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Tree diversity and alien encroachment in the native forest of Black River Gorges National Park, Mauritius

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Abstract

Because native forests of oceanic islands, including Mauritius, have almost always been destroyed soon after human colonization, there exist few quantitative descriptions of species composition and diversity in such forests. For this reason, the diversity and structure of a tropical rain forest were studied in 207 plots of 100 $m^{2,}$ randomly selected, in the Black River Gorges National Park, Mauritius. The number of species recorded was 88 for native and 43 for alien species. On average there were 2375 native stems per hectare (SD = 21.8) whereas for the alien species there were 15321(SD = 101.6). The basal area for native and alien stems was calculated to be 20.2 m^2ha^{-1} and 67.8 m^2ha^{-1} respectively and was significantly different. This study clearly demonstrated that the alien species, especially *Psidium cattleianum*, were affecting the native forests negatively. The data supported the hypothesis that alien species reduce diversity, basal area and density of native species.

Keywords: Diversity, Black River Gorges National Park, Native, alien, Basal area, *Psidium cattleianum*.

Contents

Introduction

The Republic of Mauritius is located at latitude 20° south and longitude 58° east, some 800 km southeast of Madagascar in the Indian Ocean. It has no continental shelf proper, the water reaching a depth of 3000 metres within few kilometres off its coastline (Saddul, 1995). The geology is of volcanic origin and encircled by fringing coral reefs enclosing lagoons of various widths (Saddul, 1995). Mauritius is known for its spectacular plants and animals, many of which have become extinct in a very short period of time (Strahm, 1988).It took only a few centuries of clearing the land for agriculture and introducing alien species to disrupt complex ecosystems which took million of years to evolve (Strahm, 1998). The gradual decrease of native forest cover in Mauritius is illustrated in figure 1.

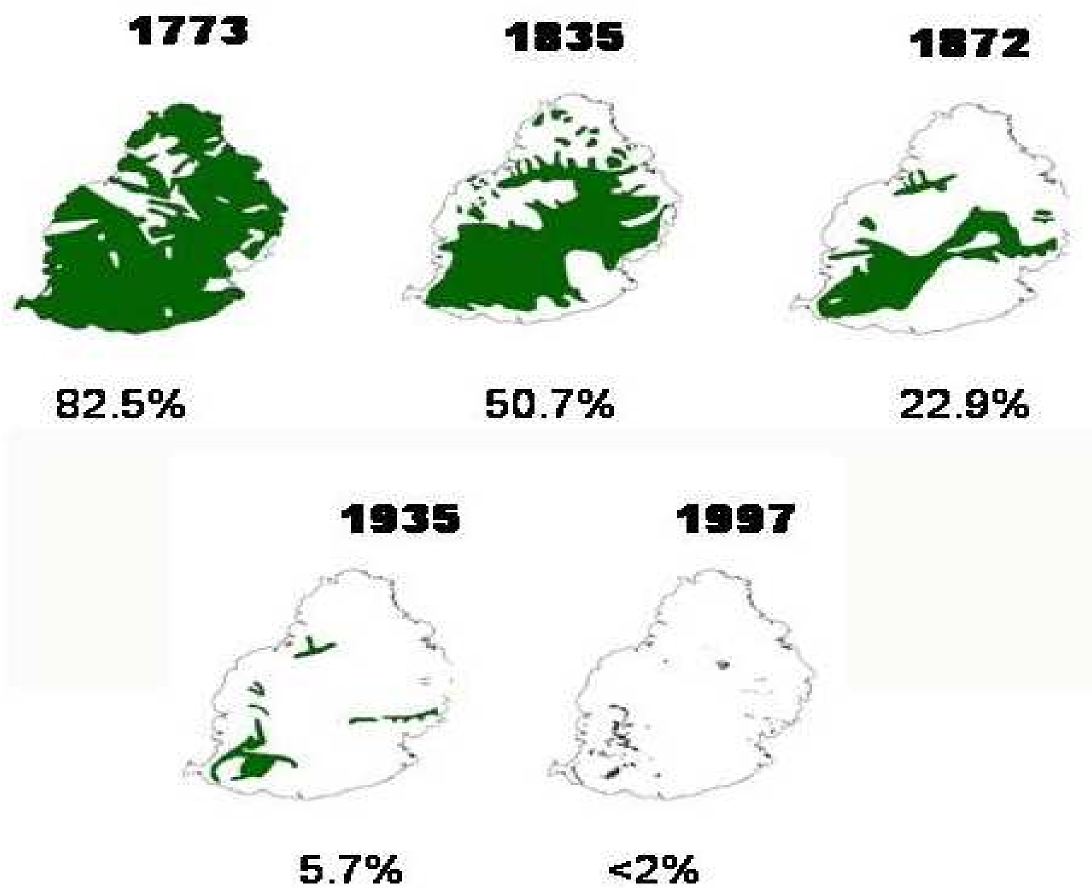


Fig. 1. State of the native forest since colonization of Mauritius (Source National Park and Conservation Services, 2006)

Biological isolation had been a major factor in the evolution of biodiversity (Clout, 1998). In isolation, different species evolved from common ancestors, special ecological relationship were built and unique ecosystems arised. Until a few hundred years ago, the faunas and floras of different part of the world mixed only through slow spread and occasional long-distance colonisation across oceans or other natural barriers and this rate of interchange was low. Human migration and colonisation began to change this slow interchange (Clout, 1998). Introduction of alien species had come to threaten biodiversity on a global scale. Many alien species invaded natural ecosystems and became ecologically and economically harmful and these were referred to as "invasive species" (Clout, 1998). The adverse changes which they caused include damage to crops, disruption of natural processes, domination of natural ecosystems and extinction of native species through competition or predation (Clout, 1998).

The faunas, floras and ecosystems which were the most threatened by invasive species were those which evolved in the greatest isolation like oceanic islands (Clout, 1998). And extinction of native species was the common result of these invasions. The process of biological invasion also seemed to be extremely linked with the fragmentation and disruption of habitats (Clout, 1998). That was because ecosystems with already depleted diversity seemed more prone to invasion. In Mauritius the alien species are now the greatest cause of extinction.

Conservation efforts started back from the 18th century. Reservation of land was carried out as early as 1750; the first "pas geometriques" were designated to protect trees around the coastline (National Parks and Conservation Services, 1998, Brouard, 1963). Furthermore in 1769, legislation required one quarter of each private concession to be kept under forest and protected trees along streams. In 1804 the mountain reserve was created and the protection of river and coastal reserves was strengthened (National Parks and Conservation Services, 1998, Brouard, 1963). These were established in Mauritius, on the basis of climatic arguments to protect the rainfall, soil erosion and to provide a sustainable timber supply (Grove, 1995). But these forward looking initiatives were poorly enforced and most of the island has been progressively developed for agriculture, forestry or other intensive uses.

Nowadays the native forests are restricted to the southwest escarpment that is not accessible or the least economically exploitable part of the island. The native forest remnants represent only 1.5% of the native vegetation (Page and D'Argent, 1997; National Parks and Conservation Services, 2006). Threats to native forests from alien species had been reported since the 1930's (Vaughan and Wiehe, 1937) though they confined their studies in native forest communities only. They classified the forests at ecosystem level describing some 15 types of forests (Strahm, 1994). Page and D'Argent (1997) classified forest quality and many studies have looked at the distribution of individual plant species (Strahm, 1994). Lorence and Sussman (1986, 1988) had the merit of creating concerns about the status of alien species and even quantified the percentage of alien species in the native forest in term of number of individual and basal area. The need for restoration of the Black River Gorges National Park forest was almost a must as Safford (1997) who conducted a survey in the remnant native vegetation of Mauritius, reported that the study area amount to 44% of the total native vegetation area.

The main gap in the study of biodiversity in Mauritius has always been insufficient biological data on the forest ecosystem and this was pointed out more clearly by the rediscovery, in the valley of Ferney, of about two plant species thought to have been extinct some 200 years ago (National Park and Conservation Services, 2006). To be able to promote sustainable restoration programme it is important to make an in-depth study of the native forest in the Black River Gorges National Park. National Park and Conservation Services (2006) identified incomplete inventory and limited research and monitoring to support adaptive management as gaps and needs for conservation and restoration of biodiversity.

In this study, woody species in the native forest of the Black River Gorges National Park, was counted and inventoried. Phytosociological parameters of the species like DBH, basal area and Importance Value was measured and calculated. The following questions were addressed:

- How many individuals and species co-exist in the Black River Gorges National Park?
- What is the relative frequency of the different species?
- How are they distributed?

Comparisons were made between natives and aliens species regarding the above questions. Then the potential threat from invasive alien species was studied paying particular attention on why they still represent threat to the native plant community of the forest. The percentage of alien vegetation (alien encroachment) of the whole area was calculated. This parameter would be a base for categorizing degradability of forest in term of alien invasion and would be a tool for prioritizing future conservation and restoration work

