BARK-STRIPPING AND FOOD HABITS OF BLUE MONKEYS IN A FOREST PLANTATION ON MOUNT MERU, TANZANIA

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AUTHORIZATION TO SUBMIT DISSERTATION

This dissertation of SAMWEL L.S. MAGANGA, submitted for the degree of DOCTOR OF PHILOSOPHY with a major in FORESTRY, WILDLIFE and RANGE SCIENCES and titled "BARK-STRIPPING AND FOOD HABITS OF BLUE MONKEYS IN A FOREST PLANTATION ON MOUNT MERU, TANZANIA," has been reviewed in final form, as indicated by the signatures and dates given below. Permission is now granted to submit final copies to the College of Graduate Studies for approval.

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ABSTRACT

Bark-stripping of Cupressus lusitanica (cypress) and Pinus patula (pine) by blue monkeys (Cercopethicus mitis kibonotensis) in Meru Forest Plantations has been a problem since they were established in the early 1950s. This study was conducted in 1987 in the Sokoine University of Agriculture Training Forest, a portion of the Meru Forest Plantations, to determine the magnitude of bark-stripping in relation to the food habits of blue monkeys.

The extent, intensity and effects of bark damage were assessed in compartments with trees 3 to 14 years old, and the pattern of debarking was monitored throughout the year. On the average, 79.5 % cypress and 88.7% pine trees were debarked. Blue monkeys preferred dominant cypress trees to intermediate trees. In contrast, intermediate pine trees were more damaged than dominant trees. In both species, suppressed trees were least damaged. In all types of trees, the most severe bark damage occurred at the middle and top of the tree trunks. Twisted bole was the most common defect developed by damaged trees; 34% cypress and 38% pine trees were twisted at the middle and top sections. Bark-stripping was low in the rain season and increased in the dry season peaking at 22% of trees damaged in June and July.

The food habits data were collected from the indigenous forest at two sites within the plantation. A total of 38 plant species were eaten by blue monkeys. Fruits were the

most frequently consumed food item and averaged 76% of the monthly feeding records. Leaves were the next important food item but they were inversely related to the feeding on fruits. The other food items (flowers, shoots, petioles and bark) were similarly inversely related to the feeding on fruits. Bark-stripping was negatively correlated to the feeding on fruits, and thus increased when the feeding on fruits declined. Fruits of *Ficus thonningii* were the prime item in the diet of blue monkeys contributing 50 to 60% of the monthly feeding records. The amount of fruit on these trees in the area was also inversely related to extent of bark damage in the plantation.

The water and carbohydrate in the bark of cypress and pine trees was determined to examine if they influenced the bark-stripping. These were poorly correlated to the monthly debarking of both tree species.

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To My Parents

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INTRODUCTION

Wildlife damage to trees in forest plantations is a problem in many countries, and those on the continent of Africa are no exception. Several countries in the eastern, central and southern part of the continent that embarked on the establishment of forest plantations of exotic trees about 40 years ago immediately started to experience tree damage by wild animals. Large mammals that damage trees in plantations include the African elephant (Loxodonta africana), African buffalo (Syncerus caffer), eland (Taurotragus oryx), Sykes or blue monkey (Cercopithecus mitis), baboon (Papio sp.), bushbuck (Tragelaphus scriptus), and other small antelopes (Gilchrist 1965, Browne 1968, Omar and de Vos 1970, Afolayan 1975, Sommerlatte 1976, de Villiers 1976, Löyttyniemi and Mikkola 1980, Evans 1982, Katerere 1982, Von dem Bussche and Van der Zee 1985).

The various countries begun to notice tree damage by wildlife at different time periods, but the reasons animals damaged the trees are likely to be the same in all countries. The reduction of wildlife habitat by human activities in the various countries is probably the underlying reason, and it may have exacerbated the damage. In Tanzania, for example, Gilchrist (1965) points out that wildlife and forestry interaction, which implies tree damage, first became evident after the Second World War following the clearing of large tracts of forest land for both agricultural and pastural developments, and for the establishment of forest plantations.

Since then, this trend has continued in East Africa (Struhsaker 1981), and by and large throughout the continent.

Wild animal damage to plantation trees, particularly by large mammals such as elephants and buffalo, can sometimes be very devastating. In the late 1960s and early 1970s tree damage by these animals in some plantations around Kilimanjaro and Meru mountains in the northeastern part of Tanzania was so severe that portions of the plantations had to be abandoned (Lundgren 1974). This situation has now slightly changed, and tree damage by elephants is no longer a very serious problem. The main reason for this change is that human pressures, such as poaching of elephants which became rampant in the mid 1970s reduced the numbers of elephants and therefore their impact on many forest plantations. Although there is a decrease of large mammal damage to plantations, smaller animals such as the blue monkey, seem to be the non-human primate causing much tree damage in some forest plantations.

The most common damage caused by blue monkeys and their related subspecies is the bark-stripping of coniferous trees in plantations. This is widespread within the range of the monkeys which is central, eastern, and southern Africa (Kingdon 1971). Tree damage by blue monkey has been documented in Kenya (Omar and de Vos 1970, de Vos and Omar 1971), in Malawi (Evans 1982), and in South Africa (Droomer 1985, Von dem Bussche and Van der Zee 1985). In all these countries, the exotic coniferous trees of the genera _Cupressus_ and _Pinus_ are most susceptible to animal damage. The number of tree species attacked by the monkey differs from one country to another, and is dependent on the tree species in the plantations.

In Tanzania, the debarking of cypress and pine trees by blue monkeys has been reported in the Sao Hill Forest Plantation in southwestern Tanzania (Mululuma 1979). According to the distribution of blue monkeys in Tanzania, the subspecies causing the damage in this plantation is the Lake Nyasa blue monkey (C. m. moloneyi) (Swynnerton and Hayman 1951, Kingdon 1971, 1981). Debarking of trees in plantations on the slopes of the Kilimanjaro and Meru mountains is caused by the subspecies known as the Kilimanjaro blue monkey (C. m. kibonotensis).

