

PREVALENCE AND CAUSES OF MONKEY DEBARKING ACROSS AGE COHORTS OF *Cupressus lusitanica* IN THE MT KENYA ECOSYSTEM

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ABSTRACT

Game debarking has been a major hindrance to high quality timber production. Debarked parts not only provide entry points to the destructive *Oemeda gaani* but also adversely affect the tree growth. Though fruits and leaves of *Moraceae* family form the most preferred diet for monkeys, other families act as fallback resource when the top diet is scarce. In a study carried out in the Mt Kenya ecosystem, it is likely that *C. lusitanica* is one the fallback resource. These monkeys were found to prefer the barks of this species. Prevalence of debarking and its associated effects pose a threat to major plantations in the Mt Kenya ecosystem. Surveys were undertaken in 2008 at Mt Kenya Ecosystem to evaluate the prevalence and cause of monkey debarking across the age cohorts of *C. lusitanica*. The study, that was confined between 1998-2100, 9968000-9996000 and 0287000-0298000 (altitude, longitude and latitude respectively), covered Nanyuki, Naromoru, Gathiuru and Kabaruru forest ecosystems. Three age cohorts, 5-10, 11-20, and >20years were selected and presence/absence of debarking, height of debarking and part of the tree trunk debarked were assessed. Total enumeration/sampling was done on 0.04ha and 0.02ha for age cohorts 11-20, >20 and 5-10 years respectively. Laboratory analysis of the tree barks was also done to determine nutritive composition. Though debarking prevalence was present in all sites, Nanyuki forest was the most statistically significant site ($P < 0.05$). Test of homogeneity of variance showed that among the three age cohorts tested for debarking, >20 years was the most statistically significant age class ($P < 0.05$). Duncan Multiple Range Test also showed that the most preferred part of the trunk was the upper portion compared to the lower, middle and top. The debarked parts of the stem showed a strong positive Pearson correlation ($n = 4$, $r_s = 0.876$, $p = 0.05$) with the height of debarking. Though study sites correlated positively with presence/absence of debarking and part of the trunk debarked, they had weak correlation (0.129 and 0.101 respectively). Lack of the most preferred *Moraceae* family in the Mt Kenya ecosystem was found to cause a shift in the diet base for the monkeys. Based on the findings of this study, it is likely that *C. lusitanica* is one among the fallback resource for the monkeys. Mass exodus of not only monkeys but also majority of the wild animals in the Mt Kenya ecosystem in the early 2000(s) from the higher to lower regions of the mountain has also contributed to this. *C. lusitanica* form 80% of exotic plantations in the sampled area while all the exotic species form around 95%. The indigenous species forms at least 5% and are mainly restricted to water catchment areas. This low percentage of indigenous species coupled with mass exodus of wild game to the lower regions has exerted pressure on the monkey diet base. There is need to plant *Moraceae* family and other fallback resource around *C. lusitanica* plantations to act as buffer zones. Restriction of movement of wild animals into the plantations like the case of the Abardere ecosystem is required. There is need to carry out further survey to establish the causes of mass exodus of wild animals from the higher to the lower regions of the mountain. Also, it is worth to carry out a socio-economic survey to determine the economic and social losses that accrue from monkey debarking and other game damage.