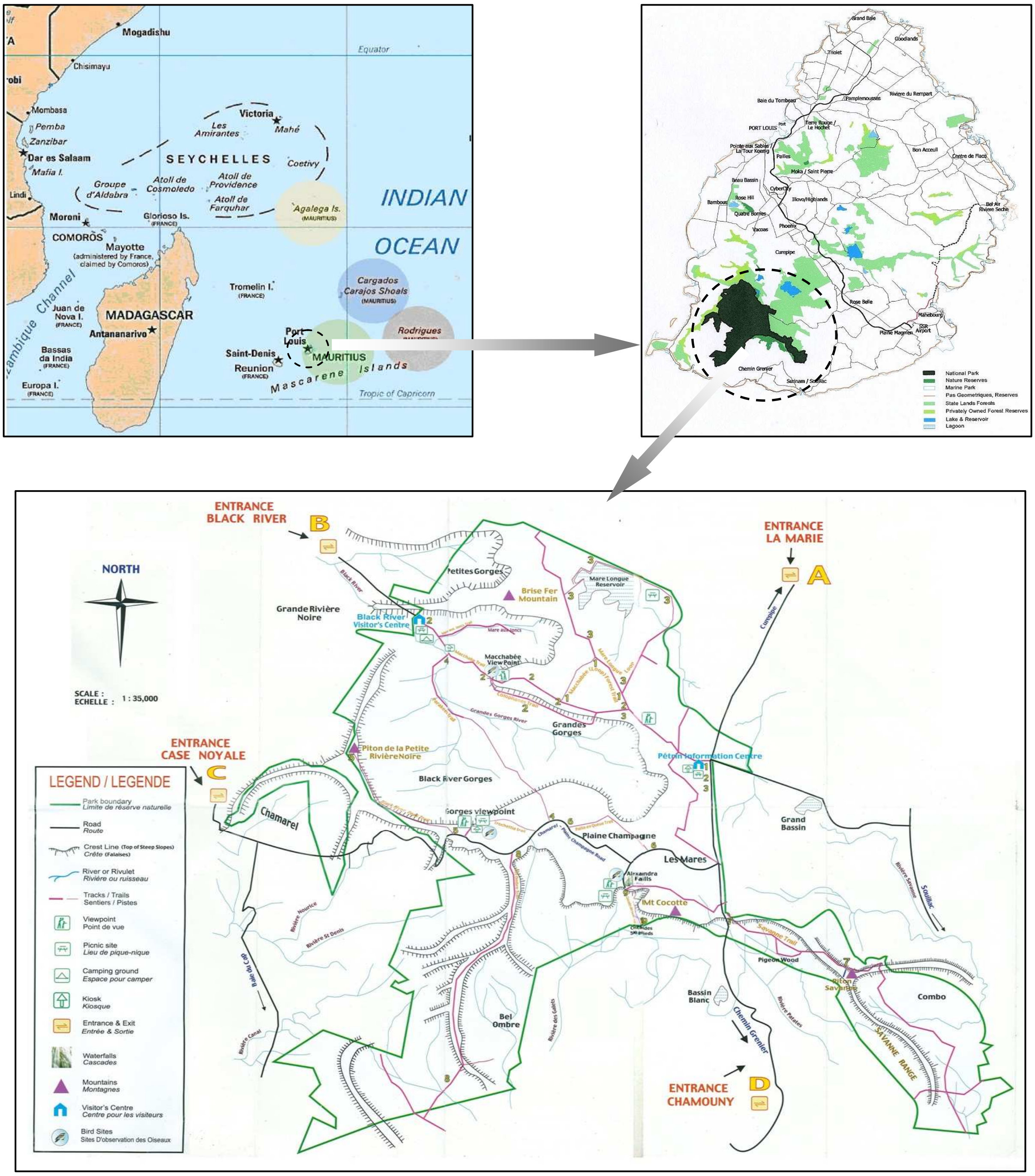
The hypothesis to be tested was that alien species greatly reduce species diversity, basal area and density of native species.

This study also examined if the decreasing trend in the density and basal area of natives reported by Vaughan and Wiehe (1937), Lorence and Sussman (1988) and Strahm (1994) is maintained despite increasing effort done todate in conservation and restoration.

Methodology

Study site

Fig. 2. Location of the study area in Black River Gorges National Park on Mauritius and the Indian Ocean (National Parks and Conservation Services, 2006)



The study was carried out in the Black River Gorges National Park (Fig. 2), Mauritius, from July 2006 to January 2007. The national park stretches from latitudes 20^0 21'S to 20^0 29'S and longitudes 57^0 22' E to 57^0 31' E, covering 65.7 km^2 of state owned land. The park includes the largest remaining tract of native forest on Mauritius (approximately 41.0 km^2) and most of the areas important for wildlife on mainland Mauritius (Jones and Hartley, 1995).

The main physical features of the park are the gorges of Riviere Noire; they are over 600 m deep and scenically magnificent. Above the gorges lies the central plateau at an elevation of about 600 to 700 m above sea level but rising to 772 m at Mt Cocotte and 828 m at Piton de la Petite Riviere Noire (the highest point of Mauritius). The area is described in more detail by Page and D'Argent (1997).

Methods

Woody vegetation was censused in plots of 100 m^2 size (4 x 25 m). All trees and bushes reaching breast height (1.3 m) and rooted in the plot were counted and the diameter at breast height (DBH) was measured. The most common alien tree, Chinese guava *P.cattleianum*, was counted only in the first 20 m^2 subplot, because it was too abundant to allow for counting in the entire plot. Measurements were taken just below small swellings or at least 0.5 m above large buttresses (Valencia et al. 2004). DBH was measured at 1.3 m vertical from ground level no matter how bended or crooked a tree was. In case a plant had many shoots, all of them that reached 1.3 m were treated as separate individuals. In the case of a slope or uneven ground, the 1.3 m stick was always placed on the south part of the plant. The methods are described in detail in Condit (1998).

All plants were identified as far as possible up to the species level. In cases where species could not be distinguished, the genus name was used and treated as one taxon in the analysis. Identification of specimens was conducted with the help of literature (Bosser et al. 1976- onwards, Atkinson and Sevathian 2005, Rouillard and Gueho 1999) and a resource person (Mr. Mario Allet, forester).

A total of 207 plots were distributed over the study area (Fig. 2). Due to inaccessibility problems, plots were distributed along major tracks. A minimum of 5 plots/km of track were surveyed so as to get a fairly representative sample of the study site given the limited time available for field work. The exact location of a plot was selected randomly, in relation to location along the track (distance from starting point), side of the track (left or right), and distance from track (between 10 and 60 m). Plots were rejected if in a steep slope, crossing a stream, or overlapping with another plot. Position and altitude of the plot was determined using GPS and altimeter.

Data analysis

To assess if the area sampled was fairly representative for the whole study site, I plotted a species accumulation curve using Species Diversity and Richness software (Henderson & Seaby, 1998). Since in all species accumulation curves, the order in which the sample were added affect the shape of the curve (Colwell, 1997), sample order was randomized 50 times to obtain a mean species accumulation curve for the study area and species sampled from all plots were pooled together. The Shannon-Wiener Index was used as a robust and simple diversity measure (Magurran 2003) and was computed using the Species Diversity and Richness software.

The methods used to describe the forest floristic composition were drawn from Mori et al. (1989). The Importance Value of a species gave an indication of the relative contribution of that species to the stand structure.

Trees were arbitrarily grouped in 9 size classes due to DBH (see Fig. 7). This classification was an important tool to analyze the forest structure in term of the distribution of the trees. The size class distribution was also used to indicate whether there was enough regeneration in the forest.

Alien species percentages were calculated in terms of number of stems and basal area. Alien species encroachment was calculated as the percentage of basal area of alien species over the total basal area of all species.

For all the above analysis, data from the 207 plots were used.

The variables in this study (basal area of all natives, basal area of all aliens, basal area of *P. cattleianum*, basal area of aliens other than *P.cattleianum*, number of all native stems, number of native species, number of all alien stems, number of alien species, number of *P. cattleianum* stems, number of alien stems other than *P. cattleianum* number of selected native species stems, altitude, and Shannon-Wiener index) were analyzed for correlation using Pearson's correlation coefficient. This analysis was conducted on managed and non-managed plots separately. The managed plots were represented by 53 plots which had only either native or alien species. Multiple regressions were performed to study relationship arising from the correlation matrix.

All statistical analysis was performed using the computer programme Minitab.

Results

Figure 3 show the study area and the distribution of the surveyed plots alongside roads and trails. There were 53 plots which have been managed and 10 of them formed part of the conservation management areas and were regularly weeded from alien species.

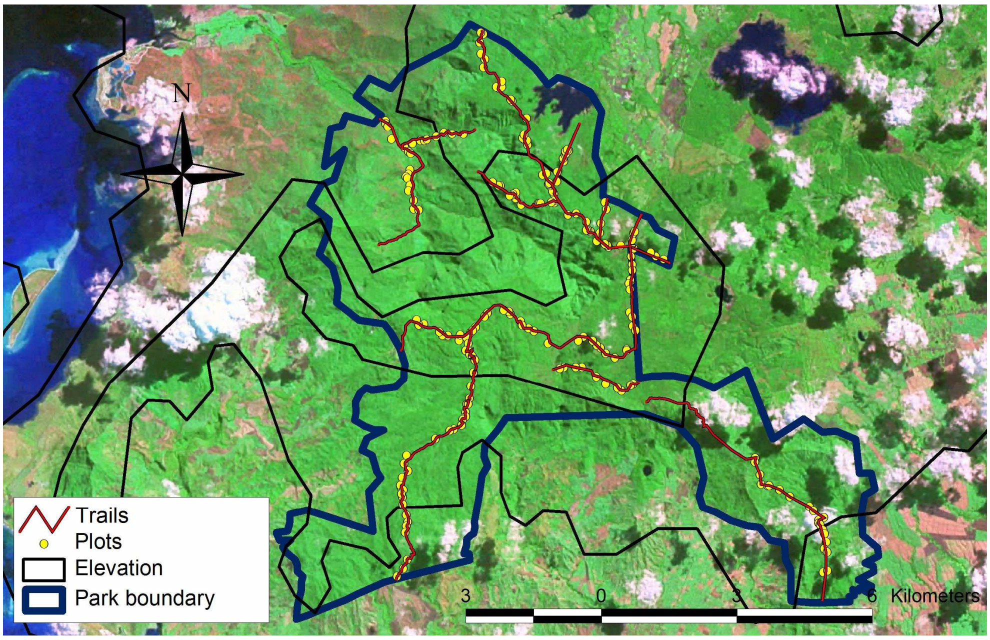


Fig. 3. The study area map with boundary, roads and trails along which the plots were surveyed

A total of 36632 stems greater or equal to 1 cm DBH were found in this study. 13.4 % of the stems identified were from the native species and the rest was composed of alien stems and forest planted trees. A list of forest planted trees is given in appendix I.

The species-area relationship suggests that the sampling area captured a fairly high proportion of the species richness that occurred in the study area, since the curve does level off at the 200^{th} quadrat (Fig. 4). It also has a steep increase in the beginning and reaches the 100^{th} species after 60 quadrats.

On average there were 2375 native stems per hectare (SD = 21.8) whereas for the alien species there were 15321(SD = 101.6). The average number of stems of trees per plot differed significantly between natives and aliens ($t = 17.92$, $df = 412$, $p < 0.0001$; Fig. 5). *P. cattleianum* was the most dominant species

representing 80 % of the number of alien stems. In the native group, the Myrtaceae and Rubiaceae were the dominant families with 10 species each followed by Euphorbiaceae (8), Flacourtaceae (7), Sapotaceae (7) and

Ebenaceae (4). There were 18 families which had only one species surveyed in the study. The alien species were represented in 27 different families and the dominant one was the Myrtaceae with 9 species. Here also as was observed in the native species, 19 families were represented by only one species. See complete list of families in appendix I.

