

# Effects of human disturbance on liana community diversity and structure in a tropical rainforest, Malaysia: implication for conservation

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## Abstract

### Aim

Due to the important role of lianas in the functioning of forest ecosystem, knowledge of the factors that affect them are important in the management of forests. Currently, there are conflicting reports on the response of liana communities to disturbance, calling for more research in the area. The present study was carried out to investigate the response of liana diversity and structure to human disturbance within two major forests in the Penang National Park, Malaysia. The study also looked at the implication of the findings for conservation.

### Methods

A total of 15 40 × 40-m<sup>2</sup> (or 40-m × 40-m) plots each were randomly located across a range of habitats in a primary forest and disturbed secondary forest. Trees with diameter at breast height ≥10 cm were examined for lianas with diameter ≥2 cm. Both lianas and trees were enumerated and compared between the two forests. Diversity and structural variables of lianas were compared between the two forests using the *t*-test analysis. Tree abundance was also compared between the two forests with *t*-test, while linear regression analysis was run to determine the effects of tree abundance on liana abundance.

### Important Findings

A total of 46 liana species belonging to 27 genera and 15 families were identified in the study. Human disturbance significantly reduced

liana species richness and species diversity in the secondary forest. Liana abundance remained the same in both forests whereas liana basal area was significantly higher in the primary forest. Twiners and hook climbers were significantly more abundant in the primary and secondary forest, respectively. Large diameter lianas were more abundant in the primary forest compared with the secondary forest. The diameter distribution of most families in the primary forest followed the inverted J-shaped curve whereas only a few of the families in the secondary forest did so. Tree abundance was significantly higher in the primary forest. The abundance of lianas significantly depended on tree abundance in all the forests. The study has provided evidence of negative effects of human disturbance on liana diversity and structure that does not auger well for biodiversity in the forest. In view of the critical role of lianas in maintaining biodiversity in the forest ecosystem, lianas in the national park should be protected from further exploitation.

**Keywords:** climbing mechanism • conservation • liana diversity and structure • human disturbance

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## INTRODUCTION

In recent times, liana research has received more attention apparently in recognition of the important ecological roles they

play in forest ecosystems, particularly in the tropics (Gerwing and Farias 2000; Pérez-Salicrup 2001; Pérez-Salicrup and Baker 2000; Schnitzer and Bongers 2002; Toledo-Aveces and Swaine, 2008). Lianas have been shown to impact greatly

on forest ecosystems through their rapid growth and proliferation. It has been established that increasing liana abundance reduces tree diversity (Schnitzer and Bongers 2011) and causes the pulling down of trees (Pereira *et al.* 2002; Vidal *et al.* 1997). This results in an increase in the number of forest gaps that may indirectly influence the composition and structure of forests (Pérez-Salicrup 2001; Schnitzer and Bongers 2002). The possession of positive and negative roles in the forest (Bongers *et al.* 2005) calls for special attention on lianas. However, they have not received much attention as needed.

Majority of studies have indicated that lianas increase in diversity and structure in response to disturbance (e.g. Rutishauser 2011; Schnitzer and Carson 2001, 2010; Schnitzer *et al.* 2004). They are said to capitalize on disturbed areas by recruiting into them with large numbers and then growing rapidly in the high-resource environment (Schnitzer and Bongers 2011). Increasing liana diversity and structure in disturbed areas is also related to their ability to proliferate in gaps by diverse modes of reproduction (Rutishauser 2011; Schnitzer *et al.* 2000). Interestingly, lianas can germinate in the canopy without contact with the forest floor, thereby contributing to their high diversity and structure (Nabe-Nielson 2001). As the forest canopy closes, lianas in the understorey may have fewer available supports and less available light (Denslow and Guzman 2000; DeWalt *et al.* 2000). Individuals that are not able to get to the canopy early before the gaps close have a lower chance of doing so later on (Letcher and Chazdon 2009). However, a few recent studies have shown that liana diversity and structure may decrease in disturbed areas due to liana harvesting and/or limited available supports (Chittibabu and Parthasarathy 2001; Addo-Fordjour *et al.* 2009a, 2009b). Thus, the exact response of lianas to disturbance will depend on the level of disturbance they are exposed to (Addo-Fordjour *et al.* 2009a, 2009b).