Keywords: Monkey Debarking, Game Damage, Fallback Resource, prevalence

INTRODUCTION

Game damage has been a challenge in forest plantations management especially where such plantations are in or near game parks and reserves. Elephants and monkeys have been reported as the major causes of plantations damage (Afolayan, 1975 and Ross, 2004). Elephants cause physical damage to trees through debarking, girdling and felling while monkeys mainly debark the stems. While elephants may cause these tree injuries not necessary in search of food, monkeys have been reported to debark trees as a means of survival (Ross, 2004) in times of competition (Xiang et al, 2006) or when the more preferred *Moraceae* are scarce (Fashing, 1999). Different species of monkeys have been found to exhibit different feeding habits, intergroup aggressions (Fashing, 1999) and resource switching flexibilities (Lambert, 2004). The *Moraceae* forms the top diet for majority of monkey species. However, in times of scarcity of the top diet, majority of the monkeys switch to different diets as fallback resource. Fashing (2004), in his study in Kakamega forest, found out that the African Cherry (*Prunus africana*) served as a fallback resource for the *Colobus* Monkeys (*Colobus guereza*) when the more preferred *Moraceae* were scarce. Elsewhere, Longonje, et al (2007) reported *Celtis africana* as a fallback resource for the red *Colobus* monkey, *Colobus badius tephrosceles* in Kibale National Park, Uganda.

Monkeys Resource switching has been found to impact negatively on forests. In most of the cases, the monkeys have been found to prefer the barks of trees as a survival technique. This debarking has been found to cause not only widespread tree mortalities but also a threat to the future of some closed forests. Ross (2004) quotes the case of the Atlas Mountains of Morocco; North Africa's largest intact forest. Though the forest plays a key ecological role in the region as well as a vital home for oaks and cedar, ecologists suggest that the forest is under a major threat. The trees have begun dying at an alarming rate; an occurrence associated to widespread debarking by the *Macaca sylvanus*. The macaques have been blamed for killing the Middle Atlas forest since the animals are known to strip bark from cedar trees to get at the moist, nutrient-rich living tissue underneath. In most of the cases, monkeys have been found to prefer larger size trees and mature forests (Yiming et al, 2000; Longonje et al, 2007). This causes major tree mortality and significant loss of tree merchantable volume.

Debarking predisposes trees to other secondary damages. Wermelinger (2006) and UNO (1994) report high incidences of bark beetles (*Oemeda gaani*) in debarked trees. The two, further, quote fungal infections in debarked stems. Further, USDA Forest Service (2000) states that debarked stems are predisposed to *Oemeda gaani*, and *Diplodia dieback*. Where debarking is beyond the threshold limit, stand dieback occurs. Mutiso (2007) reports a strong positive correlation between presence of insect pests and pathogenic indicators. He further states that the two act additively to contribute to tree mortality. Kumar (2001) reports that trees already stressed by other physical damages such as debarking are easy prey to insect pests and pathogens attack. Mutiso (2007) associates this easy susceptibility to insect pests and pathogens attack to failure of such trees to mobilize adequate defense mechanism even against some weak saprophytic fungi whose effects are rarely felt on their own. Primary and secondary damages associated with monkey debarking are of major concern in forest plantations management hence this study sought to evaluate and document this in the Mt Kenya ecosystem.

MATERIALS AND METHODS

The study was undertaken in the Mt Kenya ecosystem. The study, which was confined between 1998-2100, 9968000-9996000 and 0287000-0298000 (altitude, longitude and latitude respectively), covered Nanyuki, Narumoru, Gathiuru and Kabaru forest ecosystems. The four forest ecosystems were selected subjectively since they had plantations ≥ 36 -45 ha each for the three age cohorts 5-10, 11-20 and >20 years. Three age cohorts 5-10, 11-20 and > 20 years were selected to evaluate the prevalence and cause(s) of *C.lusitanica* monkey debarking across the age cohorts. In each forest ecosystem, all *C. Lusitanica* plantations in the range of 36-45 Ha were selected for each age cohort. In each age cohort, random numbers were generated and used to select one plantation for study. The selected plantation was transferred from the topographic map to a 30m by 30 m grid sheet at a scale of 1:10,000. A 120m by 150m systematic plot grid at a scale of 1:10,000 was used to locate plots on the grid sheet. Each plantation had 18 to 22 plots. Random numbers were generated and used to select 10 plots from the 18-22 plots. Assessment was then done in the 10 plots to give a sampling intensity of 0.4 Ha.