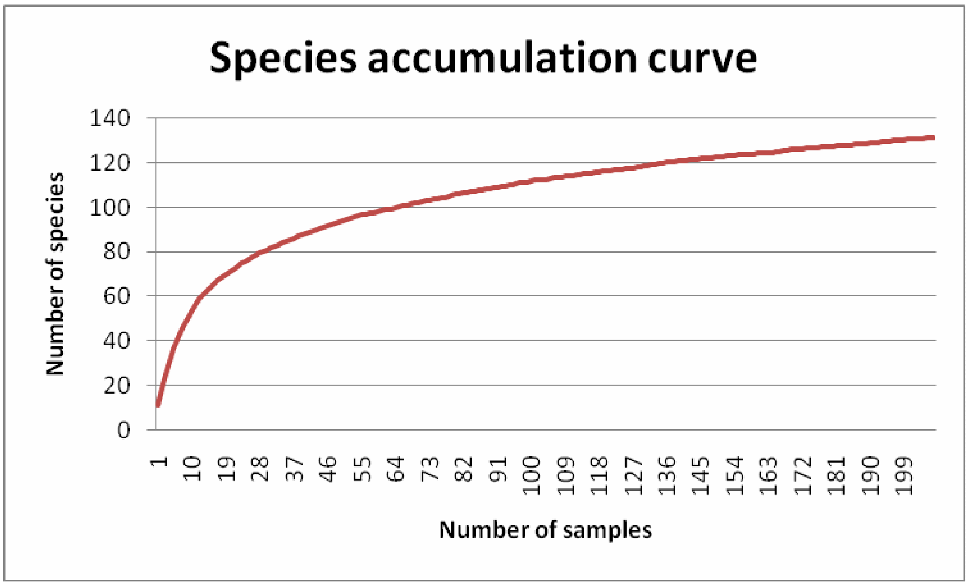
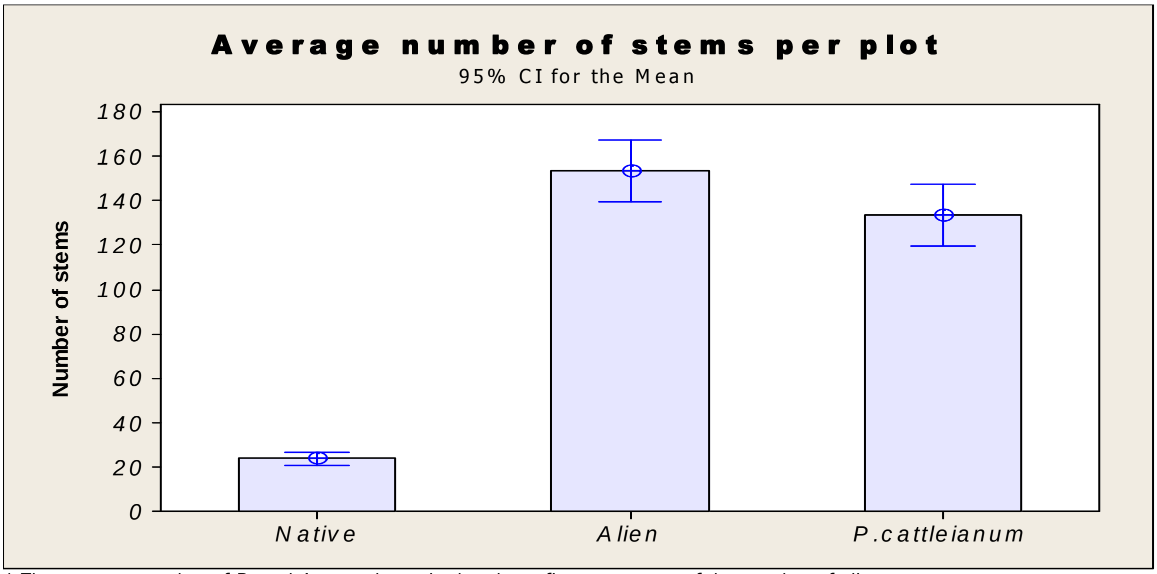


Fig. 4. Species accumulation curve for tree species in the Black River Gorges National Park, Mauritius

The mean number of native species encountered per plot was 8.2 (SD = 6.7; Fig. 6). For alien species the mean was 3.1 (SD = 2.0; Fig. 6). The means between natives and aliens were significantly different ($t = 10.29$, $df = 412$, $p < 0.001$). *Warneckea trinervis* (224 ha^{-1}) was the most abundant native in terms of number of stems, followed by *Aphloia theiformis* (161 ha^{-1}), *Sideroxylon puberulum* (114 ha^{-1}), *Olea lancea* (114 ha^{-1}), *and Securinega durissima* (108 ha^{-1}; Table 1). They altogether constituted 30.4 % of the total number of stems. Seventy-eight percent of the species were represented by less than 5 stems. The whole list of species encountered in the study is shown in appendix II.

P. cattleianum alone covered 75 % of all stems surveyed in this study. After excluding all alien species currently used in forest plantation, the most invasive species was *P. cattleianum* (Table 1). It was found in 186 quadrats and was widespread in the national park. It was absent only in conservation management areas, in plots which had recently been weeded and in some planted forest. The second most important invasive species was *Ligustrum robustum*.



* The average number of *P.cattleianum* shown in the above figure was part of the number of alien stems

Fig. 5. Average number of stems per vegetation sampling plots showing standard error of means in the Black River Gorges National Park, Mauritius

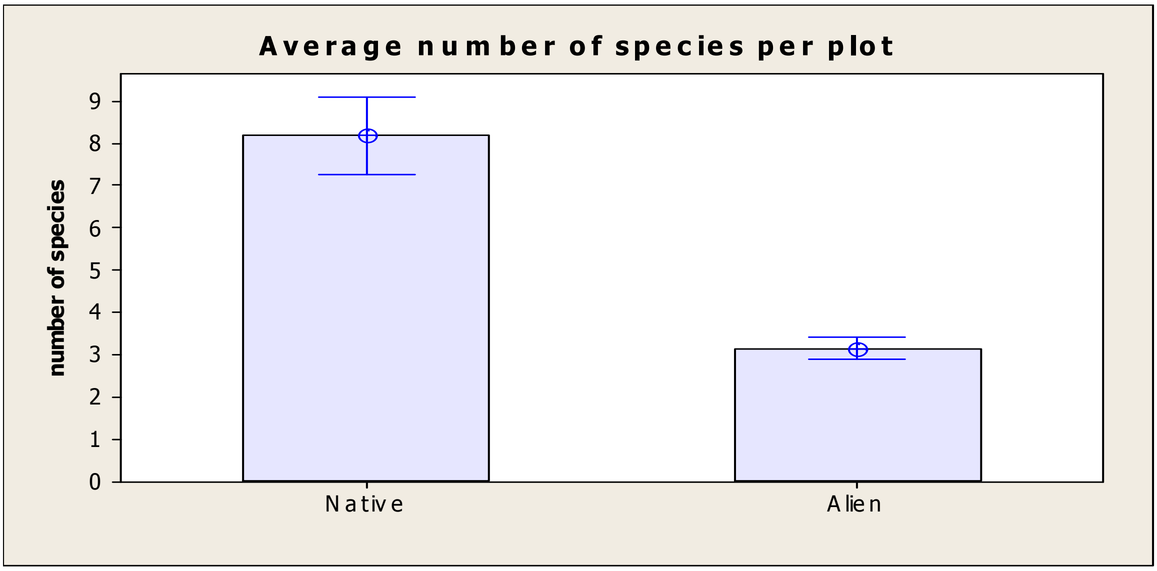


Fig. 6. Average number of species per plot surveyed in the Black River Gorges National Park and the error bars show the standard error of mean

Table 1. Distribution of stems per hectare of selected native and alien species in the study area

Native species	Number of stems per ha	Alien species	Number of stems per ha
Warneckea trinervis	224	*Psidium cattleianum*	13358
Aphloia theiformis	161	*Ligustrum robustrum* var. *walkeri*	392
Olea lancea	114	*Syzigium jambos*	248
Sideroxylon puberulum	114	*Clidemia hirta*	108
Securinega durissima	109	*Wilkstroemia indica*	93
Syzigium glomeratum	86	*Schinus terebinthifolius*	87
Gaertnera psychotriodes	82	*Ravenala madascariensis*	81
Sideroxylon cinereum	81	*Rubus alceifolius*	80
Monimiastrum globusum	78	*Homalanthus populifolius*	37
Diospyros tessellaria	73	*Litsea monopetala*	26
Nuxia verticillata	69	*Eugenia uniflora*	23
Erythrospermum monticolum var. *monticulum*	65	*Litsea glutinosa*	21
Grangeria borbonica	62	*Lantana camara*	20
Erythroxylum macrocarpum	59	*Harungana madagascariensis*	13
Calophyllum eputamen	57	*Eugenia floribunda*	13
Antirhea borbonica	55	*Hiptage benghalensis*	10
Tabernaemontana persicariaefolia	50	*Ardisia crenata*	6
Labourdonnaisia calophylloides	49	*Syzigium cumini*	6
Myonima violacea var. ovata	45	*Cinnanomum camphora*	5
Pandanus spp	45	*Rubus rosifolius*	3
Syzigium coriaceum	45	*Cordia macrostachya*	2

There was almost an inverted J distribution of DBH class intervals of natives, except for the last class where a greater number of stems was found (Fig. 7). However the effect of pooling the all the stems above 20 cm DBH into one class interval might be the reason. With selected native species, comparable results were obtained with all species except *D.tesselaria* which did not have the inverse J shape curve (Figure 8).

The number of species and the number of stems had a tendency to decrease with increasing tree size in the study area with some slight exception (Table 2). For the number of stems, the first 4 classes contributed 59 and 93 % of the total stems of native and alien species respectively. The basal area covered by native species ranged from 0 to 10379 cm^2 showing a very diverse situation, with a mean of 2019 cm^2 (SE = 159 cm^2). Significantly higher figures were obtained for alien species, which ranges from 0 to 75109 cm^2 with a mean of 6276 cm^2 (S.E = 638 cm^2).

The basal area for native and alien stems was calculated to be 20.2 m^2ha^{-1} and 67.8 m^2ha^{-1} respectively and was significantly different (t = 6.47, df = 412, p <0.0001). The five most predominant native species were *D.tesselaria, Mimusops erythroxylon, Labourdonnaisia glauca, Sideroxylon puberulum* and *Nuxia verticillata.* These 5 species contributed to the bulk basal area to the order of 36%. With the alien species, the planted forest trees as describe in appendix 1 contributed mostly to the basal area to the extent of 38%. However, *P.cattleianum* which was the most predominant alien species contributed only 9 % of total alien basal area.

Importance value calculation was shown in table 3 and 4 for the alien and native species. The 5 most important native species were *A.theiformis, W.trinervis, D.tessalaria, S.puberulum* and *O.lancea* and together they contributed to 28% of the total importance value. Data sheet with these values for all the species surveyed in the study area was given in the appendix III.