In the Meru Forest Plantations, the monkey specifically attacks Cupressus lusitanica (cypress) and Pinus patula (pine) trees. Monkeys strip the bark of cypress, gnaw the cambium, and chew the inner bark to extract the sap or juice, and spit out the wad, whereas for pine they strip the bark and mainly gnaw the cambium. Bark-stripping evidently begun early after the forest plantations were established. Cypress and pine trees that had been planted in 1953 had already been seriously damaged by 1962 (Anonymous 1962), and the damage has continued until to date.

Despite the fact that bark-stripping by blue monkeys in these plantations has occurred for at least 25 years, there has been no detailed study to determine how serious the problem is. Attempts to control the damage were limited to trapping and shooting the monkeys (Anonymous 1962, Silloh 1986, per. comm.). The effectiveness of these control methods is difficult to evaluate because data on the magnitude of damage before and during the period when the methods were implemented are lacking.

Tree damage by wild animals is influenced by a variety of factors. Major factors which may influence the bark-stripping of trees by blue monkeys in many exotic softwood forest plantations include: the specific tree species, size and age; the availability of food in the native forest; the availability of nearby agricultural crops (e.g. corn (maize) potatoes, etc.) that may serve as alternative food of blue monkeys; and some substances in the bark of various tree species (Omar and de Vos 1970, Von dem Bussche and Van der Zee 1985). The effects of these factors are expressed through blue monkeys attacking specific tree species of certain size or age classes. In addition, the extent and intensity of debarking may also differ at various parts or sections of the trees, and debarking may vary greatly over different seasons.

This study was carried out mainly to determine which factors appear to affect the debarking of plantation trees by blue monkeys. This information is essential to understand the problem, and to design management actions. Finally, this information will serve as a basis for the future research on blue monkeys and bark-stripping in the forest plantation.

The principal goal of this study was to assess the magnitude of bark-stripping of conifer plantation trees by blue monkeys, and to relate the bark-stripping to the food habits of blue monkeys. The specific objectives were:

1. To examine and compare the extent, intensity and effects of bark-stripping of _Cupressus lusitanica_ and _Pinus patula_ trees by blue monkeys in the plantation.
2. To determine the type, size, and parts of trees that were most susceptible to debarking by blue monkeys.
3. To determine how the bark-stripping of the two tree species by blue monkeys varied throughout the year.
4. To investigate the food habits of blue monkeys in the native forest and relate them to bark-stripping activities in the plantation.
5. To assess the water and carbohydrate content in the bark of the two trees species and relate them to the debarking of plantation trees by blue monkeys.
6. To develop management and/or research recommendations to deal with the problem.

CONIFEROUS PLANTATION FORESTRY IN TANZANIA

NEED FOR FOREST PLANTATIONS

Most Tanzanians rely upon wood for a variety of uses ranging from supplying energy for domestic and industrial processes to providing building materials (see Mascarenhas 1984, Openshaw 1984). Domestic uses include cooking, lighting, and heating in homes, while tobacco curing, tea drying, brick firing, and baking in commercial bakeries are among the common industrial uses.

In addition, the natural forests and woodlands cannot meet the demand for industrial wood because both the number of utilizable trees species and the number trees per unit area is very small, and thus the yield per unit area is also very low, as is generally the case in most tropical forests (UNESCO 1978:457). Therefore, about half of the wood required to sustain Tanzania's wood-based industries currently come from forest plantations.

It was the demand for wood for domestic and industrial uses that prompted Tanzania to establish forest plantations. There are several advantages of forest plantations in tropical countries but two of them deserve special mention (Lundgren 1980). First, there is the flexibility of locating plantation forests with respect to markets and transport facilities. Secondly, the yield of volume per unit area is high, predictable, and the quality is usually uniform. Another important advantage is that tree species in forest plantations, most of which are exotic, are fast-growing and thus have a shorter rotation age than the indigenous tree species of commercial value like Chlorophora excelsa, Juniperus procera, Khaya nyasica, Podocarpus spp., Pterocarpus angolensis, Ocotea usambarensis, Olea capensis, and many others.

Tanzania has many types of plantation forests that are managed by different organizations and/or institutions. The discussion that follows only focus on industrial or commercial forest plantations of conifers that are under the management of the Forest Division of the Ministry of Lands, Natural Resources, and Tourism.

HISTORICAL PERSPECTIVE

The colonial foresters realized early the need for forest plantations in what was then called Tanganyika. They started small trial plots of some of the indigenous tree species mentioned above but most were later discontinued because the trees were slow-growing. Exotic tree species, especially of softwoods were later introduced and planted in moist and cool areas. By the late 1930s the establishment of small commercial plantations had began (Lundgren 1980).

The establishment of forest plantations of softwoods on a large scale started in the early 1950s. Since then the total area of plantations in the country has increased dramatically. Moore (1971) reported the area of softwood plantations to be approximately 20,800 ha in 1967. After two decades, the area of these plantations tripled and was estimated at 63,400 ha by mid-1986 (Ahlback 1986). These plantations vary in size from about 300 ha to 40,000 ha, and occur throughout most of the country (see Dykstra 1983) except the central and western parts which are relatively hot and dry. The principal coniferous tree species in the these plantations include _Cupressus_ _lusitanica_, _Pinus_ _patula_, _P_. _eliottii_, _P_. _caribaea_, _P_. _kesiya_, _P_. _oocarpa_, and _P_. _taeda_. However, some of these plantations also have hardwood species; _Eucalyptus_ spp. being the most common.

Currently, the expansion of most forest plantations is not extensive because there is limited land available. In existing plantations much of the activity now in progress is concentrating on the replanting the areas where the first rotation trees (planted in the early 1950s) have been clearcut. This strategy is commensurate with low processing capacity of wood industries in the country. The supply of wood from plantations far exceeds what the industries can process. However, this situation may change as investment in more wood-processing industries by various public and private companies, and individuals may increase (Ntagazwa 1988).

SILVICULTURAL OPERATIONS

A variety of silvicultural operations are carried out in a forest plantation including raising seedlings, planting, weeding, pruning, thinning and clearfelling the trees. Most of these operations are done by hand and are thus labor-intensive. Table 1 summarizes the schedule of silvicultural

Table 1. Schedule of silvicultural operations for cypress and pine trees in Tanzania (According to Ahlback 1986)

Operation	Age of trees (years)	Description
Planting	0	1680 seedlings/ha
Access pruning	4	All trees pruned
High pruning	6	Selective, only final crop pruned
First thinning	10	1110 trees/ha remain
Second thinning	14	740 trees/ha remain
Third thinning	18	490 trees/ha remain
Clearfelling	25	All remaining trees clearfelled

operations in a typical plantation.