Plot Layout

Circular plots of 0.04 Ha and radius of 11.28 m were used to assess debarking in the 11-20 and >20 years age cohorts while 0.02 Ha and radius of 7.98m were used for 5-10 years age cohort. From the plot centre, general plot data was collected. Suunto clinometer was used to get the slope. Global Positioning System (GPS) receiver was used to collect coordinates of the plot centre. Distance tape and Suunto compass were used to take the distance and directions of the witness tree from the plot centre. Undergrowth within the plot was scored as none, light, medium and heavy. All the trees in the plot were numbered. Numbering ensured that all numbers are visible from the plot centre. Dbh was measured for all trees in the plot. Suunto hypsometer was used to measure the height. Heights for trees under the age cohort of 5-10, 11-20 and ≥ 20 years was taken at a slope distance of 10m, 15m, and 20m respectively.

Assessment of Debarking

All numbered trees were assessed for presence and absence of debarking across the three age cohorts in the four study sites. Further, the height of debarking was assessed using Suunto hypsometer. To test the effects and relationship between debarking height and the overall tree height, tree stems were classed into four parts namely Lower (1), Middle (2), Upper (3) and Top (4). To determine the relationship between debarked parts and presence of insect pests and pathogens, random numbers were generated and test trees selected. Finally, to determine the cause(s) of monkey debarking in *C. lusitanica* plantations in the study sites, percentage cover of the species, of all exotic species and of all indigenous species was determined

Data Analysis

To test existence of significant differences and correlation of debarking prevalence across the age cohorts in the study sites, One Way ANOVA and Pearson Correlation analysis was run. Results of debarking height were subjected to Duncan Multiple Range Test (DMRT) and Pearson Correlation to test for statistical differences and correlations. Presence of insect pests and pathogenic indicators was evaluated and results subjected to a Pearson correlation analysis. Percentage cover of *C. lusitanica* plantations in the study sites in relation to the other species, coupled with literature on top diet for monkeys was used to evaluate the cause(s) of debarking.

RESULTS

Prevalence of Debarking

Table 1 below show the frequency of debarking across the age cohorts in the four study sites. Debarking was more prevalent in Nanyuki. Among the studied sites, Duncan Multiple Range Test (DMRT) showed that Nanyuki had the most statistically significant differences ($P < 0.05$). Subjecting the studied age cohorts in the four sites and the prevalence of debarking to ANOVA, age cohort >20 years was statistically Significant ($P < 0.05$) compared to others.

Table 1: Prevalence of debarking across three age cohorts is sampled sections of Mt Kenya ecosystem in 2008

Sites	Age cohorts (yrs)						TOTAL	
	5-10		11-20		>20			
	T.stm	D.stm	T.stm	D.stm	T.stm	D.stm	T.Ss	T. Dss
Nanyuki	46	17	64	37	42	31	152	85
Gathiuru	48	7	56	34	28	22	132	63
Naromoru	66	14	47	33	29	18	142	65
Kabaru	44	6	50	33	43	35	137	74

* *T.stm* – total stems, *D.stm* – Debarked stems, *T.Ss* – total stems sampled, *T. Dss*– total debarked stems sampled

Debarking Height

The tree trunk was categorized into four parts namely, Lower (1) Middle (2), Upper (3) and Top (4). Presence of debarking in the four parts across the three age cohorts was assessed and tabulated. Debarking was more prevalent on upper (3) part of the tree (fig. 1). Test of homogeneity of variance on debarking and the height of debarking showed that the upper (3) part was statistically significant ($P < 0.05$) compared to the others in all age cohorts. Though debarking occasionally occurred in the middle part (2), no occurrences were recorded on the top most and the lower parts. A Pearson correlation analysis on occurrences of debarking and height of debarking showed a strong positive correlation. (Pearson correlation, $n = 4$, $r_s = 0.876$, $p = 0.05$).



Debarking on the upper (3) part of a tree stem.

