, the seedlings of the trees (Fig. 5) that were found in the natural forest environment had the same preference as the mature trees (Fig. 4). An exception was *Clathrotropis brachypetala* which showed higher numbers of mature trees in the natural forest and higher number of seedlings in the bamboo quadrats. The reverse of this situation is seen in the distribution of *Sterculia pruriens*, where the trees appeared to have a greater preference for the bamboo environment and the seedlings showed a greater preference for the natural forest environment. These distributions may be a result of transient seedling populations resulting from a recent germination. Further work needs to be done to find the reasons for these distributions.

From the results obtained, the microenvironments and woody vegetation immediately surrounding *Bambusa vulgaris* were different from the surrounding forest. Of the characteristics of invasive species previously described, *B. vulgaris* had a tendency to form monodominant stands and modify the ecosystem. Bamboo, however, is not seen as a major problem in the Arena Reserve and is reported to be overtopped and outcompeted by native trees eventually (Vernon Ragbir *pers. comm.*). However, the results of this study seem to indicate that the vegetation communities in the forest were influenced by bamboo; the process of succession was likely to be slowed after the disturbance from charcoal burning; and there was a reduction of numbers of individuals of regenerating woody vegetation. In addition, the different responses of species of woody vegetation to the bamboo microenvironment indicated succession was probably deflected from the expected course in natural forest in areas close to bamboo stands.

The results also indicated the possibility of more severely disturbed forests where *B. vulgaris* forms much larger monodominant stands, and in more open deciduous forests, such as exist in Tobago, which may be more severely affected by the presence of *B. vulgaris*. This study is by no means complete and future research needs to be done to examine the relationships of single species with *Bambusa vulgaris*.

Appendix 1. List of species found during study

Species	Family	Lifeform
Bauhinia cumanensis Kunth	Leguminosae	Vine
Calophyllum sp.	Guttiferae	Tree
Carapa guianensis Aubl.	Meliaceae	Tree
Cecropia peltata L.	Moraceae	Tree
Clathrotropis brachypetala (Tul.) Kleinh	Leguminosae	Tree
Eschweilera subglandulosa (Steud ex Berg) Miers.	Lecythidaceae	Tree
Eugenia sp.	Myrtaceae	Tree
Euterpe precatoria Mart.	Palmae	Palm
Forsteronia acouci (Aubl.) A. DC.	Apocyanaceae	Vine
Heliconia psittacorum L.f.	Musaceae	Herb
Hirtella racemosa Lam.	Chrysobalanaceae	Tree
Jacaranda sp.	Bignoniaceae	Tree
Lacistema aggregatum (Berg.) Rusby	Flacourtiaceae	Tree
Macfadyena unguis-cati (L.) A.H. Gentry	Bignoniaceae	Vine
Manicaria saccifera Gaertn.	Palmae	Palm
Miconia laevigata (L.) D. Don	Melastomaceae	Shrub
Miconia pubipetala Miq.	Melastomaceae	Tree
Myrcia leptoclada DC.	Myrtaceae	Tree
Nectandra martinicensis (Jacq.) Mez.	Lauraceae	Tree
Ocotea eggersiana Mez.	Lauraceae	Tree
Olyra caudata Trin.	Gramineae	Herb
Pachira insignis Sw.	Bombaceae	Tree
Paullinia fuscescens Kunth	Sapindaceae	Vine
Pentaclethra macroloba (Willd) Kuntze	Leguminosae	Tree
Philodendron acutatum Schott.	Araceae	Vine
Pinzona coriacea Mart. & Zucc	Dilleniaceae	Vine
Protium guianense (Aubl.) March	Burseraceae	Tree
Psychotria muscosa (Jacq.) Steyerm	Rubiaceae	Shrub
Rollinia exsucca (Dun.) A. DC.	Annonaceae	Tree
Rudgea hostmanniana Benth.	Rubiaceae	Tree
Ryania speciosa Vahl	Flacourtiaceae	Tree
Schefflera morototoni (Aubl.) Maguire, Steyerm & Frodin	Araliaceae	Tree
Scleria sp.	Cyperaceae	Herb
Serjania paucidentata DC.	Sapindaceae	Vine
Sloanea trinitensis (Sandwith)	Eleocarpaceae	Tree
Sterculia pruriens (Aubl.) Schum	Sterculiaceae	Tree
Tabebuia sp.	Bignoniaceae	Tree
Tabernaemontana undulata Vahl	Apocyanaceae	Tree
Tapirira guianensis Aubl.	Annonaceae	Tree
Terminalia amazonia (J.F.Gmel.)Excell	Combretaceae	Tree
Tovomita eggersii Vesque	Guttiferae	Tree
Vismia falcata Rusby	Guttiferae	Tree

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