Planting is usually carried out during the wet season at a spacing of 2.4 x 2.4 m, giving a stocking of about 1680 seedlings per hectare. In some cases wider spacing may be used depending on the intended end-use of the trees, and the tree species. Planting is normally organized such that seedlings of one tree species are planted in areas called compartments. These become discrete management units comprising a single tree species of one age. Many contiguous compartments of different age classes and species make a plantation block, and two or more such blocks make a forest plantation.

Weeding is carried out after planting until tree canopy closure. At canopy closure stage weeding is stopped because the weeds are suppressed by the shade of the trees. The annual frequency of weeding varies from one place to another because of the differences in climate, soils, and type of weeds in the area. For example in areas with two wet seasons two weedings may be necessary in a year in order to keep the trees free of competition from weeds.

In some forest plantations, for example the Meru Forest Plantations, weeding is not actually carried out by the agency managing the plantation. Instead workers of the plantation projects and the local people living nearby are allowed to interplant (agroforestry) corn (maize), beans, peas, and potatoes with trees for three or four years until tree canopy closure. In this way the people are provided with land to grow their crops but when they weed their crops trees are weeded at the same time.

Cypress and pine trees also need to be pruned. Pruning is carried out in the dry season to avoid the infection of trees by fungi. There are two types of pruning; access pruning and high pruning. Access pruning is carried out when trees are four years old (Table 1). As the name implies, this pruning is done to facilitate accessibility into the stands, and hence all trees are pruned to an average person's height. High pruning, on the other hand, is selective and takes place about six years after planting the trees. The purpose of high pruning is to produce knot-free lumber and therefore only prospective final crop trees are pruned.

Thinning is another important operation carried out to ensure that the final crop trees are large and are of good quality. Three thinnings are carried out before trees are clearfelled at full rotation age of 25 years (Table 1). During each thinning, approximately one third of the remaining trees are removed, and at the end of the rotation age only a third of the original trees planted are harvested.

NATURAL HISTORY OF THE BLUE MONKEY

TAXONOMIC CLASSIFICATION AND DISTRIBUTION

Blue or Sykes monkeys form a large group of not less than 20 interrelated subspecies that are restricted to the suitable habitats of only eastern, central, and southern Africa. These monkeys, belonging to the family Cercopithedae, have been classified differently by various authors (see Booth 1968). Some classify them as _Cercopithecus_ _mitis_ and consider the variations as only intraspecific variations or subspecies (Dorst and Dandelot 1970), whereas other authors group the monkeys into two separate species; _C_. _mitis_ (Blue monkeys) and _C_. _albogularis_ (Sykes monkeys) (Hill 1966). Since in the most recent literature the former classification has been adapted, it is accordingly used here.

The blue monkey that strips the bark of plantation trees on Mount Meru is the Kilimanjaro blue monkey (_C_. _m_. _kibonotensis_) which occurs in the forests of northeastern Tanzania (Kingdon 1971). It inhabits forests of the Kilimanjaro and Meru mountains and the river valleys on the slopes of these mountains, the Pare and Usambara mountain ranges, and some coastal forests of this section of the country. These habitats are actually ecological islands inhabited by isolated populations of this subspecies of blue monkeys.

GENERAL BIOLOGY

The size of blue monkeys varies greatly. They weigh from 6 to 12 kg, and the body length (excluding tail) ranges from 50 to 70 cm (Kingdon 1971). This is largely due to the dimorphism of the sexes; males being larger than females. Generally, it is difficult to determine the sex of these primates in the field especially of subadult animals. Gartlan and Brain (1968) concluded that distinguishing males from females of *C. mitis* is almost impossible. Size is the main characteristic therefore used to identify adult males, whereas adult females may be singled out if they are accompanied by young.

Blue monkeys seem to be seasonal breeders. Rudran (1978) found that the monkeys of the Kibale forest in Uganda had two breeding seasons. Breeding in blue monkeys during this study period on Mt. Meru was observed to take place largely between May and September with a slight increase in June/July. The gestation period is approximately 140 days (Napier and Napier 1985) with a litter size of one.

The major predators of blue monkeys are the leopard, and the crowned hawk eagle (*Stephanoaetus coronatus*). This is usually a forest dwelling bird of prey and is sometimes referred to as the monkey eating eagle because it frequently occurs where there are monkeys (Williams 1964, Napier and Napier 1967, Gartlan and Brain 1968). Blue monkeys may also be preyed on by other primates. Wrangham (1977) found that blue monkeys were occasionally preyed by chimpanzees (*Pan* *troglodytes*). Humans also used to kill blue monkeys to obtain their skins for export, and in some countries they are still hunted for meat (Welfheim 1983).

HABITAT AND HOME RANGE

The prime habitat of the blue monkeys is high forests, since tall trees are very important for providing food and shelter. Because of these requirements, blue monkeys are generally confined to semi-evergreen and evergreen montane forests, riverine forests, lowland forests, and bamboo forests (Swynnerton 1958, Gartlan and Brain 1968, Omar and de Vos 1970). Shade seems to be an essential requirement for blue monkeys as they have a habit of descending into the lower forest story for shade at mid-day. Kingdon (1971) suggests that shade excludes blue monkeys from dry open habitats. However, since these animals are very arboreal, other resources, such as the abundance and distribution of tall trees and food may be more important than shade.

The size of home ranges varies substantially depending on the monkey group size, the density of monkeys, and the abundance and distribution of the resources, particularly food. Workers in different parts of the blue monkey range have reported home range sizes of from 13.2 ha to 100 ha (Welfheim 1983). But certain authors have considered that home ranges and territories of blues monkeys are the same (de Vos and Omar 1971, Rudran 1978). This interpretation has occurred because of the behavior of most primates.

Primate groups are rarely involved in actively defending certain areas to prevent their use by other conspecific groups by belligerent confrontations (Bates 1970). In addition, group territories may be advertised only by vocalization resulting into group avoidance. Consequently the distinction between home range and territory is blurred.