Figure 1: Debarking occurrence on the upper (3) part of a tree trunk in sampled sections of Mt Kenya ecosystem in 2008

Debarking Occurrence across the Age Cohorts and its Effects on Tree Growth.

Debarking was found to impact negatively on the tree growth. However, the impact was only visible mostly on age cohort > 20 compared to 5-10 and 11-20 years. Sampled debarked trees in age cohort >20 showed loss of apical dominance and broken tops especially where debarking occurred in the upper (3) part of the tree (figure 2).



Loss of apical dominance due to debarking subsequently leading to a broken top and dieback

Figure 2: Loss of apical dominance and subsequent broken top due to debarking of upper (3) part of a *C. lusitanica* in sampled sections of Mt Kenya ecosystem in 2008

It was however, difficult to estimate where the top was at the time of loss of apical dominance especially where new branches had already started to assume leader but have not grown to the position occupied by other stems in the stand canopy. Surveys done on the trees that had lost apical dominance but whose debarking was below the threshold (20%) had since recovered but assumed double leader status. Where debarking severity was above the threshold limit (20%), most stems remained epicormics (figure 3)



Epicormics following severe debarking and loss of apical dominance

Figure 3: *C. lusitanica* epicormic following severe debarking and Loss of apical dominance in sampled sections of Mt Kenya ecosystem in 2008

Debarking and its Secondary Effects

Debarked parts showed a strong positive Pearson correlation ($n = 4$, $r_s = 0.90$, $P < 0.05$) with presence of insect pests and pathogenic indicators. *Oemeda gaani* galleries characterized debarked areas (figure 4a). Examination of the bole of a mature *C. lusitanica* stem (21 years old) that had severe debarking (>50%) indicated not only presence of heavy infestation by *Oemeda gaani* but also termites (figure 4b) and other fungal pathogens (figure 4c). Heart rot along the bole caused by both the bark beetles and pathogenic indicators were however, not visible especially in the undebarked part of the bole but a cross section of such tree showed severe bole damage (figure 4d). Further examination of a dead decaying bole indicated presence of other saprophytic fungi whose effects may not be felt on their own but rather acted as stressors to the debarked tree. Debarked trees that had lost apical dominance and subsequently lost their tops had incidences of *dieback*; a disorder commonly associated with loss or death of terminal shoots (figure 7). Though monkeys were found to debark trees on the upper (3) part, elephants preferred the lower (1) (figure 1). Trees that had been affected by elephant and monkey debarking had died or lost 50% of their branches.