P.cattleianum was the predominant species and accounting for 42% of the total importance value. *R.madacariensis, L.robustum* and *S.jambos* were the other important alien species and remaining species from table 3 were the planted forest trees.

The most important species when all species were compounded was *P.cattleianum.* It was the most invasive species in the national park as shown by the number of stems and the Importance value, and it was found in 90% of the sampled area.

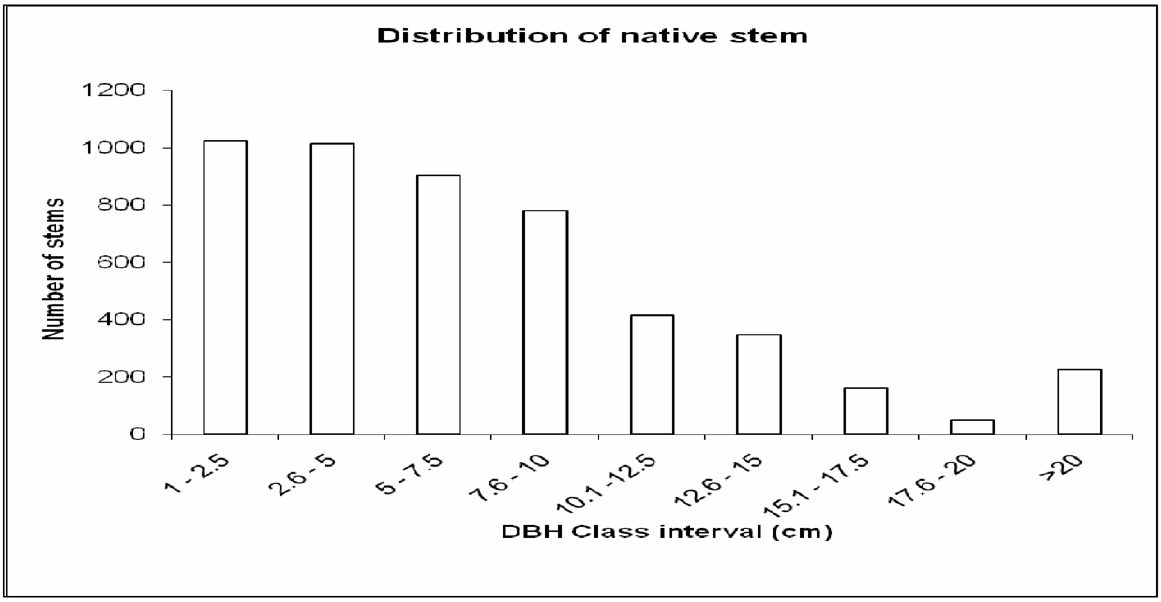


Fig. 7. The distribution of native stems sampled in the Black River Gorges National Park in a DBH class interval

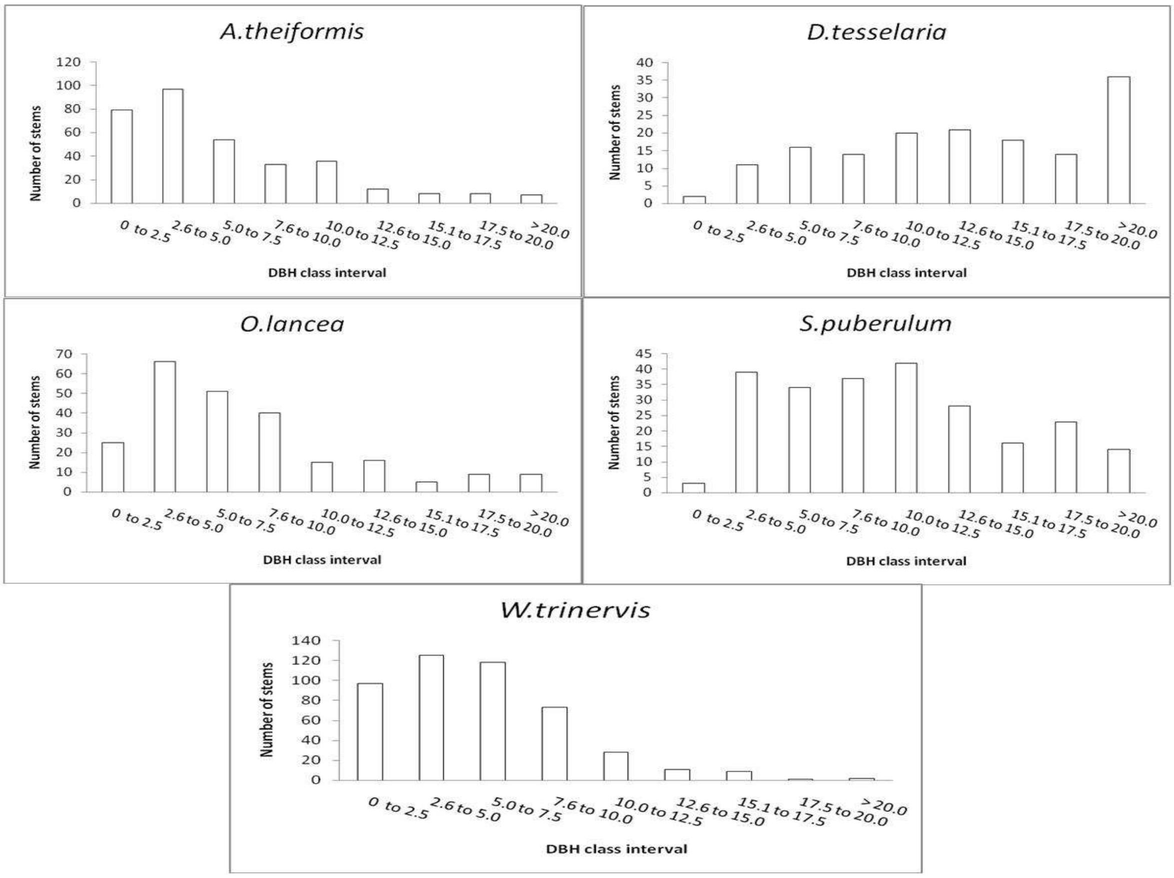


Fig. 8. The distribution of selected native stems sampled in the Black River Gorges National Park, Mauritius, in a DBH class interval

Table 2. Basal area class-wise number of species and stems for the 207 plots of Black River Gorges National Park, Mauritius

	Native Species		Alien Species	
Basal Area Class Interval	No. of Species	No. of stems	No. of species	No. of stems
0 to 10	57	1138	19	15822
11 to 20	62	890	18	11820
21 to 30	49	543	11	1718
31 to 40	52	360	8	270
41 to 50	47	250	7	86
51 to 60	43	199	9	93
61 to 70	38	156	7	21
71 to 80	42	175	8	37
81 to 90	30	87	5	25
91 to 100	42	119	5	12
>100	30	1000	32	1811

Alien species encroachment mean percentage was 57% with S.E = 2.6. *P.cattleianum* alone contributed to a mean percentage of 13 % (S.E = 1.0)

Table 3. Relative density, relative dominance, relative frequency and Importance Value of selected alien tree species in the Black River Gorges National Park, Mauritius

Species	Relative Density	Relative Dominance	Relative Frequency	Importance Value
Psidium cattleianum	87.19	9.16	28.70	125.05
Pinus elliotii	1.41	25.44	6.48	33.33
Ravenala madascariensis	0.53	11.80	4.78	17.11
Ligustrum robustum var. walkeri	2.56	1.16	13.27	16.99
Eucalyptus tereticornis	0.64	8.99	3.70	13.33
Syzigium jambos	1.62	7.00	4.32	12.94
Terminalia arjuna	0.10	8.61	1.08	9.79
Cryptomeria japonica	0.35	5.18	1.85	7.39
Eucalyptus robusta	0.25	3.40	1.70	5.35
Tabebuia pallida	0.14	3.44	1.54	5.12

Table 4. Relative density, relative dominance, relative frequency and Importance Value of selected native tree species in the Black River Gorges National Park, Mauritius

Species	Relative Density	Relative Dominance	Relative frequency	Importance Value
Aphloia theiformis	6.79	3.80	5.91	16.50
Warneckea trinervis	9.44	3.77	3.07	16.28
Diospyros tessellaria	3.09	9.10	2.07	14.26
Sideroxylon puberulum	4.80	6.48	1.77	13.05
Olea lancea	4.80	3.61	3.90	12.31
Mimusops erythroxylon	1.73	7.81	2.66	12.20
Nuxia verticillata	2.91	5.92	2.36	11.19
Securinega durissima	4.58	4.47	2.01	11.06
Labourdonnaisia glauca	1.22	6.91	2.72	10.85
Sideroxylon cinereum	3.42	3.52	1.83	8.77
Syzigium glomeratum	3.64	2.77	2.30	8.72
Labourdonnaisia calophylloides	2.07	4.11	2.42	8.61
Grangeria borbonica	2.62	3.49	2.25	8.36
Gaertnera psychotriodes	3.44	1.36	2.36	7.16
Erythrospermum monticolum var. monticulum	2.73	1.77	2.36	6.86
Calophyllum eputamen	2.42	1.80	2.48	6.70
Monimiastrum globusum	3.29	1.46	1.60	6.35
Syzigium coriaceum	1.89	2.81	1.60	6.29
Erythroxylum macrocarpum	2.48	1.81	1.95	6.24
Cassine orientalis	1.28	1.94	1.95	5.17
Ochna mauritiana	1.81	0.67	2.30	4.79
Antirhea borbonica	2.30	0.44	1.89	4.62

When native and alien species were pooled together, mean Shannon-Wiener index ranged from 0.1727 to 2.8710 with a mean of 1.0802 and S.E = 0.0030.

For native species, mean Shannon-Wiener Index was 1.4037 (S.E = 0.0731) and for alien species it was 0.409 (S.E = 0.028; Fig. 9) and they were significantly different ($t = 12.65$, $p < 0.001$ and $df = 412$).

For managed plots, Shannon-Wiener Index differed significantly from that for non- managed plots ($t = 10.16$, $p < 0.0001$ and $df = 50$; Fig. 10).