Interestingly, all the studies in which liana diversity and structure were found to decrease with respect to disturbance were conducted in Africa and Asia (Cabellé and Martin 2001; Chittibabu and Parthasarathy 2001; Addo-Fordjour *et al.* 2009a, 2009b; Ewango 2010). Therefore, it has been suggested that more studies be carried out in these two continents to confirm this emerging trend (Schnitzer and Bongers 2011). If confirmed, the difference between the patterns in Africa and Asia on one hand and other parts of the world on the other hand could be related to differences in climate, plant phylogenetic composition and relative abundance, and natural and anthropogenic disturbances as hypothesized by Schnitzer and Bongers (2011). Though a call has been made for more research works to be conducted in these two continents for verification of the dissenting trend, not much has been done so far. The current study therefore has the potential of contributing towards the above call.

Although studies on liana ecology have increased in recent time, the ecology of lianas in most forests is either unknown or poorly understood. The Penang National Park remains one of the forests whose liana ecology has never been studied. Con-

sidering the critical role of lianas in contributing to the overall biodiversity in tropical forest ecosystems (Pérez-Salicrup and Baker 2000; Schnitzer *et al.* 2000; Pérez-Salicrup 2001; Schnitzer and Bongers 2002), there is the need for ecological studies to be conducted on lianas in the Penang National Park. What is more, the current disturbance status of the forest reserve makes it imperative that liana diversity and structure are studied to determine the effects of disturbance on them. The findings of such a study would be necessary in managing lianas in the forest reserve (Parren and Bongers 2005), so as to maximize the ecological benefits of lianas while reducing their negative impacts on the forest.

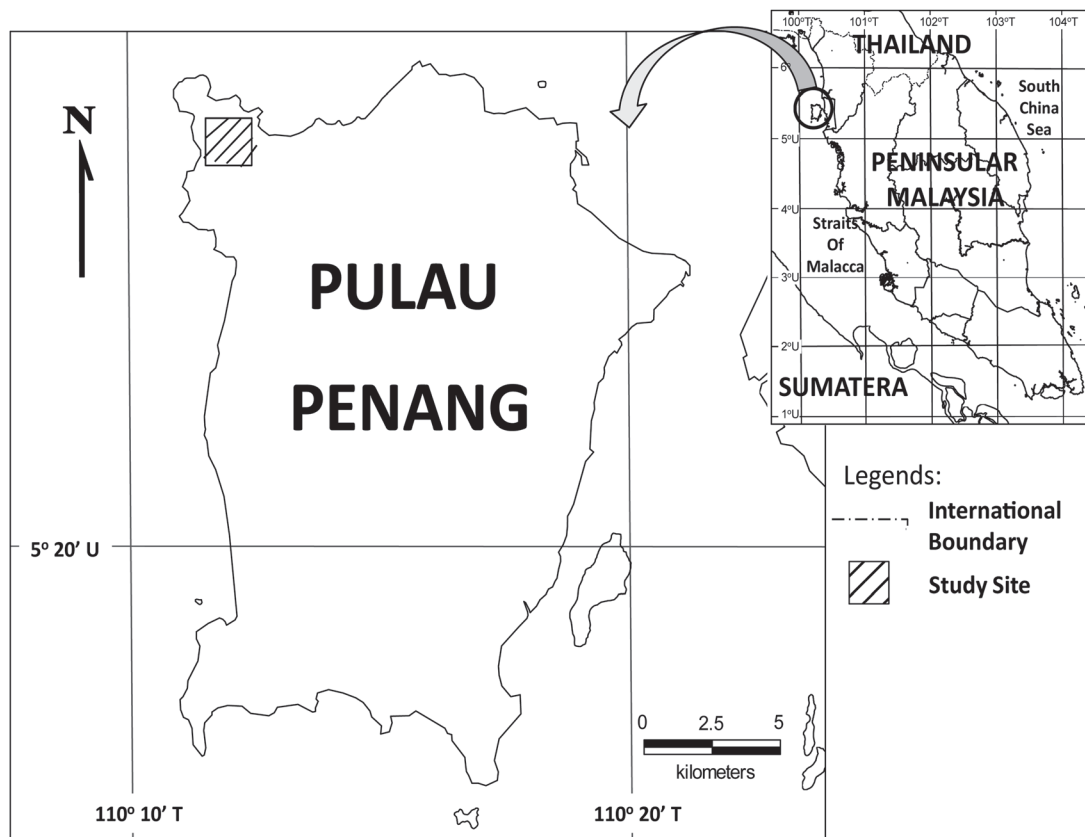
This paper was aimed at contributing to understanding the effects of disturbance on the patterns of liana diversity and structure in view of the mixed patterns that have emerged so far. It was also intended to provide information on liana diversity and structure for effective management of the national park. The present study was carried out to investigate the response of liana diversity and structure patterns to human disturbance within the Penang National Park, Malaysia. The study also looked at the implication of the findings for conservation. The study addressed the following questions: (i) how does human disturbance affect liana diversity? and (ii) how does human disturbance affect liana structure?