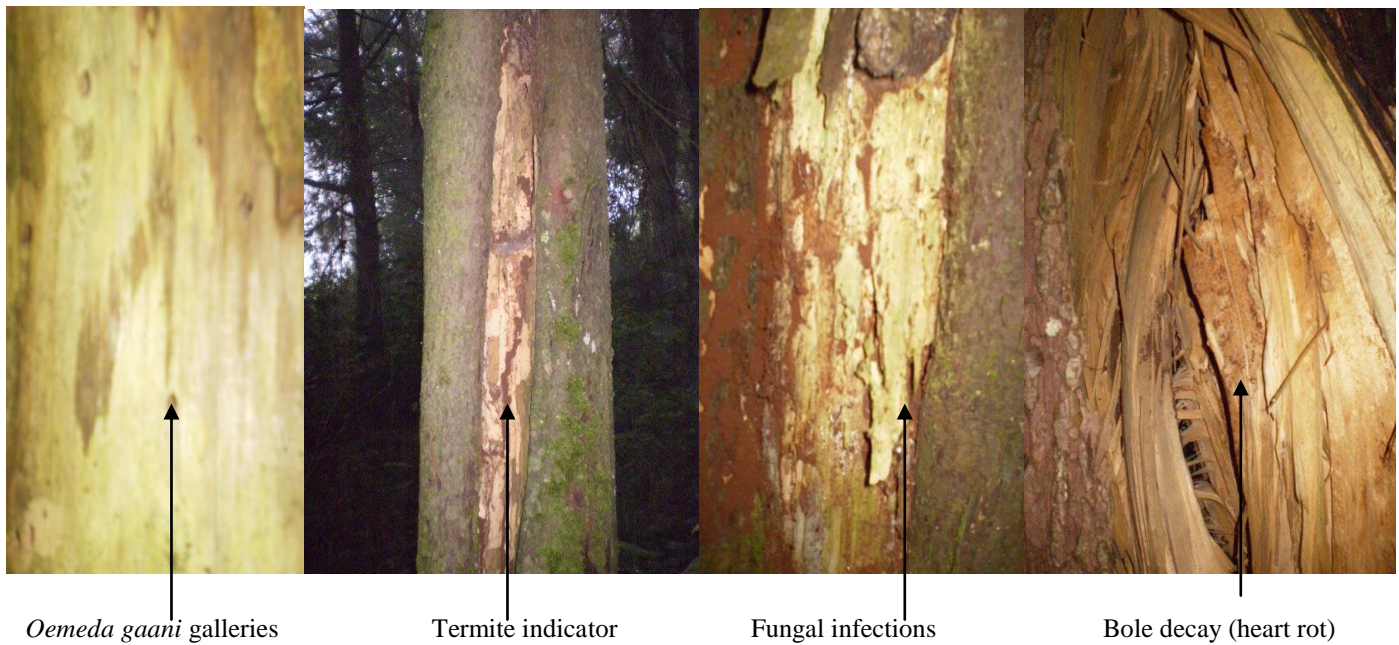


Figure 4: *Oemeda gaani* galleries (4a), Termite indicator (4b), Fungal infections (4c) and Bole decay (heart rot) (4d) on stems of *C. lusitanica* in sampled sections of Mt Kenya ecosystem in 2008

Causes of Debarking

C. lusitanica formed 80% of exotic plantations in the sampled areas. 15% accounted for the other exotic species while 5% were mainly indigenous species in water catchments areas. The *Moraceae* family, the key diet for the monkeys was scarce and entirely missing in some study sites such as Nanyuki. Other key fallback resources such as *Prunus Africana*, *Celtis africana* etc were also scarce and missing in some sites. Further survey conducted indicated that there has been an increase in the number of wild game occasioned by mass exodus (in early 2000's) from the higher parts of Mt Kenya to the lower regions which are mainly occupied by plantations.

DISCUSSION

Prevalence of Debarking

Nanyuki forest had the highest incidences of monkey debarking. This site had a high number of monkey population especially in the *C. lusitanica* plantations compared to the other studied sites. It had a lower elevation thus a higher temperature compared to other sites. The low altitude and moderate temperatures compared to other sites makes it a more suitable habitat for wildlife. It is likely that during the mass exodus of wild game from the higher to lower regions of Mt Kenya, this site was a major target. Efforts to tame the wild game in the site are evidenced by a number of private game ranches as opposed to the other studied sites. Pressure on the diet base for the monkeys especially in the smaller portions of the site occupied by indigenous species may have contributed to a shift in feeding habit. The *C. lusitanica* which occurs in the greater part of the site provided a fallback resource for the monkeys in absence of the more preferred *Moraceae*.

This work agrees with Fashing (2004) who found out that *Colobus guereza* preferred *P. africana* as a fallback resource when the more preferred *Moraceae* family was scarce in the Kakamega ecosystem. Elsewhere, Ross (2004) records that, in Atlas Mountains of Morocco (North Africa's largest intact forest), trees have begun dying at an alarming rate. He attributed this to *Barbary macaques* struggle to survive by killing the middle forest through debarking the trees to get at the moist nutrient-rich living tissue underneath the bark. The World Conservation Union (IUCN) has designated the *Macaca sylvanus* as a vulnerable species.