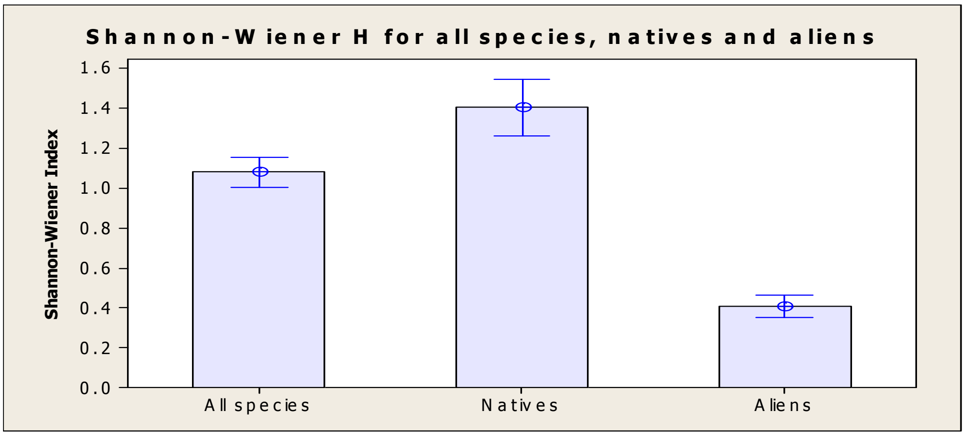


Fig. 9. Mean Shannon-Wiener index for all species encountered during the survey and also for natives and aliens species grouped separately in Black River Gorges National Park, Mauritius

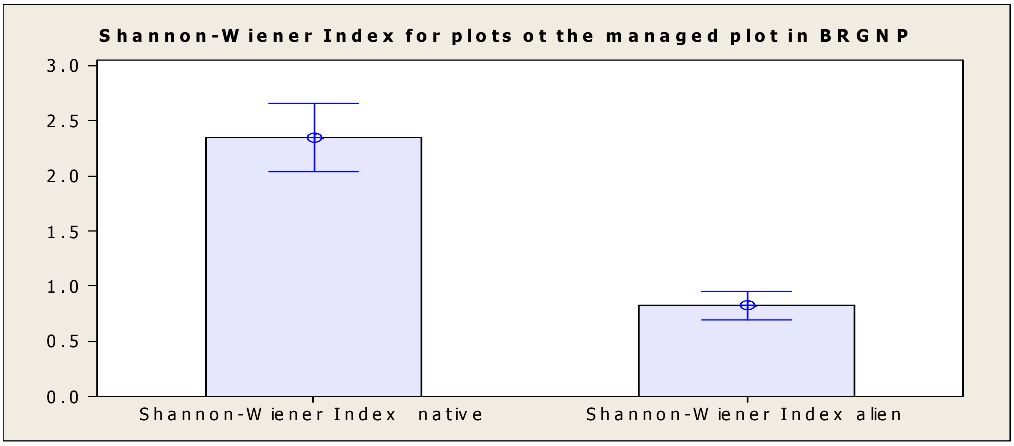


Fig. 10. Average Shannon-Wiener Index with standard errors for managed plots which contain only natives and Aliens in the Black River Gorges National Park, Mauritius

Correlation result between all the parameters of the study is shown in table 5, 6 and 7.

Table 5. Correlation results among different parameters studied in the Black River Gorges National Park, Mauritius

Parameters	Positive correlation	Negative correlation
Basal Area of all Natives	Basal area *P.cattleianum* Number of all native stems Number of all native species Number of *D. tesselaria* stems Shannon-Wiener Index for all species Shannon-Wiener Index for native only	Basal area of all Alien Basal area of alien other than *P. cattleianum* Number of all alien species Number of alien stem other than *P. cattleianum* Shannon-Wiener Index for alien species only
Basal area Alien	Basal area of alien other *than P. cattleianum* Number of all Alien species Number of alien stems other than *P. cattleianum* Shannon-Wiener Index of Alien only	Number of all native stems Number of all native spp. Number of *O.lancea* stem Number of *S.puberulum* stem Altitude Shannon-Wiener Index of all species
Basal area *P. cattleianum*	Number of all alien stem Number of *P.cattleianum* stems	Shannon-Wiener Index of all species Shannon-Wiener Index of alien only

Table 6. Correlation results among different parameters studied in the Black River Gorges National Park, Mauritius

Parameters	Positive correlation	Negative correlation
Number of all native stem	Number of all native species Number of *D. tesselaria* stem Number of *A. theiformis* stem Number of *O. lancea* stem Number of *S. puberulum* stem Number of *W. trinervis* stem Altitude Shannon-Wiener Index for all species Shannon-Wiener Index for native only	Number of all alien stem Number of alien stem other than *P. cattleianum* Shannon-Wiener Index of alien only
Number of all native species	Number of *D. tesselaria* stem Number of *A. theiformis* stem Number of *O. lancea* stem Number of *S. puberulum* stem Number of *W. trinervis* stem Altitude Shannon-Wiener for native only	Number of all alien species Number of other alien stem than P. cattleianum Shannon-Wiener Index for Alien only
Number of all alien stem	Number of *P. cattleianum* stems Number of *S. puberulum* stem	Number of *D. tesselaria* stem Shannon-Wiener Index for all species Shannon-Wiener for alien only
Number Of all alien species	Number of alien stem other than *P. cattleianum* Shannon-Wiener Index for alien only	Number of *O. lancea* stem Number of *S. puberulum* stem Altitude Shannon-Wiener Index for native only

Table 7. Correlation results among different parameters studied in the Black River Gorges National Park, Mauritius

Parameters	Positive correlation	Negative correlation
Number of *P. P.cattleianum* stems	Number of *A. theiformis* stem Number of *O. lancea* stem Number of *S. puberulum* stem Altitude	Shannon-Wiener Index for all species Shannon-Wiener Index for alien only
Number of alien stem other than *P. cattleianum*	Shannon-Wiener Index for alien only	Number of *O. lancea* stem Number of *S. puberulum* stem Altitude Shannon-Wiener Index for native only
Number of *D. tesselaria* stem	Shannon-Wiener Index for all species Shannon-Wiener Index for native only	Number of *O. lancea* stem Number of *S. puberulum* stem Altitude
Number of *O. lancea* stem	Altitude Shannon-Wiener Index for all species	Shannon-Wiener Index for alien only
Number of *S. puberulum* stem	*O. lancea* stem *W. trinervis* stem Altitude Shannon-Wiener Index for native only	Shannon-Wiener Index for alien only
Number of *W. trinervis* stem	Shannon-Wiener Index for native only	
Altitude	Shannon-Wiener Index for native only	Shannon-Wiener Index for alien only
Shannon-Wiener Index for all species	Shannon-Wiener Index for native only Shannon-Wiener Index for alien only	

Correlation matrices for managed plots are shown in appendix IV. For the managed plots with only alien species, the basal area of alien other than *P. cattleianum* was highly positively correlated to basal area of alien species.

O. lancea stems was highly correlated to those of *S. puberulum* and there was also positive correlation between *D. tesselaria* stems and *W. trinervis* in the managed plots with native species only. There was also a negative correlation between the number of *W. trinervis* and altitude.

The number of native species per plot increased with altitude (Pearson correlation; $r=0.616$, $p<0.0001$). When controlled for the effect of altitude, the number of native species decreased with an increasing number of alien species (multiple regression; coef=-1.828, $t=-8.78$, $p<0.0001$). However basal area is not correlated with altitude ($r = - 0.074$, $p= 0.288$).

Discussion

This study clearly demonstrated that the alien species, especially *P. cattleianum*, were affecting the native forests negatively. The data supported the hypothesis that alien species reduce diversity, basal area and density of native species.

There was a limitation in this study as for convenience and security; the survey was carried out along tracks and trails within a range of ten to sixty metres. It was assumed that beyond the 60 m perpendicular to the track, the vegetation was homogeneous. It should be noted that this area was a natural reserve since the 1950's and there were restricted zones and no exploitation was allowed. Even though Lorence and Sussman (1988) reported that invasion by *P.cattleianum* continued as they were dispersed by alien animals and birds.

The sample area needed to provide an accurate representation of diversity in tropical forests have been much discussed (Ashton 1965; Riswan 1987; Richards 1996). Ashton (1965) has suggested an area between 2 and 5 ha as a suitable area, although Sist and Saridan (1998) have found that 12 ha were not enough. As documented by Gentry (1982, 1986) sample of 1000 m^2 of tropical forest gave an adequate idea on number of species and its diversity when individual greater or equal to 2.5 cm DBH were recorded. Although Gentry (1982) estimated that areas over one km^2 may be necessary for a species/area curve to reach an asymptote in some Neotropical forest, the curve from this study showed considerable leveling off. In fact the shape of the curve adopted the classic form, that is, a rapid increase in the number of species encountered initially, but as the area increased the curve leveled forming a plateau at the point of maximum number of species which exist in an area. This showed that the area sampled had captured the bulk of the diversity, and that additional sample could have added only a few more species but would involve a greater sampling effort at a much higher cost.

This study showed a comparatively lower number of native stems ha^{-1} (2375) compared to 19370 stem ha^{-1} (Vaughan and Wiehe, 1937) and 11370 stem ha^{-1}(Strahm, 1988). This lower figure was probably because the other authors surveyed plots which were weeded regularly for a long time. However, the control unweeded plot set by Strahm yielded 3390 stems ha^{-1}. This clearly demonstrated a negative effect of alien species on the number of stems of natives. Other studies in Mauritius upland forest showed a lot of variation in terms of density of native plants. Such examples are from 7760 to 13530 (Strahm, 1994), 7150 (Lorence and Sussman, 1988), 6490 to 14290 (Ramlagun, 2003), 6106 to 12473 (Seegoolam, 2005), 1050 (Zmanay, 2004).

The density of trees in the study area remain the most dense forest as has been confirmed earlier Vaughan and Wiehe (1937), Lorence and Sussman (1988) and Strahm (1994). They all concluded that it was the natural response to cyclones which occur frequently in Mauritius. Moreover the Upland forests are very deficient in lianas (Strahm, 1994) which give them more stability and thus to be able to resist gust of more than 200 $kmhr^{-1}$, the natives adapted by growing closer to each other. There is a downward trend in the number of native stems when comparing results from previous studies and mine and to preserve the status of the national park forest, this trend has to be reversed or else degradation would be the ultimate fate.