## METHODOLOGY

### Study area

The study was conducted in the Penang National Park, Penang, Malaysia (5° 27.583' 100° 12.350') (Fig. 1). The National Park which is the smallest in the world has a total area of 1213 ha. The national park consists of two forest types, primary and disturbed secondary forests. The park is reported to harbour over 1000 species of plants that are dominated by the family Dipterocarpaceae, Leguminosae, Apocynaceae, Anacardiaceae, Euphorbiaceae and Moraceae. The park is also said to be rich in animals, with a total of 190 species being recorded. These include 25 mammal species, 53 butterfly species, 46 bird species and other reptiles, insects and amphibians (Wern and Weng 2010). The Penang National Park became a national park recently on 4 April 2003 and gazetted under National Park Act 226 of 1980 on 10 April 2003.

Massive deforestation in the Penang National Park started in the 1920s. This intensified from the 1940s when people from Indonesia, India and other countries migrated to Penang. Although deforestation resulted from logging, farming, hunting and gathering activities, logging was the major form of disturbance in the secondary forest. Logging activities continued in the secondary forest until 1996 when it officially ended. Though logging activities officially ended, the other forms of human disturbance continued until 2003 when the forest became a national park and had more protection. The secondary forest possess relics of considerable historical land use activities such as clear cutting, farming, logging, bush burning, etc., due to its close proximity to the community. The secondary forest



**Figure 1:** Map of Penang State showing the location of the study area (Penang National Park).

is also characterized by some ancient logging routes, confirming its extensive use in the distant past. The impact of past disturbance on the secondary forest has led to invasion of a considerable part of the secondary forest by an invasive alien fern species, *Pteris vittata*, in most parts of the forest. The provision of infrastructure in the secondary forest of the national park has also contributed to loss of forest cover and resulted in fragmentation in some parts of the forest. There is also encroachment of urban and agricultural land use into the park as well as illegal developments (Wern and Weng 2010). Therefore, the present composition, structure and dynamics of the secondary forest reflect both past and current human disturbance. The secondary forest is in its early succession stage with many small size trees under the canopy. There are many canopy gaps in the secondary forest. It must be stated that the national park consisted of one intact forest prior to human disturbance. The secondary forest was created following human disturbance in a section of the park. Therefore, differences in plant communities between the two forests could be largely attributed to human disturbance.

### Sampling

In order to obtain a true representation of lianas and account for the variation within each forest in the national park, three

sites, namely Flatland, Slope and Valley were identified and sampled in each forest. In order to eliminate the effects of topography in the study, sites selected in the primary forest of comparable to sites in the secondary forests with regard to slope and altitude. The sites were at least 2 km apart. In each forest, five  $40 \times 40\text{-m}^2$  (or  $40\text{-m} \times 40\text{-m}$ ) plots were randomly demarcated in each of the sites. Therefore, a total of 30 plots were sampled in the study (15 plots in each forest). Within each plot, trees with diameter at breast height (d.b.h.)  $\geq 10$  cm were critically examined for the presence of lianas with diameter  $\geq 2$  cm. Liana d.b.h. was measured at a height of 1.3 m from the rooting base. Only lianas rooted within the plots and located on trees were included in the survey. Lianas were counted and their diameter measured. The climbing mechanisms of lianas were recorded to ascertain whether their relative importance in terms of liana species richness and abundance change with disturbance. Total number of individual trees ( $\geq 10$  cm) within each plot was counted so as to determine whether they relate with liana abundance or not.

Plant identification was carried out with the assistance of plant taxonomists and by reference to regional manuals and Floras (Hooker 1875; Dransfield 1979; Keng and Keng 1990; Zhengyi et al. 2010). Nomenclature followed King (1902), Dransfield (1979) and Keng and Keng (1990). Voucher

specimens were kept at the herbarium of the School of Biological Sciences, Universiti Sains Malaysia, Penang, Malaysia.

### Data analyses

Liana diversity was determined using the Shannon diversity index (Magurran 1988). This together with all other liana and tree attributes was determined on individual plot basis.