SOCIAL ORGANIZATION AND HABITS

Blue monkeys are commonly found in groups ranging between 2 to about 30 individuals (Rudran 1978, Struhsaker 1978a, Aldrich-Blake 1979). Occasionally, solitary males may be seen. The age composition of a group typically consists of one adult male with several adult females, juveniles, and infants. However, the sex composition of a group is difficult to ascertain because it is difficult to determine the sex of juveniles and infants.

Generally, blue monkeys are relatively social and quiet primates compared for example with the noisy olive baboons (*Papio anubis*) which also inhabit these slopes of Mt. Meru. Intergroup conflicts and aggressive encounters are very rare, and were not seen during the study period. Similarly, de Vos and Omar (1971) did not observe any direct conflicts between the groups they studied in Kenya, whereas Rudran (1978) and Aldrich-Blake (1979) reported infrequent intergroup interactions. Nevertheless, in all three studies blue monkeys were regarded as territorial animals possibly because of their intergroup avoidance.

Blue monkeys usually feed in the morning and late in the afternoon, and rest in shade during the hot hours of the day (Haltenorth and Diller 1980). The food of blue monkeys consists largely of different parts of plants, but they also feed on insects. The plant parts eaten include leaves, flowers, young shoots, and fruits (Omar and de Vos 1970, Schlichte 1975, Van der Zee and Skinner 1977, Rudran 1978, Struhsaker 1978a, Aldrich-Blake 1979). Where agricultural crops are available nearby, blue monkeys also feed on corn, beans, and potatoes. They have sometimes been classified as omnivores (e.g. Struhsaker 1978a) or as frugivores (Nishida 1972, Richard 1985). Since it has been established that their annual diet is predominantly (more than 50%) fruits (Struhsaker 1978a, Rudran 1978, Aldrich-Blake 1979), it is probably proper to classify them as frugivores. There is, unfortunately, no information on their daily food intake.

STUDY AREA

LOCATION AND SIZE

The study area is situated 3°14'S and 36°41'E on the southwestern slopes of Mount Meru in northeastern Tanzania (Figure 1). The plantation is managed by the Sokoine University of Agriculture for training and research purposes. It is therefore known as the Sokoine University of Agriculture Training Forest (Training Forest), and is part of the Meru Forest Plantations. These plantations extend west of the mountain covering a total area of 5,600 ha at elevations ranging from 1,500 to 2,500 m.

The Training Forest occupies approximately 850 ha, and is divided into the northern and southern blocks called Laikinoi and Narok, respectively (Figure 1). It is bordered by natural forest to the north and east, and settlements to the southwest. The area that is actually planted is about 660 ha. There are patches of remnant indigenous forest within the plantation particularly along stream valleys. These forest patches are used by blue monkeys.

CLIMATE

The climate of this area is fairly variable but principally there are two rain seasons and one long dry season. The first rain season begins in February and ends in May, and the second season is short with rains falling in November and December. January is usually a dry month.

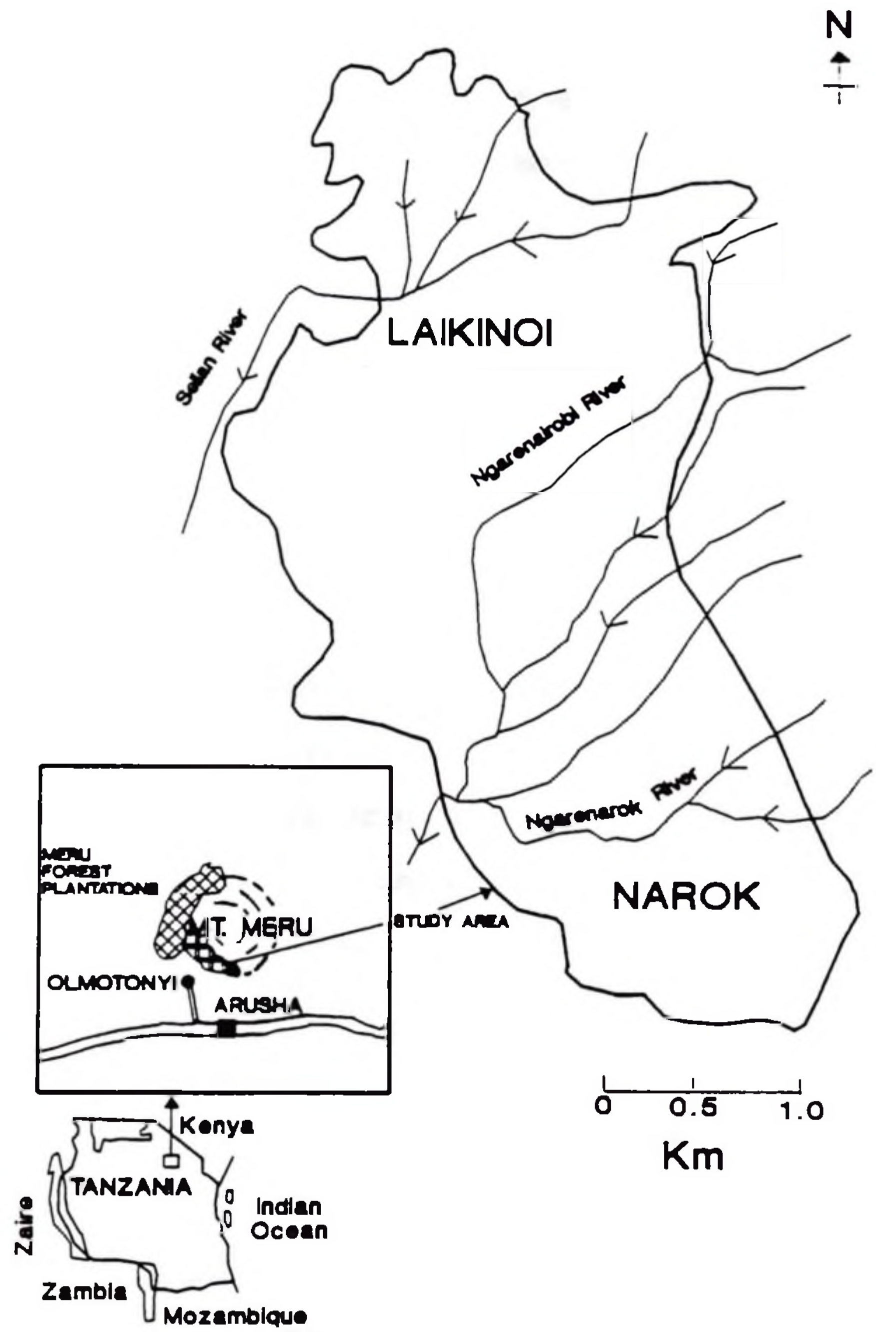

Figure 1. Location of the Meru Forest Plantations and the study area: Sokoine University of Agriculture Training Forest.