Debarking was found to be more prevalent on the older age cohort (>20 years) compared to others. This finding is further supported by Yiming et al (2000) who found out that monkeys showed preference for older forest trees. The mature stem barks provides the most thick moist and nutrient-rich living tissue compared to young ones (Ross, 2004). Primatologists also, urge that such barks are a source of water for the monkeys in drought seasons. Yiming et al (2000), in a study in Shennongjia Nature Reserve, China, found out that snub-nosed monkey (*Rhinopithecus roxellanae*) preferred mature forests. In the study, significant differences were found across the age cohorts where trees over 20 years were the most debarked. These findings are supported by Yiming et al (2000) who found out that the mean circumference of a tree had little effect on its preference score, but preferred species tended to be larger. A Wilcoxon signed-rank test on their work indicated that the percentage of trees used and average number of feeding bites per tree was significantly greater for larger trees. In this study, the number of stripped parts per tree had a significant positive correlation with the average stem diameter. Similar observations were made by Yiming et al (2000) where the number of bites per tree had a significant positive correlation with average tree circumference.

Height of Debarking

There were significant differences on the height of debarking across the three studied age cohorts. Almost all debarking incidences occurred on the upper (3) part of the tree trunk across the three age cohorts. The fact that this portion occupied the upper canopy; where monkeys prefer to stay, might have been the major cause of intense debarking on this part of the tree trunks. Ross (2004), further found out that in the rain forest of Peru, the white fronted capuchin and brown capuchin monkeys preferred to live on the upper canopy spending about 80% of the day-light moving through the forest debarking trees. This study found significant differences between the lower, middle, upper and top parts of the trunk and the incidence of debarking. The proportion of the bark eaten on the upper (3) part was much bigger compared with the small portion on the middle (2) and null on the lower (1) and top (4) portions. The upper (3) part was found to be moister compared to the lower and middle parts while the top was found to be tender to be debarked. Ross (2004), also, found that the moist part was not only nutritive but also the *Macaca sylvanus* preferred it to slake their thirst in time of water scarcity. Longonje et al (2007) in a study in Kibale National Park, Uganda, found significant differences between the age categories of the bark, between the number of the barks eaten and those not eaten by the *Colobus*. They also found significant differences between the lower, middle and upper branches in percentage and the mean number of bark samples was positively correlated to the percentage damage.

Effects of Debarking on Tree Growth

Loss of apical dominance characterized trees severely debarked. Severe debarking mostly on the upper (3) part of the tree trunk basically had adverse effect on translocation of water and food to and from the top parts of the tree. Such trees, which in most cases had lost their tops, remained epicomics or assumed double leader status. Epicomics were found to survive in less optimal conditions of the middle stand canopy while double leaders were struggling to occupy the upper canopy of the stand. Differences in DBH between the healthy and the epicomics as well double leaders stems was wide spread with the affected having a much small diameter. This stunted and/or slow growth may be greatly attributed to adverse effects on water and nutrients translocation as well as poor hormonal translocation (especially those translocated from the tree apex downward the stem) following loss of apical dominance. USDA forest service (2000), further, associated loss of apical dominance not only to stunted growth but also other secondary effects such as decay. White and brown rotters fungi mainly use open tops following loss of the tree top as entry points to tree bole. It is possible that loss of apical dominance and subsequent stresses occasioned by invading pathogens drastically reduce tree growth. Already stressed trees are easy prey to pathogens even by other weak saprophytic fungi whose effects are rarely felt on their own (Mutiso, 2007). Many trees respond to invading pathogens by mobilizing all food reserve towards developing defense mechanism through production of phenolic substances to counter the invading pathogens. Food reserves that could otherwise be used for growth are used to mobilize defense mechanism hence stunted growth. Debarked trees that recover from loss of apical dominance will depend on emergence of a live branch to assume leader status otherwise epicomics will remain epicomics.