To determine the effects of human disturbance on liana diversity and structure, the following liana diversity and structural variables were compared between the primary and secondary forests with the *t*-test analysis: species richness, species diversity, abundance and basal area. The abundance of the various liana climbing mechanisms was compared between the two forests with the *t*-test analysis. Root, stem tendril and thorn climbers were omitted from the analysis due to their low abundance. Tree abundance was compared between the two forests using the *t*-test analysis. The effect of tree abundance on liana abundance in each forest was determined through linear regression analysis. Tree abundance was used as the independent variable whereas liana abundance was the dependent variables. All analyses were conducted with the 11th Edition of GenStat software (VSN International Ltd, Hemel Hempstead, UK) at a significance level of 5%.

## RESULTS

### Diversity of lianas

The liana flora in the Penang National Park was composed of 46 species (Table 1). They were distributed in 27 genera and 15 families. A total of 35 species composed the liana flora in the primary forest whereas 27 species occurred in the secondary forest. There were 19 liana species exclusive to the primary forest compared to 11 species that were unique to the secondary forest. A total of 16 species were found in both forests. Lianas in the primary forest were represented by 13 families whereas those in the secondary forest were represented by 12 families. Majority of the families (10 families) in the secondary forest were present among the families in the primary forest. The families that contributed most to liana flora in the primary forest were Fabaceae (seven species), Annonaceae (five species) and Apocynaceae (five species). On the other hand, Connaraceae (four species) was the most diverse family followed by Apocynaceae (three species), Fabaceae (three species) and Palmae (three species) in the secondary forest. Lianas were more diverse in the primary forest in relation to the secondary forest (Table 2). The difference in diversity between the primary and secondary forest was significant ( $P < 0.001$ ). The mean liana species richness per plot also differed significantly between the primary and secondary forests ( $P < 0.001$ ).

A total of six climbing mechanisms were identified in the study (Figs 2 and 3). Twining was the most diverse climbing mechanism used by lianas in both the primary and secondary forests (Fig. 2). In the primary forest, twiners were the most abundant whereas in the secondary forest hook climbers were

the most abundant (Fig. 3). Twiners and leaf tendril climbers were significantly more abundant in the primary forest ( $P < 0.001$  and  $P = 0.038$ , respectively) whereas hook climbers were more abundant in the secondary forest ( $P = 0.002$ ).

### Liana structure

A total of 454 liana individuals were identified in the two forests (Table 1). The total number of lianas in the primary forest (250 individuals) was higher than that of the secondary forest (202 individuals). Though liana abundance per plot was higher in the primary forest than in the secondary forest, the difference was not significant ( $P = 0.166$ ) (Table 2). Liana basal area in the primary forest was significantly higher than that of the secondary forest ( $p = 0.043$ ). The most abundant species in the primary forest was *Artabotrys oblongus* followed by *Tetracera macrophylla*, *Gnetum latifolium* and *Willughbeia angustifolia* (Table 1). On the other hand, *Strychnos curtisii* and *Willughbeia* sp. occurred as the most abundant species in the secondary forest.

Family Annonaceae contributed most to liana abundance in the primary forest followed by family Apocynaceae (Fig. 4). Family Annonaceae was more abundant in small (2–5 cm), medium size (5–8 cm) and large size (8–11 cm) lianas compared to the other families. With regard to very large size (>11 cm) lianas, Fabaceae was more prominent than the other families. Most of the families did not record at least one of the liana diameter class sizes in the forest. Liana numbers in most of the families decreased with increasing diameter. In the secondary forest, Loganiaceae contributed most to liana abundance followed by Apocynaceae (Fig. 5). Family Loganiaceae was more abundant in all categories of lianas than the other families except the large size lianas. Very large size lianas were more abundant in Loganiaceae. Only two of the families, namely Loganiaceae and Connaraceae, recorded lianas in all the diameter size classes. Only a few of the families in the secondary forest had their liana numbers decreasing with increasing diameter. Family Fabaceae contributed most to the total basal area in the primary forest followed by Apocynaceae and Annonaceae (Fig. 6). In the secondary forest, Loganiaceae was the most important species with regard to basal area contribution followed by Annonaceae and Connaraceae.

Tree abundance was significantly higher in the primary forest compared with the secondary forest (Table 2;  $P < 0.001$ ). Liana abundance depended significantly on tree abundance in the primary and secondary forests ( $P = 0.19$ ,  $r^2 = 30.8$  and  $P = 0.19$ ;  $r^2 = 30.6$ , respectively).