The amount of rainfall over the area varies with altitude and site location with respect to the ridges and narrow valleys on the slopes. The annual mean rainfall is about 800 mm, but varies from 500 mm to 1,200 mm. The five-month dry season starts from June to October. In most days the area is cloudy and sometimes foggy.

The annual mean temperature is about 20°C with a minimum of 8°C and a maximum of 26°C. Usually the coolest months are June and July when night temperatures at higher elevations, for instance Laikinoi area, may drop so low that frost may occur.

PHYSIOGRAPHY AND SOILS

Deep narrow valleys dissect almost the entire slopes of Meru mountain. Valleys originate as small stream valleys high up the mountain and join one another down the slopes to form larger valleys at the lower slopes as they pass through the plantations. Some of these streams flow throughout the year with a peak flow in the rain season.

Protruding between these valleys are ridges which may be only a few hundred meters wide. These ridges are very susceptible to soil erosion when the forest is opened up by selective felling or are subjected to grazing. This happens because of the nature of the volcanic soils of this area.

Mt. Meru is said to be a dormant volcano. It was reported that volcanic activity was observed as a column of smoke from the inner crater in December 1910 (Uhlig 1911 cited in Hedberg 1951). Soils on its slopes are formed from volcanic ash which are classified as andosols (Buringh 1979). The soils are deep, immature, fertile, light with low bulk density, and show little development Lundgren and Lundgren (1972). Being light, they are so highly erodible that during the wet season deep valleys can easily develop particularly in areas that are devoid of vegetation. In the dry season on the contrary, soils become powdery making the area dusty.

VEGETATION

The principal tree species in the plantation are Cupressus lusitanica (cypress) and Pinus patula (pine). Of the area that was planted, about 52% and 43% was covered by cypress and pine, respectively, and 5% was occupied by other species including Eucalyptus spp., Acacia melanoxylon, and Grevillea robusta. The cypress and the pine are both native to mountain ranges of Mexico. These trees grow up to a height of 20 to 30 m, but branches of cypress are curved upwards whereas those of pine are horizontal and whorled. Cypress stands have dense canopy and not much undergrowth. The pine canopy is lighter and therefore pine stands have more understory vegetation than cypress stands.

The native submontane/montane evergreen forest occurs on the wetter part of the mountain between 1,700 and 2,700m (Moreau 1936 cited in Hedberg 1951). On the lower slopes and along stream valleys, the dominant trees forming the upper canopy are Albizia gummifera, Croton macrostachys, and C.

megalocarpus. In the middle story, *Dombeya* sp. is the main tree species.

At middle elevations (2,000 to 2,250 m) the upper story of the forest is composed of *Ficus thonningii*, *Entandrophragma excelsum*, *Allophylus* sp., *Prunus africana*, *Ekebergia capensis*, *Tabernaemontana holstii*, and *Schefflera volkensii*. The lower layer is dominated by small trees and shrubs like *Xymalos monospora*, *Turrea holstii*, *Maesa lanceolata*, and lianas such as *Urera hypselodendron*. In disturbed areas of the forest however, *Neuboutonia macrocalyx*, *Cordia abyssinica*, and *Nuxia congesta* are common.

On drier ridges at 2,100 to 2,300 m, *Podocarpus gracilior*, *Olea hochschetteri*, and *Juniperus excelsa* (*J. procera*) occur. The montane bamboo (*Arundinaria alpina*), replaces the forest between 2,300 to 2,700 m but some trees and shrubs are interspersed in the bamboo thicket.

On slopes of approximately 2,500 m the composition of the forest gradually changes into *Hagenia* woodland. The principal trees are *Hagenia abyssinica*, *Podocarpus usambarensis*, and large trees of *J. excelsa*. Higher up the slope *Erica arborea* and *Stoebe kilimandscharica* become dominant. The woody vegetation fades away above 3,000 m where tussock grassland growing on loose volcanic ash is predominant.

WILDLIFE

The avifauna of the area is diverse consisting of many species of birds. The most noticeable birds are the Hartlaub's turaco (*Tauraco hartlaubi*), and the silvery-cheeked hornbills (*Bycanistes brevis*) that make loud calls in the forest. These birds are frequently found feeding on fruits in the same trees with blue monkeys. The crowned hawk eagle (*Stephanoaetus coronatus*) is the principal bird of prey found in this area and was always noted to induce alarm calls and panic among blue monkeys whenever they spotted it.

The ungulate mammals include Harvey's red duiker (*Cephalophus harveyi*), the bush pig (*Potamochoerus porcus*), and the bushbuck (*Tragelaphus scriptus*). The elephant (*Loxodonta africana*) and the Cape buffalo (*Syncerus caffer*) are not common and they are restricted to the natural forest on the slopes above the forest plantation. They occasionally however, pass through the plantation.

Among primates, the black and white colobus (*Colobus abyssinicus caudatus*) harmoniously share the same trees with blue monkeys. The olive baboon (*Papio anubis*) also inhabits the area. The small nocturnal and arboreal primates, the thick-tailed galago (*Galago crassicaudatus*) and the lesser galago (*G. senegalensis*) probably occur in this area as well (Swynnerton and Hayman 1951, Dorst and Dandelot 1970). The sounds of galago in trees are usually heard at night.

The leopard (*Panthera pardus*), and the ubiquitous spotted hyaena (*Crocuta crocuta*) are the main large carnivores in this area although the density of leopard is probably low due to illegal trapping of the cat. Undoubtedly, there are other species of the smaller carnivores. These may include some genets (Genetta spp.), African civet (Viverra civetta) and some species of the genus Felis.