The density of alien species which was very high indicated a very high degree of invasibility of the forest, mainly from the *P. cattleianum*. This species is forming dense thicket in many areas of the national park. Vaughan and Wiehe (1937, 1941) stated that invasion by alien was already a serious problem in the 1930's although they did not include the aliens in their surveys. Lorence and Sussman (1986) demonstrated in their study that even in the absence of cutting and direct disturbances, invasion is a serious problem in the Mauritius upland forest. They are shade tolerating species, thriving well in the under-storey and has other dispersal mechanisms. They were mainly dispersed by feral pigs and alien birds. The aliens, although constituting a very small number of species, vastly outnumbered the natives in terms of number of stems as shown in this study. In selected sites, Lorence and Sussman (1988) found that the aliens comprised 74 to 97 % of the total stems, which is in the same range as in the present study (86.5 %). Other comparable results are from 89 % in Macchabe (Motala, 1999), ranging from 84 to 89 % (Ramlagun, 2003) and 81 to 91 % by Seegoolam (2005). However Zmanay (2004) found that in Bel Ombre the invasion is 70 % and he explained that was because the invasion was recent there. So 70% of the upland forest had more than 50% alien invasion which showed how precarious were the native forests.
The second most important alien in term of density is *L. robustum* and according to my personal observation during the field work, it occupies mainly slopes. It was suspected to be of allelopathic nature by Strahm (1994). *L. robustum* remained a major alien in neighbouring Reunion Island and had a

density of 15000 stems ha-1 in the forest of Cilaos, Reunion (Mc Donald et al, 1991). Laboratory test on allelopathy effect of *L. robustum* did show that it inhibits the germination of tomato seeds (Lavergne, 1998) and he inferred that leaves and fruit decomposing in the litter might inhibit the development of native seeds and seedlings.

The distribution of native stem in the sample showed that there is no great dominance from any species. *A. theiformis* constitute of about 9% of all the

stems surveyed in this study. The 10 dominant species occupied 47% and the rest by 78 species. It was worth noting the high percentage of species which were represented by less than 5 stems (29%) and 11 species had one stem in the whole sample area.

Size class distribution of the natives in the sample showed an inversed J-shaped curve (Whitmore, 1998). The normal J-shape curve showed that there was regeneration occurring and it was similar to that of Neotropical forests in Amazonia (Mori et al, 1989). However it should be noted that the majority of the alien ranged in the smallest class interval and outnumbered the natives. This implies that there was greater competition with the natives' recruitment which might affect the regeneration of the natives. *D.tesselaria* however seemed not to be regenerating like the other selected species. So it should be given more priority in restoration strategy and there is a need for further studies to investigate thoroughly the matter.

The trend of decreasing diversity with increasing basal area class is similar to that observed by Paijmans (1970) in New Guinea, Jeffre and Veillon (1990) in New Caledonia, Newbery et al. (1992) in Malaysia and Hara et al. (1997) in Taiwan.

Vaughan and Wiehe (1941), Lorence and Sussman (1988) and Strahm (1994) recorded high values for basal area of natives. Recent studies in the national park's forest in selected sites gave 40 to 49 m^2ha^{-1} (Ramsing, 2003), and 23 to 64 m^2ha^{-1} (Ramlagun, 2005). The result of 20.2 m^2ha^{-1} obtained from the present study were considerably lower than the above studies. The average value for tropical forests was around 32 m^2ha^{-1} (Mabberley, 1993). Gentry (1998) did note that African forests had the tendency to have more large trees and high basal area. He reported basal area to be 70.7 m^2ha^{-1}. Kolongo et al, (2006) recorded 89.3 in the Tai National Park, Cote D'Ivoire.

So this study clearly demonstrates that the basal area of forests of Mauritius have been declining with time to about 10% of what it was in the 1930's. According to Smiet (1992), basal area values may be related to the stand disturbance. So, in heavily disturbed forest stands the basal area is lower than in undisturbed stands. If the assumption that high basal area was an adaptation to cyclones, then I could assume that since there was a decrease in the basal area, the Upland forests would be more prone and susceptible to damage by cyclonic winds. Vaughan and Wiehe (1937) did raise the alarm and it was after their studies that the areas were set aside as protected reserves. But no active management was practiced and Lorence and Sussman (1988) reported that invasion was still proceeding on in the reserve even in the

absence of disturbances. It was in 1994 that the study area was decreted a managed and protected park.

P. cattleianum was the most important species among the aliens, constituting 42% of the Importance Value It had the highest relative density as it had the highest number of stems, highest relative frequency being present in the maximum number of plots but only third in relative dominance as they were mostly represented in thicket of small DBH. Moreover when pooled together with all species occurring in the national park, it came to have the highest importance value, thus being the most important species.

The nine most important native species (Importance Value > 10) dominated the forest stands and they contributed to 39% of the total importance value. But none of them alone contributed to more than 5% of importance value. This was in total contradiction with previous studies conducted in selected sites in the national park. Ramsing (2003) reported an importance value of 25.7 for *C. orientalis* in Brise Fer and 23.1 for *S. durissima* in Mare Longue. Moreover at Brise Fer, only *D. tesselaria* was found in the 5 most important species and only *A. theiformis* for Mare longue. Seegoolam (2005) too reported higher importance value of 21.2 for *N. verticillata* in Macchabe and 22.8 for *S.glomeratum* in Mare Longue.

The Shannon-Wiener Index varied a lot among plots, showing great heterogeneity in the study area. The average Shannon-Wiener index is lower than found by Seegoolam (2005) which ranges from 3.1 to 3.5 in Mare Longue, Macchabe and Brise Fer. It was in the same range as in the Eastern Himalaya, India which ranged from 0.7 to 2.0 (Bhuyan et al, 2003) and to that in Madagascar (0.89 to 3.1) reported by Brown and Gurevitch (2004). Result in this study was lower to those reported in African forest, 3.3 in Kenya (Fashing et al, 2004) and ranged from 4.6 to 5.1 in Campo-Ma'an rainforest of Cameroon (Tchouto et al, 2006). Asian forest also had higher values as in Gorakhpur, India, 3.9 was recorded by Pandey and Shukla (2003), 3.5 in the Jaintia Hills, Meghalaya India (Upadaya et al, 2003), 2.4 to 3.1 in the Eastern Ghats, India (Kadavul and Parthasarathy, 1999). Langhaberger et al. (2006) reported a range of 2.2 to 3.9 in Philippines.

This lower figure was due to the fact that the native forest had lesser number of species than the other forests surveyed. Another interesting finding was that the Shannon-Wiener index for natives was higher than when all species were pooled together. This would be another good reason for controlling aliens: to obtain a richer forest in term of native species.

Basal area of natives increased with increase in number of native stems, number of *D. tesselaria* and surprisingly with basal area of *P. cattleianum*. This suggested that basal area of P. cattleianum increased with increase of native basal area. However, even though the number of *P. cattleianum* outnumbered considerably the native stems, the basal area of *P. cattleianum* constituted only about 9% of the total alien's basal area. The majority of *P. cattleianum* were found in the lowest DBH class interval. Zmanay (2004) reported no correlation between basal area of native and alien, but recorded a positive correlation of basal area of aliens with basal area of understorey natives. This was a clear indication that most of the damage were done to the understorey species as *P. cattleianum* was better adapted to shade and were outcompeting the natives in that canopy area. Ramlagun (2003) reported high negative correlation between basal area of native and alien in Macchabe and Mare Longue but no significant correlation in Brise Fer. Seegoolam (2005) recorded positive correlation in Macchabe, negative correlation in Mare Longue and no correlation in Brise Fer. These results clearly indicated the heterogeneous nature of the forests in the national park. Similarly as stated earlier, they were studying selected sites whereas the present study was conducted to be somewhat more representative of the whole area.

Another interesting aspect was with basal area of *P. cattleianum* which was negatively correlated to both Shannon-Wiener Index of all species and that of alien too. This index, being components of number of stems and species, decreased with basal area of *P. cattleianum*. So it was a clear indication that there was a negative impact on number of stems and species of other alien. It can also infer that when removing *P. cattleianum* stems from a stand care must be taken that it is not replaced by another alien species. Huenneke and Vitousek (1990) reported basal area of *P. cattleianum* to be a maximum of 66.9 $cm^2 m^{-2}$ at an altitude of 610 m but this decreased in upper altitude of 762m.

As expected the number of stems and number of species decreased when number of stems of aliens and number of species of aliens other than *P. cattleianum* increased. So there was intense competition between native and alien species and it was more severe with the understorey species and also with rare native species.

The number of other alien's stems was negatively correlated to number of native stems like *O. lancea* and *S.puberulum*. The other aliens were negatively correlated to native species thus could be more invasive in the lowland where *P. cattleianum* is not predominant. This study found that *D. tesselaria* was negatively correlated to altitude confirming historical records that it was dominant in the lowlands. *D. tesselaria* was not associated with *O. lancea* and *S. puberulum* which were more of the upland forest's species.

No relationship was found when analyzing the ten managed plots with native only except a high positive correlation between *O. lancea* and *S. puberulum*. However these results could well be non representative of the area as number of plots were small. In the analysis of the 43 managed plots with alien species only, the number of alien stems was negatively correlated with altitude as it was for the non-managed plots.

The native forests of national park contain an astonishingly high proportion of endemic trees but have a somewhat lower endemicity with herbs and shrubs (Cheke, 1987). In addition, the isolation from the continent had made it a flora with a quite different balance of families from elsewhere. If the flora is to be saved, together with the endemic fauna, the forests themselves need to be saved which means somehow reversing the progressive degradation from alien plants and animals.

Conclusion

There is a clear tendency that number of native stems and basal area had decreased considerably during the past 60 years. The alien encroachment kept on increasing thus degrading more and more the native forests with possible negative effect in the ecosystem functions that the native forest were providing.

If nothing more than actual conservation and restoration is done now, the native forest might reach a point where it can lose its resilience and completely change from a diverse native forest to a monotypic thicket of *P. cattleianum*.

Recommendations

Further studies in ecology of alien invasive species are needed in the short term. Dispersal mechanism and establishment of alien species can be included. These studies will give a better understanding of these species and will help in minimizing their negative effect in native forest.

Further studies to investigate *D.tesselaria* and some emergent species regeneration should be envisaged. Their reproduction and survival should be studied.

Population dynamics of both native and alien species should be studied in order to plan long term conservation and restoration work in the national park. Monitoring of the study area should be established routinely in the short term.

A complete inventory of all species found in the national park should be carried out in the near without any limitation as discussed in this study.

Restoration of this native forest should be enforced and should not be limited to the park but can be extended to mountain slopes and hills of Mauritius with *D.tesselaria* as the main target species.