## DISCUSSION

In view of the fact that secondary forests offer much more ideal conditions for lianas (see Schnitzer and Bongers 2011), their diversity is expected to be higher in secondary forests than primary forests. However, the reverse was the case in the

**Table 1:** liana species composition and abundance in the primary forest (PF) and secondary forest (SF)

Species	Family	Abundance	
		PF	SF
<i>Agelaea borneensis</i> (Hook. f.) Merr.	Connaraceae	4	—
<i>Agelaea macrophylla</i> (Zoll.) Leenh.	Connaraceae	10	13
<i>Artabotrys maingayi</i> Hook.f. & Thomson	Annonaceae	1	—
<i>Artabotrys oblongus</i> King	Annonaceae	41	5
<i>Bauhinia audax</i> (de Wit) G. Cusset	Fabaceae	1	—
<i>Bauhinia bidentata</i> Jack	Fabaceae	7	—
<i>Bauhinia ferruginea</i> Roxb.	Fabaceae	8	1
<i>Bauhinia</i> sp.	Fabaceae	1	—
<i>Caesalpinia parviflora</i> (Prain ex King) Prain	Fabaceae	1	—
<i>Calamus longisetus</i> Thwaites	Palmae	1	—
<i>Calamus minutus</i> Dransf.	Palmae	—	1
<i>Calamus palustris</i> Griff.	Palmae	4	2
<i>Calamus tomentosus</i> Becc.	Palmae	—	1
<i>Cleghornia malaccensis</i> (Hook. f.) King & Gamble	Apocynaceae	1	—
<i>Cnestis palala</i> Merr.	Connaraceae	1	10
<i>Coptosapelta parviflora</i> Ridl.	Rubiaceae	12	12
<i>Cyathostemma hookeri</i> King	Annonaceae	3	3
<i>Daemonorops micracantha</i> (Griff.) Becc.	Palmae	2	—
<i>Dalbergia pinnata</i> (Lour.) Prain	Fabaceae	—	2
<i>Dalbergia rostrata</i> Hassk.	Fabaceae	15	1
<i>Dichapetalum longipetalum</i> (Turcz.) Engl.	Dichapetalaceae	—	3
<i>Ficus</i> sp.	Moraceae	3	—
<i>Fissistigma manubriatum</i> (Hook. f. & Thoms.) Merr.	Annonaceae	5	—
<i>Gnetum latifolium</i> Blume	Gnetaceae	25	3
<i>Gnetum</i> sp.	Gnetaceae	—	2
<i>Mitrella kentii</i> Miq.	Annonaceae	9	—
<i>Piper maingayi</i> Hook.f.	Piperaceae	4	—
<i>Porana spectabilis</i>	Convovulaceae	—	3
<i>Rourea rugosa</i> Planch.	Connaraceae	3	3
<i>Salacia</i> sp.	Celatraceae	2	—
<i>Spatholobus ferrugineus</i> (Zoll. & Moritzi) Benth.	Apocynaceae	3	8
<i>Strophantus perakensis</i> Scort. ex King & Gamble	Apocynaceae	1	1
<i>Strophantus</i> sp.	Apocynaceae	1	—
<i>Strychnos axillaris</i> Colebr.	Loganiaceae	2	—
<i>Strychnos colubrina</i> L.	Loganiaceae	1	—
<i>Strychnos curtisii</i> King & Gamble	Loganiaceae	—	70
<i>Strychnos ignatii</i> Berg.	Loganiaceae	7	13
<i>Strychnos</i> sp.	Loganiaceae	5	—
<i>Tetracera indica</i> Merr.	Dilleniaceae	—	4
<i>Tetracera macrophylla</i> A. Chev.	Dilleniaceae	28	1
<i>Uncaria tomentosa</i> (Wild) D.C.	Rubiaceae	—	5
<i>Willughbeia angustifolia</i> (Miq.) Markgr.	Apocynaceae	25	13
<i>Willughbeia</i> sp.	Apocynaceae	12	18

**Table 1:** Continued

Species	Family	Abundance	
		PF	SF
<i>Ziziphus grewoides</i> (Warb.) L.M.Perry	Rhamnaceae	1	—
<i>Ziziphus</i> sp. 1	Rhamnaceae	—	5
<i>Ziziphus</i> sp. 2	Rhamnaceae	—	1

**Table 2:** summary characteristics of liana diversity and structure and tree abundance (standard error of mean is indicated) in the study area