Debarking and its Secondary Effects

Debarking predisposed affected stems to a wide range of secondary infections and damage. Debarked parts showed strong positive correlation to presence of insect pests. Debarked parts provided easy entry points for *Oemeda gaani*. Where infection by the bark beetles was beyond the threshold limit (20%), the stems exhibited high presence of necrotic and disease products pathogenic indicators. This strong correlation of insect pests and pathogenic indicators was else where found in Kakamega and Mt Elgon (Mutiso, 2007). In this, the two were found to have additive effects thus causing tree mortality.

Key among necrotic pathogenic indicators that were widely prevalent in bark beetle infected parts were *dieback*, mould, broken tops, and death of the whole tree. Trees are known to react to invasion by necrotic pathogens through hypersensitive reactions. This hypersensitivity is characterized by abnormal intense metabolic reactions at the tissue level. The nucleus of the cells around the infected area swells. Bursting of the swollen cells not only kills them but ensures the invading pathogens are killed thus preventing the spread of the pathogens beyond the infected area. This hypersensitive reactions lead to dieback, death of infected parts or the whole tree. Since debarking occurred on the upper (3) part of trees, those that had severe debarking and subsequent infection by *Oemeda gaani* and pathogenic indicators exhibited severe dieback characterized by loss of apical dominance and broken tops. It was however, difficult to estimate the severity of dieback where the broken tops could not be traced. It was also not easy to estimate the extent of bole damage especially where external indicators were not visible on the remaining tree trunk. USDA forest service (2000) and UNO (1994) cite bole damage caused by dieback and decay as a major source of overestimation of quality of standing timber. Acrossection of a bole of tree that had lost its top indicated not only severe decay of the trunk but presence of brown and white rotters' fungi. Mutiso (2007) reports that some fungal pathogens are rarely destructive on their own, though in already stressed trees, their cumulative effects are destructive. In this study, debarking, bark beetles and dieback acted additively to cause tree mortality. It is highly possible that debarking reduced the trees defense mechanism through interference with water and mineral uptake. Reduction in defense mechanism made trees more susceptible to insect pests, pathogens and other weak saprophytic fungi whose effects are rarely felt on their own.

Kumar (1999) cites already stressed trees by mechanical injury as easy prey for insect pests and pathogens. Trees already infected by insect pests and pathogens exhibit stunted growth as observed in this study. These infections and their predisposing factor; debarking, cause severe stress to such trees. To counter such infections, trees respond by mobilizing all reserved food energy towards development of defense mechanisms and little or nothing is left for growth. Defense against invading pathogens entails production of phenolic substances; a high energy requiring process at the expense of tree growth. Where defense fails, tree mortality occurs. Kumar (2001) cautions that if these stresses are in exceedance beyond a given limit, wide spread tree mortality occurs and the stand may change into a different state. UNO (1994) report that debarking of large size classes of tree cause fungal infections and the development of heart rot which reduce the timber value of the stem. Further, Wermelinger (2007) reported that in addition to bark removal by monkeys, secondary damages do occur. These types of damages are often caused by

wood borers (beetles) or by fungi which attack debarked parts. It is therefore highly important to examine the extend of damage caused by debarking on standing timber of the affected plantations in the study sites.

Causes of Debarking

The bark of *C. lusitanica* provides a fallback resource to the high population of monkeys in the study areas. Movement of monkeys and other wild animals from the higher parts of Mount Kenya to the lower regions seem to have drastically exerted pressure on the limited diet base for the monkeys in the plantations. Low population of the top diet (*Moraceae* family) and other fallback resources such as *Prunus africana* (Fashing, 2004), *Celtis africana* (Longonje et al, 2007) etc in the limited indigenous species in the area probably forced the monkey to switch diets. Lambert (2004), in his study on *Cercopithecoids* found diet switching a common occurrence. He suggested that resource switching is facilitated by digestive flexibility. Such a mechanism allow species packing and co-existence because it allows animals a means to switch to other dietary resources in the presence of other animals competitors or during times of seasonal scarcity (Lambert, 2007).