HUMAN ACTIVITIES

Meru Forest Plantations are part of the Meru Forest Reserve, and therefore all laws pertaining to forest reserves apply. Human activities within the reserve such as grazing of livestock, hunting, and cutting of trees without special permission are not allowed. Although the forest is supposed to be patrolled by forest guards, there is illegal grazing of livestock, particularly cattle, goat and sheep. Illegal trapping and hunting of animals, even with the aid of dogs is not uncommon in the area. There is also human damage to trees within and outside the forest plantations. Trees are cut for firewood and for building poles. Above all, ring-barking especially of cypress trees is widespread throughout the plantation, and this contributes to a substantial portion of the tree mortality in the plantation.

Farming is the principal activity in the settlements just outside the plantation. Agricultural crops that are grown include coffee, bananas, corn, peas, beans and potatoes. Because of the land scarcity, permission has been granted to interplant annual crops with trees in the plantation after clearfelling, and from the time the first year trees are planted until trees close their canopies. This interplanting is beneficial both to the agency managing the forest plantation and the local people. The local people are provided with land to grow food crops, but in the process of weeding their crops, they simultaneously weed the trees.

GENERAL SAMPLING PROCEDURES

The procedures used to select compartments for study, and selecting sites for collecting food habits of blue monkeys in the natural forest are broadly discussed here. Detailed description of the methods are described in the specific sections of the manuscript.

SELECTION OF COMPARTMENTS AND SITING OF PLOTS

Compartments were selected based on the age of trees, availability, accessibility, and location relative to the whole plantation. Compartments with trees of ages between 3 and 14 years were selected since these are ages that are mainly susceptible to damage by blue monkeys (about 6 to 12 years). There were a total of 18 compartments of cypress trees within these ages in the plantation covering approximately 216 ha. Seven of these compartments (81 ha) were selected for study. Only six compartments (45 ha) of pine trees of this same age class were available and five compartments covering 43 ha were selected. Thus a total of 12 compartments were selected comprising an area of about 124 ha (Figure 2 and Appendix I). The ages of trees in the selected compartments ranged from 4 to 14 years for cypress, and 6 to 10 years for pine.

In each compartment, two or three 25 X 20 m (0.05 ha) plots were randomly sited and marked. Two plots were established in compartments that were less than 10 ha in size,

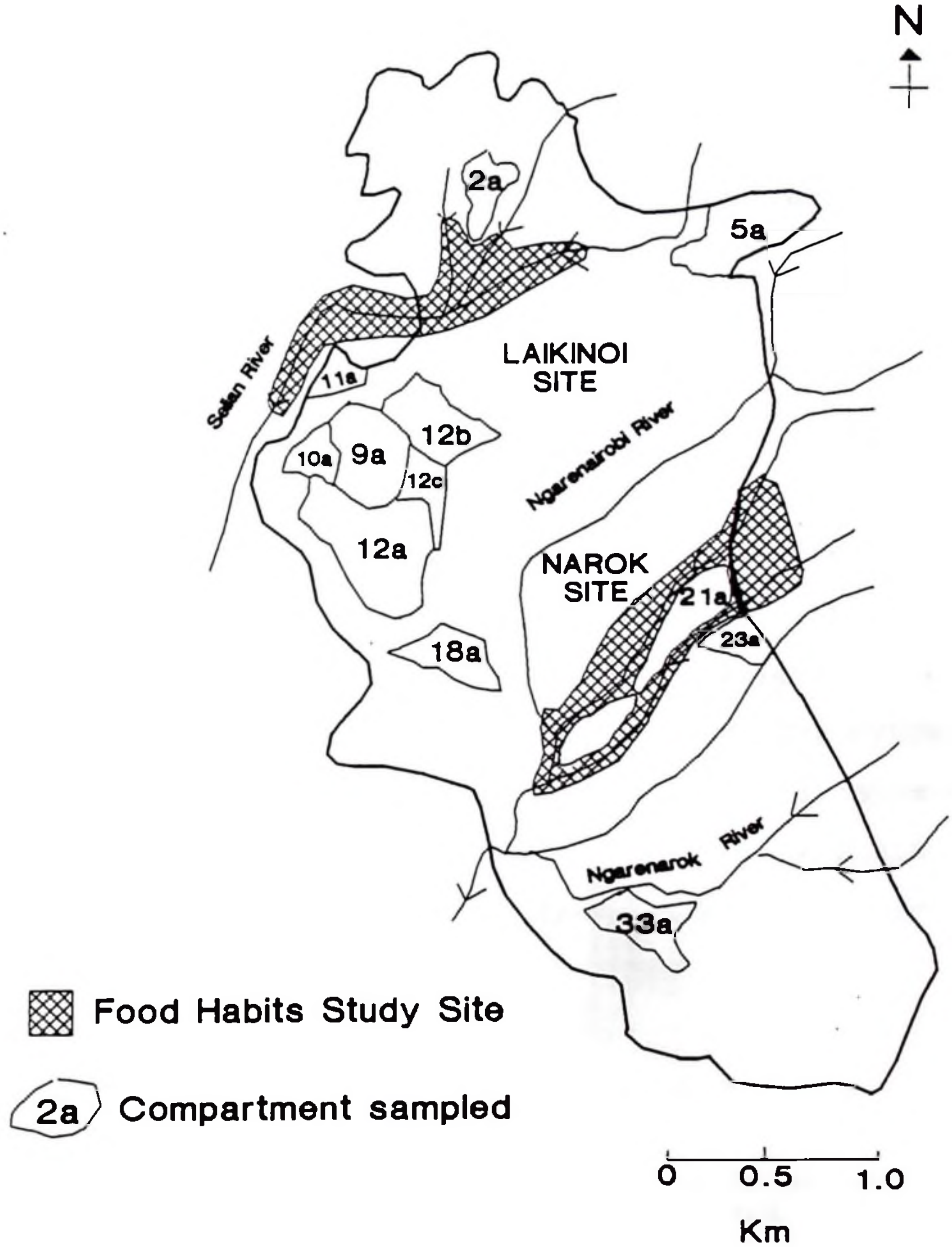

Figure 2. Location of compartments sampled and the sites where the food habits data of blue monkeys was collected

and three plots were established in compartments larger than 10 ha. Twenty plots were established in cypress compartments and 11 plots were established in pine compartments. Overall, there were 12 compartments and 31 plots in which tree damage was assessed. The extent, intensity, and effects of damage were investigated.