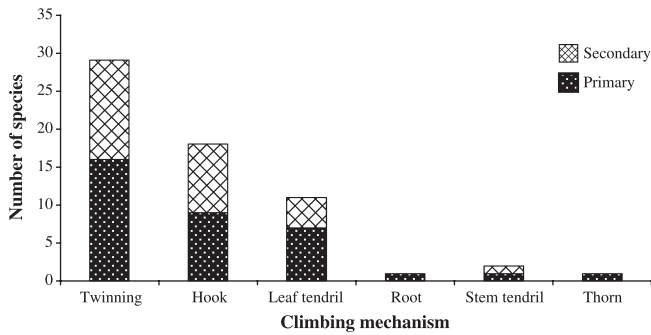
Characteristic	Primary forest	Secondary forest
Liana		
Mean species richness per plot	7.40 <sup>a</sup> ± 0.57	3.87 <sup>b</sup> ± 0.47
Mean species diversity per plot	1.74 <sup>a</sup> ± 0.077	1.077 <sup>b</sup> ± 0.12
Mean abundance per plot	16.60 <sup>a</sup> ± 1.15	13.67 <sup>a</sup> ± 1.40
Mean basal area (cm <sup>2</sup> /ha)	570.4 <sup>a</sup> ± 84.42	352.9 <sup>b</sup> ± 57.92
Tree		
Mean tree abundance per plot	41.60 <sup>a</sup> ± 2.50	23.00 <sup>b</sup> ± 1.31

Means with different superscripts in the same row are significantly different ( $P < 0.05$ ).

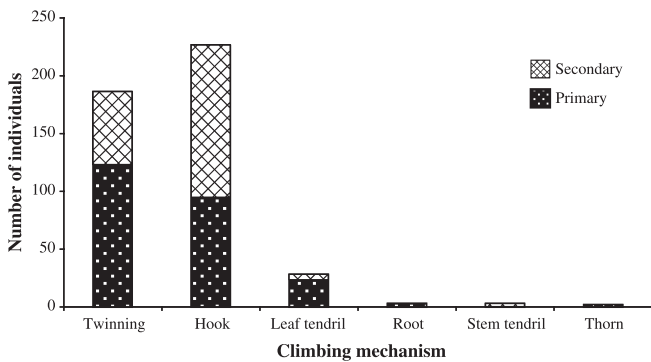
current study as liana diversity was significantly higher in the primary forest. Though this trend is quite unusual, it is supported by similar studies conducted in tropical forests in India (Chittibabu and Parthasarathy 2001) and Bangladesh (Rahman *et al.* 2010). In as much as human disturbance has the potential of maintaining liana diversity within forests (Schnitzer and Carson 2001; van der Heijden and Philips 2009), high levels of past and present disturbance such as liana cutting can reduce liana diversity (Chittibabu and Parthasarathy 2001). Furthermore, tree removal could also limit host availability for lianas (Addo-Fordjour *et al.* 2009a, 2009b) that may affect their diversity. This finding and others (Lertpanich and Brockelman 2003; Mascaro *et al.* 2004) point to the fact that primary forests could serve as an important ecosystem for maintaining liana diversity. The invasion of the secondary forest by *P. vittata* could be partly responsible for the low liana diversity considering the devastating effects invasive alien species can exert on natural regeneration of other plant species (Sala *et al.* 2000; Stein *et al.* 2000). It is worth mentioning that lianas were completely absent from areas where invasion had occurred.

Interestingly, most of the abundant liana species in the primary forest had very low abundance in the secondary forest. Similarly, most of the lianas that constituted the abundant species in the secondary forest occurred in low numbers in the primary forest. Though effects of disturbance may be responsible for this variation, possible habitat associations by the species may be operating. Thus, *S. curtisii* and *C. pallala* that were more abundant in the secondary forest may be good indicators of forest disturbance. Though many studies have cited