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Appendix 1. List of aliens surveyed in the Black River Gorges National Park, Mauritius, which are used for other purpose

Species	Main Use	Number of stems
Pinus elliottii	Timber	446
Bambusa spp	Ornamental	300
Eucalyptus tereticornis	timber	204
Cryptomeria japonica	Timber	112
Eucalyptus robusta	Timber	80
Tectona grandis	Timber	49
Pinnus spp	Timber	46
Tabebuia pallida	Timber	43
Terminalia arjuna	Timber	33
Cupressus spp	Ornamental and timber	25
Callistemon citrinus	Ornamental	24
Vitex glabrata	Timber	23
Euphorbia longan	Fruit	16
Mangifera indica	Fruit	11
Albizia procera	Timber and fodder	6
Acacia farnesiana	Timber and erosion control	2
Jatropha curcas		2
Artocarpus heterophyllus	Fruit and timber	1
Camellia sinensis	Manufacture of tea	1
Dipterocarpus spp	Timber	1
Psidium guajava	Fruit	1
Terminalia catappa	Timber	1

Appendix 2. List of species surveyed in Black River Gorges National Park, Mauritius

Scientific Name	Family	Number of stems
Acalypha integrifolia Willd	Euphorbiaceae	19
*Acantophoenix rubra (*Bory) H. Wendl.	Arecaceae	1
Antidesma madagascariense Lam.	Euphorbiaceae	34
Antirhea borbonica J.F. Gmelin	Rubiaceae	113
Aphloia theiformis Vahl Benn.	Flacourtiaceae	334
Apodytes dimidiata E. Meyer ex Arn.	Icacinaceae	6
Bertiera zaluziana Gaertner. F.	Rubiaceae	59
Calophyllum eputamen P.F. Stevens	Clusiaceae	119
Canarium paniculatum (Lam.) Benth. Ex Engl.	Burseraceae	13
Casearia coriacea Vent.	Flacourtaceae	2
Cassine orientalis Jacq.	Celastraceae	63
Chassalia coriacea Verde.	Rubiaceae	7
Cnestis glabra Lam.	Connaraceae	61
Colea colei (Bojer ex Hook.) M.L. Green	Bignoniaceae	6
Cordemoya integrifolia (Willd.) Pax	Euphorbiaceae	44
Cossinia pinnata Commerson ex Lam.	Sapindaceae	5
Croton grangerioides Bojer ex Baillon	Euphorbiaceae	3
Cyathea borbonica Desv.	Cyatheaceae	58
Doratoxylon apetalum var diphyllum (Poir.) Radlk.	Sapindaceae	1
Diospyros boutoniana DC.	Ebenaceae	1

Diospyros egratterum I.B.K. Richardson	Ebenaceae	9
Diospyros revaughanii I.B.K. Richardson	Ebenaceae	5
Diospyros tessellaria Poiret	Ebenaceae	152
Dracaena concinna Kunth	Dracaenaceae	4
Dracaena reflexa Lam.	Dracaenaceae	11
Erica brachyphylla Benth.	Ericaceae	10
Erythrospermum monticolum Thouars. *var. amplifilium* (Thouars) Sleumer	Flacourtaceae	4
Erythrospermum monticolum Thouars *var. monticulum*	Flacourtaceae	134
Erythrospermum monticolum Thouars *var. pyrifolium (*Lam. Ex Poiret) Sleumer	Flacourtaceae	7
Erythroxylum macrocarpum O.E. Schulz	Erythroxylaceae	122
Eugenia lanceolata Lamk.	Myrtaceae	1
Eugenia lucida Lam.	Myrtaceae	19
Eugenia tinifolia Lam.	Myrtaceae	25
*Faujasiopsis fluxiosia (*Lam.) C. Jeffrey	Compositae	52
Fernelia buxifolia Lam.	Rubiaceae	29
Ficus reflexa Thunb.	Moraceae	3
Gaertnera calophylloides	Rubiaceae	89
Gaertnera petrenensis Verde	Rubiaceae	4
Gaertnera psychotriodes (DC.) Baker	Rubiaceae	169
Geniostoma borbonicum (Lam.) Sprengel	Loganiaceae	80
Grangeria borbonica Lam.	Chrysobalanaceae	129
Helichrysum proteoides (Lam.) Baker	Asteraceae	10

Homalium paniculatum (Lam.) Baillon	Flacourtiaceae	3
Hugonia tomentosa Cav.	Linaceae	6
Labourdonnaisia calophylloides Bojer	Sapotaceae	102
Labourdonnaisia glauca Bojer	Sapotaceae	60
Lantania loddigesii Mart	Arecaceae	1
Lautembergia neraudiana (Baillon) Coode	Euphorbiaceae	48
Lomatophyllum purpureum (Lam.) Dur. & Schinz	Asphodelaceae	1
Ludia mauritiana J.F. Gmelin	Flacourtaceae	24
Macaranga mauritiana Bojer ex Muell. Arg.	Euphorbiaceae	1
Mimusops erythroxylon Bojer ex DC.	Sapotaceae	85
Mimusops petiolaris (DC.) Dubard	Sapotaceae	1
Molinaea alternifolia Willd.	Sapindaceae	38
Monimiastrum globusum Gueho & A.J. Scott	Myrtaceae	162
*Myonima violacea (*Lam.) Verde var. ovata (Poiret.) Verde	Rubiaceae	93
Myonima violacea (Lam.) Verde var. *Violacea*	Rubiaceae	3
Nuxia verticillata Lam.	Loganiaceae	143
Ochna mauritiana Lam.	Ochnaceae	89
Olea lancea Lam.	Oleaceae	236
Pandanus eydouxia Balfour.f.	Pandanaceae	14
Pandanus rigidifolius Vaughan & Wiehe	Pandanaceae	1
Pandanus spp	Pandanaceae	93
Phylica nitida Lam.	Rhamnaceae	2
Pittosporum senacia Putterl. ssp. Senacia	Pittosporaceae	1

Pleurostylia leucocarpa Baker	Celastraceae	24
Psathura sp	Rubiaceae	30
Protium obtusifolium (Lam.) Marchand	Burseraceae	11
Psidia viscosia (Lam.) A.J. Scott	Asteraceae	6
Psiloxylon mauritianum (Bouton ex Hook. f.)Baillon	Myrtaceae	3
Securinega durissima J.F. Gmelin	Euphorbiaceae	225
Sideroxylon cinereum Lam.	Sapotaceae	168
Sideroxylon puberulum DC.	Sapotaceae	236
Sideroxylon sessiliflorum (Poiret) Capuron ex Aubreville	Sapotaceae	6
Sophora tomentosa L.	Fabaceae	1
Stillingia lineata var *lineata* (Lam.) Muell. Arg.	Euphorbiaceae	59
Syzigium commersonii Gueho & A.J. Scott	Myrtaceae	34
Syzigium coriaceum Bosser & Gueho	Myrtaceae	93
Syzigium glomeratum (Lam.) DC.	Myrtaceae	179
Syzigium mauritianum Gueho & A.J. Scott	Myrtaceae	19
Syzigium petrenense Bosser & Gueho	Myrtaceae	2
Tabernaemontana persicariaefolia Jacq.	Apocynaceae	103
Tambourissa cordifolia D. Lorence	Monimiaceae	12
Tambourissa peltata R.Br.ex Baker	Monimiaceae	2
Toddalia asiatica (L.) Lam.	Rutaceae	6
Trochetia triflora DC.	Sterculiaceae	1
Vepris lanceolata (Lam.) G. Don	Rutaceae	9
*Warneckea trinervis (*DC.) Jacq.-Fel.	Melastomataceae	464
Acacia farnesiana L.	Mimosoideae	2

Albizia procera (Roxb.).Benth.	Fabaceae	6
Ardisia crenata Sims.	Myrsinaceae	13
Artocarpus heterophyllus Lam.	Moraceae	1
Bambusa spp	Poaceae	300
Callistemon citrinus (Curtis) Skeels	Myrtaceae	24
Camellia sinensis (L.) O. Kuntze	Theaceae	1
*Cinnanomum camphora (*L.) Presl	Lauraceae	11
Clidemia hirta (L.) D. Don	Melastomataceae	224
Cordia macrostachya (Jacq.) Roemer & Schultes	Boraginaceae	4
Cryptomeria japonica (Thunberg ex Linnaeus f.) D. Don	Taxiodaceae	112
Dipterocarpus spp	Dipterocarpaceae	25
Eucalyptus robusta J.E. Smith	Myrtaceae	1
Eucalyptus tereticornis J.E. Smith	Myrtaceae	80
Eugenia floribunda L.	Myrtaceae	204
Eugenia uniflora L.	Myrtaceae	27
Euphorbia longana Lam.	Sapindaceae	47
Harungana madagascariensis Lam. Ex Poiret	Clusiaceae	16
Hiptage benghalensis (L.) Curz	Malpighiaceae	27
Homalanthus populifolius Graham	Euphorbiaceae	20
Jatropha curcas L.	Euphorbiaceae	77
Juniperus bermudiana L.	Cupressaceae	2
Lantana camara L.	Verbenaceae	41
Ligustrum robustum Blume var. *walkeri* (Decaisne) Mansf.	Oleaceae	811
Litsea glutinosa (Lour.) C.B. Robinson	Lauraceae	44
Litsea monopetala (Roxb.) Pers.	Lauraceae	54

Mangifera indica L	Anacardiaceae	11
Pinnus spp	Pinaceae	46
Pinus elliottii Engelm.	Pinaceae	446
Psidium cattleianum Sabine	Myrtaceae	27651
Psidium guajava L.	Myrtaceae	1
Ravenala madascariensis Sonnerat	Musaceae	167
Rubus alceifolius Poiret	Rosaceae	165
Rubus rosifolius J.E. Smith	Rosaceae	6
Schinus terebinthifolius Raddi	Anacardiaceae	181
Syzigium cumini (L.) Skeels	Myrtaceae	12
Syzigium jambos (L.) Alston	Myrtaceae	513
Tabebuia pallida (Lindl.) Miers	Bignoniaceae	43
Tectona grandis L. F.	Verbenaceae	49
Terminalia arjuna (Roxb.) Wight & Arn.	Combretaceae	33
Terminalia catappa L.	Combretaceae	1
Vitex glabrata R. Br.	Lamiaceae	23
Wilkstroemia indica (L.) C. A. Meyer	Thymeliaceae	193

Appendix 3. Importance value for native species in the Black River Gorges National Park, Mauritius