In order to include compartments representing the ages between 3 and 14 years for each tree species, compartments were selected from three age classes: 1=3 to 6, 2=7 to 10, and 3=11 to 14 years. The distribution of the selected compartments is shown in Table 2. Monitoring of tree damage, sugar and water content in the bark was restricted to eight of the 12 compartments in 20 plots (14 plots in five cypress compartments and six plots in pine compartments) (Appendix I). The carbohydrate and water content in the bark was also monitored from randomly selected trees outside the plots but within the eight compartments.

Table 2. Distribution of compartments used to monitor tree damage, water and carbohydrate content in bark.

	Age classes (years)		
Tree species	3-6	7-10	11-14
C. lusitanica	1	2	2
P. patula	1	2	*

* There were no compartments in this age class in the plantation

STUDY SITES FOR FOOD HABITS OF BLUE MONKEYS

Sites for observing the food eaten by blue monkeys were selected after surveying the natural forests along the river valleys to identify areas frequently used by monkey groups. When these areas were identified, they were assumed to represent home ranges and consequently selected as observation sites. One site was located in the Narok area along two tributaries of the Ngarenairobi River including a portion of the forest from the plantation boundary up to about half a kilometer into the forest (Figure 3). The second site was selected in the Laikinoi area along the Selian River and its tributaries.

The study site at Narok was approximately 1.75 km^2 ranging in elevations from 1,800 to 1,950 m. The Laikinoi study site was about 1.8 km^2 and elevations ranged from 1,900 to 2,200 m. Because of the proximity to settlements and lower altitude, the vegetation at Narok was more disturbed than that of Laikinoi. Also due to elevational gradient, the floristic composition was slightly different between the two study sites The Narok site was frequented by four groups of blue monkeys whereas five groups used the Laikinoi study site. Group sizes varied from approximately 15 to 35 individuals. Monkeys were observed monthly throughout the year except in January at Laikinoi and in February at Narok.

BARK-STRIPPING BY BLUE MONKEYS: MAGNITUDE, EFFECTS, AND SEASONAL VARIATION

METHODS

Field Procedures

Assessment of the bark damage was carried out in all 12 compartments (Appendix I). All trees in each the of 31 plots were physically examined for both old and new wounds caused by monkeys. New wounds were identified by the teeth marks and the pieces of stripped bark left dangling from the ends of wounds. The unique characteristics of wounds caused by monkeys and their location on the tree allowed them to be distinguished from wounds caused by harvesting operations (Maganga and Chamshama 1984). Old wounds were identified by the dry stripped bark dangling from partially healed wounds. A total of 1676 trees were examined in all plots; 1002 cypress and 674 pine trees. During the process, trees were classified as dominant, intermediate, or suppressed based on the size of the tree and the position of its crown in the canopy. The diameter at breast height (dbh) was also measured.

The location of wounds on trees was recorded in one of the four categories; base, middle, top, and branch. The base was defined as the tree trunk portion between the ground level to 1.5 m. The rest of the tree trunk was occularly divided into two equal halves such that the first bottom half next to the base was called middle, and the second upper half was called top. Branch was defined as any limb attached to the trunk at any height.

The intensity or degree of damage was also occularly estimated and recorded in three classes. These classes were minor, moderate, and severe, and they were based on the number and size of wounds. Minor damage had one or two small wounds that covered less than one fourth of the girth; moderate damage had several wounds that covered up to one half of the girth; and severe damage had many or multiple wounds that covered more than half up to the whole girth (ring-barked).

In addition to the damage intensity, the effects emanating from monkey damage such as bent or crooked bole, forked, fungus-infected, large branches developed, top dead (dried-up top), tree dead, and twisted bole, were identified and recorded in numbered codes. Effects were also classified and recorded as occurring either at the base, middle, top or other. The intention was to ascertain the frequency of the various kinds of secondary defects and infections at different parts of the tree trunk.

Tree damage was monitored monthly from January to December 1987 in only eight of the 12 compartments to determine the annual pattern of damage (Appendix I). This was carried out in the same plots that were established for the general assessment of tree damage. Plots were visited once a month and all trees were inspected for new wounds inflicted by monkeys within that month. After trees were examined, all pieces of bark dropped around the debarked trees were removed so that new bark-stripping could be easily detected in the subsequent month.

Analytical Procedures

Damage frequency tables were obtained by compartment, plot, tree species, tree type, and tree part damaged using SAS computer programs (SAS 1982). To test the hypothesis that the extent of debarking of cypress and pine trees was the same, percent trees damaged in the plots of the two tree species were compared by Mann-Whitney U test (Zar 1984).

The damage frequency tables were similarly used to obtain the intensity, and the effects of damage. Percentages of each damage intensity category were calculated by tree species, tree type, and part of tree damaged. Since compartments sampled were of different ages, the mean dbh for each tree type and compartment were computed as well.

To obtain the monthly variation in tree damage, the same procedures of using frequency tables was carried out. Monthly percentages of trees damaged for each tree species were calculated as follows. For each tree species, trees debarked in all plots for each month were added. This number was then computed as a percent of the total number of trees (damaged and undamaged) in all plots of the tree species in that month. The monthly mean percent of trees damaged for each tree species were calculated. To test if these means were the same, the monthly percentages of tree damaged were compared by Mann-Whitney U test.

RESULTS

Extent of Debarking

On the average about 82.7% of all trees assessed were bark-stripped either at base, middle, top, branch or any combination of them (Table 3). An average of 79.5% cypress trees were damaged and 88.7% pine trees were damaged but the difference was not significant (Mann-Whitney U test, $P<0.05$). The extent of damage by type and part of tree is shown in Table 4, and the mean dbh for each tree type and compartment are given in Appendix I. For cypress, more dominant and intermediate trees (80.1% and 66.4% respectively) suffered damage than suppressed trees (20.3%). By contrast, a greater percent (67.7%) of intermediate pine trees were damaged than dominant (49.0%) or suppressed (46.9%) trees.