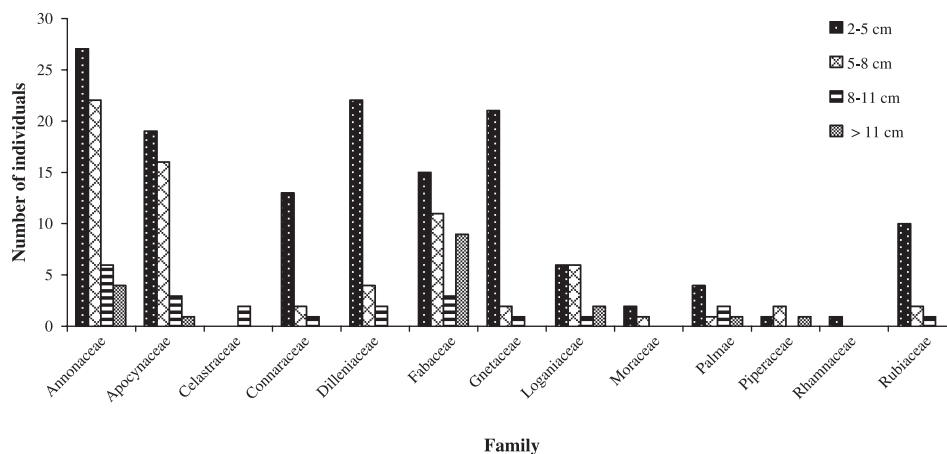
human disturbance as a major factor responsible for liana proliferation in secondary forests (Schnitzer and Carson 2001, 2010; Schnitzer *et al.* 2004), liana abundance remained the same in the secondary and primary forest in this study. Limited abundance of host trees as well as removal of lianas by the local community was at least responsible for the trend observed in this study. This is supported by the significantly lower



**Figure 2:** Liana species richness per climbing mechanism in the primary and secondary forests.



**Figure 3:** Liana abundance per climbing mechanism in the primary and secondary forests.



**Figure 4:** Liana abundance per family in the various diameter classes within the primary forest.

tree abundance recorded in the secondary forest. This provides further evidence to support the finding that liana abundance may decrease in disturbed forests if the disturbance results in the removal of lianas (Chittibabu and Parthasarathy 2001; Rahman *et al.* 2010) and/or reduces host species abundance (see Addo-Fordjour *et al.* 2008, 2009a; Allen *et al.* 2005; Rahman *et al.* 2010). The devastating effect of disturbance on liana structure was more pronounced on basal area. Though the difference in liana abundance between the primary and secondary forest was marginal, liana basal area in the primary forest was significantly higher than that of the secondary forest. The decrease in liana basal area in response to disturbance is in conformity with the work of van der Heijden and Philips (2008). Generally, lianas in the primary forest were larger in diameter than those in the secondary forest. The removal of mature lianas from the secondary forest, both in the past and present, could be responsible for the difference. This obviously translated into the significant difference in basal area that was observed between the two forests. Furthermore, the low abundance of large and tall trees in the secondary forest also reduced the probability of lianas reaching the canopy to access sunlight to increase their diameter (van der Heijden and Philips 2008). This is substantiated by the fact that most liana individuals in the secondary forest did not reach the canopy unlike those in the primary forest. However, since the secondary forest is in its early successional stage, lianas in it have the opportunity to reach the canopy before it closes (Letcher and Chazdon 2009). Twinners were significantly more abundant in the primary forest compared with the secondary forest. This provides substantiation in support of other studies that had similar results (DeWalt *et al.* 2000, 2003). The predominance of twinners in primary forest has been related to the abundance of large diameter trees in old age forest (DeWalt *et al.* 2003; Putz 1984). On the other hand, the predominance of hook climbers in the secondary forest was as a result of the presence of more small-diameter trees compared to the primary forest (Nabe-Nielsen 2001).

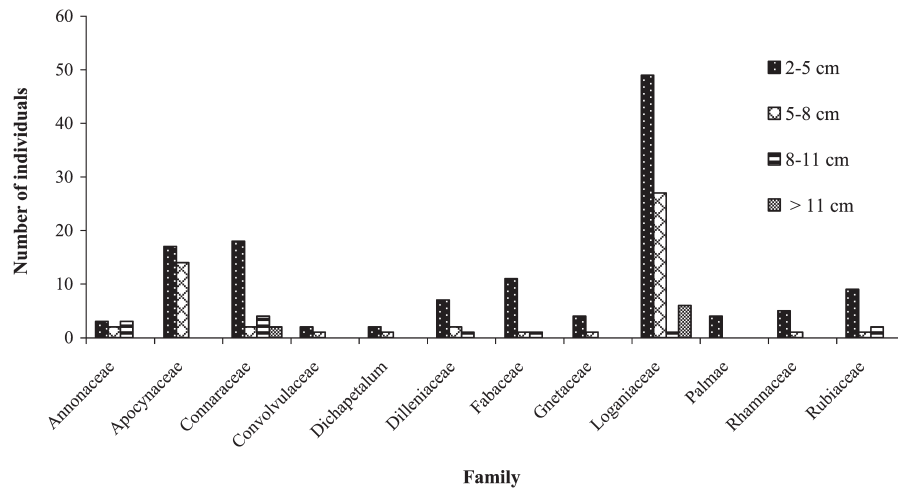


Figure 5: Liana abundance per family in the various diameter classes within the secondary forest.