Species	Relative Density	Relative Dominance	Relative frequency	Importance Value
Aphloia theiformis	6.79	3.80	5.91	16.50
Warneckea trinervis	9.44	3.77	3.07	16.28
Diospyros tessellaria	3.09	9.10	2.07	14.26
Sideroxylon puberulum	4.80	6.48	1.77	13.05
Olea lancea	4.80	3.61	3.90	12.31
Mimusops erythroxylon	1.73	7.81	2.66	12.20
Nuxia verticillata	2.91	5.92	2.36	11.19
Securinega durissima	4.58	4.47	2.01	11.06
Labourdonnaisia glauca	1.22	6.91	2.72	10.85
Sideroxylon cinereum	3.42	3.52	1.83	8.77
Syzigium glomeratum	3.64	2.77	2.30	8.72
Labourdonnaisia calophylloides	2.07	4.11	2.42	8.61
Grangeria borbonica	2.62	3.49	2.25	8.36
Gaertnera psychotriodes	3.44	1.36	2.36	7.16
Erythrospermum monticolum var. Monticulum	2.73	1.77	2.36	6.86
Calophyllum eputamen	2.42	1.80	2.48	6.70
Monimiastrum globusum	3.29	1.46	1.60	6.35
Syzigium coriaceum	1.89	2.81	1.60	6.29
Erythroxylum macrocarpum	2.48	1.81	1.95	6.24
Cassine orientalis	1.28	1.94	1.95	5.17
Ochna mauritiana	1.81	0.67	2.30	4.79
Antirhea borbonica	2.30	0.44	1.89	4.62
Tabernaemontana persicariaefolia	2.09	0.66	1.60	4.35
Gaertnera calophylloides	1.81	0.87	1.54	4.22
Erythrospermum monticolum var. Pyrifolium	0.14	3.36	0.59	4.09
Cnestis glabra	1.24	0.42	2.30	3.96

Myonima violacea var. Ovata	1.89	0.49	1.48	3.86
Molinaea alternifolia	0.77	0.72	2.19	3.68
Geniostoma borbonicum	1.63	0.44	1.54	3.60
Pandanus spp	1.89	0.38	1.24	3.52
Cordemoya integrifolia	0.89	0.76	1.71	3.37
Lautembergia neraudiana	0.98	0.69	1.30	2.97
Canarium paniculatum	0.26	2.04	0.53	2.84
Bertiera zaluziana	1.20	0.22	1.24	2.66
Cyathea borbonica	1.18	0.28	0.89	2.34
Antidesma madagascariense	0.69	0.31	1.24	2.24
Eugenia tinifolia	0.51	0.64	1.06	2.21
Hugonia tomentosa	0.12	0.02	1.77	1.91
Diospyros egratterum	0.18	1.54	0.18	1.90
Stillingia lineata var lineata	1.20	0.22	0.41	1.83
Faujasiopsis fluxiosia	1.06	0.05	0.71	1.82
Psiloxylon mauritianum	0.06	0.04	1.71	1.81
Mimusops petiolaris	0.02	0.30	1.48	1.80
Eugenia lucida	0.39	0.17	1.18	1.74
Syzigium commersonii	0.69	0.30	0.71	1.71
Ludia mauritiana	0.49	0.32	0.89	1.69
Ficus reflexa	0.06	0.56	1.00	1.62
Dracaena concinna	0.08	0.18	1.36	1.62
Pleurostylia leucocarpa	0.49	0.30	0.71	1.50
Erica brachyphylla	0.20	0.18	1.06	1.45
Pandanus eydouxia	0.28	0.57	0.59	1.44
Fernelia buxifolia	0.59	0.20	0.59	1.38
Acantophoenix rubra	0.02	0.04	1.30	1.36
Eugenia lanceolata	0.02	0.01	1.30	1.33
Syzigium mauritianum	0.39	0.62	0.24	1.25
Protium obtusifolium	0.22	0.72	0.30	1.24
Helichrysum proteoides	0.20	0.03	1.00	1.24
Psathura sp	0.61	0.10	0.35	1.07
Homalium paniculatum	0.06	0.02	0.95	1.02
Apodytes dimidiata	0.12	0.25	0.53	0.90
Cossinia pinnata	0.10	0.01	0.59	0.71
Acalypha integrifolia	0.39	0.01	0.30	0.69
Lomatophyllum purpureum	0.02	0.00	0.65	0.67
Gaertnera petrenensis	0.08	0.04	0.47	0.59
Dracaena reflexa	0.22	0.13	0.18	0.53

Tambourissa cordifolia	0.24	0.14	0.12	0.50
Psidia viscosia	0.12	0.07	0.30	0.49
Vepris lanceolata	0.18	0.10	0.18	0.46
Chassalia coriacea	0.14	0.02	0.24	0.40
Colea colei	0.12	0.01	0.24	0.36
Syzigium petrenense	0.04	0.14	0.18	0.36
Myonima violacea var. Violacea	0.06	0.03	0.24	0.32
Sideroxylon sessiliflorum	0.12	0.07	0.12	0.31
Lantania spp	0.02	0.16	0.12	0.30
Croton grangerioides	0.06	0.06	0.18	0.29
Phylica nitida	0.04	0.01	0.24	0.29
Diospyros revaughanii	0.10	0.01	0.12	0.23
Erythrospermum monticolum var. Amplifilium	0.08	0.02	0.12	0.22
Tambourissa peltata	0.04	0.03	0.12	0.19
Pandanus rigidifolius	0.02	0.05	0.12	0.19
Toddalia asiatica	0.12	0.00	0.06	0.18
Casearia coriacea	0.04	0.01	0.12	0.17
Macaranga mauritiana	0.02	0.02	0.12	0.16
Doratoxylon apetalum var diphyllum	0.02	0.01	0.12	0.15
Diospyros boutoniana	0.02	0.01	0.06	0.09
Pittosporum senacia ssp. Senacia	0.02	0.01	0.06	0.09
Trochetia triflora	0.02	0.00	0.06	0.08
Sophora tomentosa	0.02	0.00	0.06	0.08

Appendix 4. Importance Value for alien species surveyed in the Black River Gorges National park

Species	Relative Dominance	Relative Frequency	Importance Value
Psidium cattleianum	9.16	28.70	125.05
Pinus elliotii	25.44	6.48	33.33
Ravenala madascariensis	11.80	4.78	17.11
Ligustrum robustrum var. walkeri	1.16	13.27	16.99
Eucalyptus tereticornis	8.99	3.70	13.33
Syzigium jambos	7.00	4.32	12.94
Terminalia arjuna	8.61	1.08	9.79
Cryptomeria japonica	5.18	1.85	7.39
Eucalyptus robusta	3.40	1.70	5.35
Tabebuia pallida	3.44	1.54	5.12
Wilkstroemia indica	0.02	4.01	4.64
Litsea glutinosa	0.48	3.55	4.17
Litsea monopetala	0.62	2.93	3.72
Mangifera indica	2.21	1.23	3.48
Schinus terebinthifolius	0.61	2.01	3.19
Vitex glabrata	1.85	1.08	3.00
Harungana madagascariensis	0.43	2.31	2.83
Homalanthus populifolius	0.14	2.31	2.70
Cinnanomum camphora	2.15	0.31	2.49
Syzigium cumini	1.30	1.08	2.41
Cupressus spp	1.20	1.08	2.36
Clidemia hirta	0.01	1.54	2.26
Rubus alceifolius	0.02	1.70	2.24
Euphorbia longan	1.33	0.46	1.84
Tectona grandis	0.79	0.62	1.56
Pinnus spp	0.93	0.46	1.54
Callistemon citrinus	0.12	1.08	1.28
Bambusa spp	0.11	0.15	1.21
Albizia procera	0.28	0.77	1.07
Hiptage benghalensis	0.07	0.77	0.91
Eugenia floribunda	0.65	0.15	0.89
Eugenia uniflora	0.03	0.46	0.64
Lantana camara	0.02	0.46	0.61
Ardisia crenata	0.00	0.46	0.50

Cordia macrostachya	0.02	0.31	0.34
Jatropha curcas	0.11	0.15	0.27
Dipterocarpus spp	0.10	0.15	0.25
Acacia farnesiana	0.09	0.15	0.25
Psidium guajava	0.05	0.15	0.21
Artocarpus heterophyllus	0.04	0.15	0.20
Rubus rosifolius	0.00	0.15	0.18
Terminalia catappa	0.02	0.15	0.18
Camellia sinensis	0.01	0.15	0.17

Appendix 5. Correlation matrix of the 43 managed plots with no native species in Black River Gorges National Park, Mauritius

		Basal area Alien	Basal Area *P.cattleianum*	Basal area other alien	Number of Alien spp	Number of Alien stem	Number of *P.cattleianum* stems	Number of other alien stem
Basal Area *P.cattleianum*	R	-0.114						
	p	0.468						
Basal area other alien	R	**0.999**	-0.146					
	p	**<0.001**	0.349					
Number of Alien stem	R	0.017	**0.691**	-0.006				
	p	0.914	**<0.001**	0.97				
Number of Alien spp	R	-0.191	-0.113	-0.187	0.036			
	p	0.219	0.47	0.23	0.818			
Number of *P.cattleianum* stem	R	0.029	**0.761**	0.003	**0.945**	-0.052		
	p	0.855	**<0.001**	0.983	**<0.001**	0.74		
Number of other alien stem	R	-0.036	-0.234	-0.028	0.137	0.268	-0.193	
	p	0.82	0.131	0.859	0.38	0.082	0.215	
Altitude	R	-0.137	0.047	-0.138	0.107	**-0.354**	0.068	0.115
	p	0.38	0.765	0.377	0.496	**0.020**	0.666	0.461

*bold text show significant corrrelation

Appendix 6. Correlation matrix of the 10 managed plots with no alien species

		Basal area Native	No. of Native stem	Number of native spp	No. of *D.tesselaria* stem	No. of *A.theiformis* stem	No. of *O. lancea* stems	No. of *S. puberulum* stem	No. of *W.trinervis* stem
No. of Native stem	R	0.261							
	p	0.497							
No. of Native spp	R	0.203	0.631						
	p	0.601	0.068						
No. of *D. tesselaria*	R	0.55	0.392	-0.004					
	p	0.125	0.297	0.992					
No. of *A. theiformis* stem	R	0.255	0.153	0.186	-0.02				
	p	0.508	0.695	0.632	0.959				
No. of *O. lancea* stem	R	-0.545	-0.262	-0.529	-0.356	-0.052			
	p	0.129	0.495	0.143	0.347	0.895			
No. of *S. puberulum* stem	R	-0.611	-0.27	-0.362	-0.36	-0.08	**0.945**		
	p	0.081	0.483	0.339	0.341	0.837	**<0.001**		
No. of *W. trinervis* stem	R	0.308	0.455	-0.142	**0.805**	-0.076	-0.244	-0.357	
	p	0.42	0.218	0.716	**0.009**	0.845	0.526	0.345	
Altitude	R	**-0.676**	-0.42	0.074	-0.586	-0.254	0.38	0.532	**-0.743**
	p	**0.045**	0.26	0.851	0.097	0.509	0.313	0.141	**0.022**

*Bold text show significant corrrelation