Diet switching arises out of necessity to survive in times of scarcity of preferred diet or competition. Following the mass exodus of monkeys and other wild animals in 2000's from the higher parts of Mount Kenya to lower parts which are mainly occupied by exotic plantations, probably triggered the need to switch diets to counter competition and scarcity of top diet. This resource switching has caused great harm to the *C. lusitanica* plantations. Such damage will drastically reduce the quality of timber in the longrun. Elsewhere, monkeys have been blamed for deforestation of the North Africa's largest intact forest, the Middle Atlas forest, Morocco (Ross, 2004). However, Andrea Camprio Ciani, Primatologist at the University of Pedna, says the monkeys have widely become "scape goats for all that is wrong in the area". In fact, he argues that, Macaques are the victims of the dying forest, not the other way round. In the Atlas mountains, debarking provides a means of survival for the *Macaca sylvanus*. They were found to strip bark cedar trees to get at the moist, nutrients-rich living tissues underneath. It is worth noting that *Juniperus procera* plantations in the studied areas were not debarked. This may be attributed to the absence of *Macaca sylvanus*, which are only found in Morocco, Algeria and Gibraltar. Elsewhere, in a study in Kibale National park, Uganda (Longonje et al, 2007) concluded that the bark of *Celtis africana* was a seasonal food for the red *Colobus* monkeys and had an impact on the tree. Though the number of food items exploited by monkeys varies markedly among seasons (Xiang et al, 2006), with dietary diversity being greatest in spring and summer, it was difficult (in this study) to associate the debarking to seasonal variations. This study was undertaken between April and July which are basically wet months of the year in the region. Xiang et al (2006) found out that, in winter, black white snub-nosed monkeys had to subsist on fallback foods such as dried grass and bark.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- ✓ Prevalence of debarking in the four study sites was found to have significant differences ($P < 0.05$). Nanyuki forest was the most affected; an occurrence attributed to its favorable climatic conditions for wild game and its vicinity to a number of game ranches;
- ✓ Statistically significant differences ($P < 0.05$) were also evident in the prevalence of debarking across the age cohorts. Monkeys were found to prefer trees in the age cohort >20 years compared to the lower age classes. This was attributed to the thick-moist nutrient-rich bark in mature trees compared to young ones;
- ✓ Duncan Multiple Range Test (DMRT) showed significant differences ($P < 0.05$) on the debarked part of the tree stem. Debarking mainly occurred at the upper (3) part as opposed to the top (1), middle (2) and lower (1). Pearson correlation analysis showed a strong positive correlation between the presence of debarking and the debarked part of the stem ($n = 4$, $r_s = 0.876$, $p < 0.05$). This was mainly attributed to the monkeys' habit of foraging in the upper canopy of a forest;
- ✓ Lack of the more preferred *Moraceae* family and other fallback resources for monkeys coupled with mass exodus of the wild game (in early 2000s) from the higher parts of Mt Kenya to the lower regions were some of the causes of high population and consequently debarking. *C. lusitanica* is a fallback resource for the monkeys in times of competition, lack of the more preferred *Moraceae* and during seasonal scarcity of other fallback resources; and
- ✓ Finally, this debarking has a negative impact on *C. lusitanica* plantations in the studied sites.

Recommendations

Management

- There is need to enrich water catchment areas in the study sites with the *Moraceae* family and other fallback resources such as *P. africana*, *C. africana* among others to increase dietbase for the Colobines and consequently ease pressure on *C. lusitanica*.

Research

- There is need to carry out a socio-economic survey to establish the actual losses that accrue due to monkey debarking. The mass exodus of wild game from the higher parts of Mt Kenya to the lower regions need to be investigated; and
- Better management practices for the high population of monkeys in the game ranches and forests should be explored. Such management strategies should focus more on introduction of an ecological balance that will keep the monkey population on check since the electric fence in some parts of the Mt Kenya ecosystem cannot restrict the monkeys from entering the forest plantations.

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