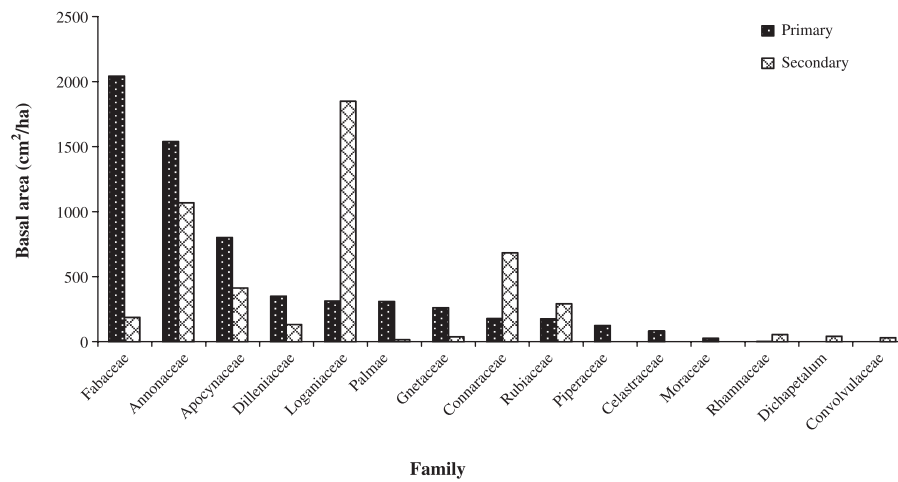


Figure 6: Family basal area contribution to liana structure in the primary and secondary forest.

Generally, certain families were made up of high numbers of large diameter lianas than others. While this may be due to the natural occurrence of large diameter lianas in certain families, the effects of human disturbance in reducing the number of large lianas in some families cannot be ruled out (Addo-Fordjour *et al.* 2009b). Liana diameter distribution according to family varied between the two forests. Whereas the distribution of most of the families in the primary forest followed the inverted J-shaped curve, only a few of the families in the secondary forest did so. This indicates that natural regeneration in most of the families in the primary forest was superior to that of the secondary forest (Alelign *et al.* 2007). This could be another reason for the higher liana diversity and structure in the primary forest. Like diameter distribution, liana families that contributed high basal area in one forest had low basal area in the other forest. However, Annonaceae was an exception, maintaining high basal area in both

forests. This family appears to thrive well in both disturbed and non-disturbed forests.

### IMPLICATION FOR CONSERVATION

Though high diversity of lianas in forest ecosystems could have adverse effects on trees, their low diversity could be unfavourable to the overall biodiversity in forests. This is because lianas provide food for animals especially in the dry season when most trees are unable to provide that function. Interestingly, some of these animals are important dispersers of trees and therefore, the provision of food to them by lianas is crucial for the survival of trees themselves (see Bongers *et al.* 2005). To this end, lianas in the national park should be protected from exploitation by human beings especially in the secondary forest where their diversity is very low. This is particularly more important for the secondary forest where

tourists mostly visit to observe wild animals. Thus, harvesting and encroachment on the forest should be controlled. This point is strengthened by the fact that liana diversity was limited by availability of host species in the secondary forest. The invasion of the secondary forest should be controlled to facilitate liana regeneration. In view of the high liana diversity and structure in the primary forest part of the national park, lianas in the primary forest should be monitored regularly so as to mitigate any negative impact they may exert on tree species. This study has provided evidence to support the finding that liana success decrease with disturbance in some forests in African and Asian forests (Chittibabu and Parthasarathy 2001; Schnitzer and Bongers 2011). This and other previous studies support the need to test the hypothesis put forward by Schnitzer and Bongers (2011). If the hypothesis is eventually proven to be true, disturbance could be used as a management tool in controlling lianas in the forests of Africa and Asia so as to maintain the overall biodiversity of forests.

## CONCLUSION

Liana diversity was significantly reduced in the secondary forest, reflecting the impact of human disturbance on it. Liana abundance remained the same in both forests whereas liana basal area was significantly higher in the primary forest. Large diameter lianas were more abundant in the primary forest compared with the secondary forest. In view of the important role lianas play in maintaining biodiversity, human activities in the park should be controlled to mitigate their effects on lianas. Plant invasion should also be controlled to enhance natural regeneration of lianas and other plants.

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