The general trend however, was that about two thirds or more of the trees assessed of each species had wounds in the middle and/or top portions of the trunks (Table 4: see column totals for middle and top). Base damage was the next to middle and top damage, whereas branch damage was the least in decreasing order of percent damage. Base damage was higher in cypress (30.4%) than in pine trees.

Intensity of Debarking

The intensity or degree of debarking was defined as the number and size of wounds on a particular part of a tree. Tables 5 and 6 indicate that the degree at which blue monkeys attacked trees varied with the type and part of the tree.

Table 3. Mean percent of *C. lusitanica* and *P. patula* trees debarked by blue monkeys in 31 plots

Tree species	Mean % Trees debarked	S.D.	Range of % trees debarked
C. lusitanica (n = 20 plots)	79.5[a]	29.5	4.6 - 100.0
P. patula (n = 11)	88.7[a]	7.9	72.9 - 98.0
Pooled data (n = 31)	82.7	24.3	4.6 - 100.0

a The letter indicates means do not differ significantly, (P<0.05, Mann-Whitney U test)

S.D. = Standard deviation

Table 4. Extent (percent of total) of bark-stripping of *C. lusitanica* and *P. patula* trees by blue monkeys classified by type and part of tree debarked

Tree species	Tree type	Part of tree debarked				
		Base	Middle	Top	Branch	Total
C. lusitanica (n = 1002)	Dominant	14.8	30.9	28.1	6.3	80.1
	Interm.	10.9	28.9	23.9	2.7	66.4
	Suppressed	4.6	7.9	7.2	0.6	20.3
	Total	30.4	67.7	59.2	9.6	* *
P. patula (n = 674)	Dominant	3.9	22.9	20.3	1.9	49.0
	Interm.	7.1	28.3	29.3	2.5	67.7
	Suppressed	13.7	14.8	17.8	0.6	46.9
	Total	24.7	66.6	67.7	5.0	* *

* * Will not add to 100% because of multiple debarking of all parts of the same tree (damage on the tree parts is not mutually exclusive)

Interm. = intermediate

Table 5. Intensity (percent of total) of bark-stripping of *C. lusitanica* trees by blue monkeys classified by type and part of tree, and intensity classes (n = 1002)

Tree type	Part of tree debarked	Intensity (degree) of debarking			
		Minor	Moderate	Severe	Total
Dominant	Base	7.8	3.0	4.0	14.8
	Middle	3.3	5.0	22.6	30.9
	Top	2.8	3.5	21.9	28.2
	Branch	1.0	2.2	3.1	6.3
	Total	14.9	13.7	51.6	80.2
Interm.	Base	7.5	2.0	1.4	10.9
	Middle	7.0	5.4	16.6	29.0
	Top	4.7	3.7	15.5	23.9
	Branch	0.6	1.2	0.9	2.7
	Total	19.8	12.3	34.4	66.6
Suppressed	Base	3.4	0.5	0.7	4.6
	Middle	2.9	1.3	3.7	7.9
	Top	1.7	0.9	4.6	7.2
	Branch	0.2	0.2	0.2	0.6
	Total	8.2	2.9	9.2	20.3

Interm. = intermediate

Table 6. Intensity (percent of total) of bark-stripping of *P. patula* trees by blue monkeys classified by type and part of tree, and intensity classes (n = 674)

Tree type	Part of tree debarked	Intensity (degree) of debarking			
		Minor	Moderate	Severe	Total
Dominant	Base	3.4	0.3	0.2	3.9
	Middle	4.8	2.2	15.9	22.9
	Top	4.8	1.5	14.1	20.4
	Branch	1.2	0.3	0.3	1.8
	Total	14.2	4.3	30.5	49.0
Interm.	Base	6.1	0.6	0.5	7.2
	Middle	7.3	4.0	17.1	28.4
	Top	7.4	4.0	18.4	29.8
	Branch	1.6	0.3	0.6	2.5
	Total	22.4	8.9	36.6	67.9
Suppressed	Base	11.6	0.9	1.2	13.7
	Middle	5.0	2.8	7.0	14.7
	Top	3.6	2.7	11.6	17.9
	Branch	0.1	0.1	0.3	0.5
	Total	20.3	6.5	20.1	46.9

Interm. = intermediate

Both cypress and pine trees had the highest percent of severe bark-stripping at the middle and top sections of the trunks of all types of trees. For cypress, severe bark-stripping was highest in the middle and top of the dominant trees (22.6% and 21.9%) followed by intermediate trees (16.6% and 15.5%), and lastly suppressed trees (3.7% and 4.6%). However for pine, the order was intermediate trees (17.1% at middle and 18.4% at top), next was dominant trees (15.9% and 14.1%), and finally suppressed trees (7.0% and 11.6%). As for damage at the base, a larger percent of all tree types of both species had minor damages than moderate and severe damages.

Effects of Bark-stripping

Table 7 shows the various defects and infections resulting from blue monkey debarking. Approximately 72.4% of the cypress trees examined had one or a combination of the defects, whereas 65.5% of pine trees had the defects. Twisting of boles was most frequent defect among trees. Of all the trees examined, 34.0% of cypress and 48.0% of pine trees were twisted. A large percent of the twisting occurred in the middle and top sections of the boles. Only 0.1% of either cypress or pine trees assessed were dead whereas 6.8% cypress and 11.4% pine trees examined had dead tops. The drying at the top results from the complete girdling of the tops which is not common at the base or middle sections of the trunks. More cypress trees developed excessively large branches than pine trees. This was particularly more

Table 7. Percent of *C. lusitanica* (Cl) and *P. patula* (Pp) trees with various effects from blue monkey debarking (Cl n = 1002, Pp n = 674)

Effects	Total		Base		Middle		Top	
	Cl	Pp	Cl	Pp	Cl	Pp	Cl	Pp
Bent bole	13.1	3.7	0.3	0.3	8.8	2.2	4.0	1.2
Forking	2.0	1.3	NA	NA	NA	NA	2.0	1.3
Fungus-inf.	11.0	1.2	7.2	0.7	3.4	0.3	0.4	0.2
Large brh.	5.4	0.1	NA	NA	3.6	0.1	1.8	0
Top dead	6.8	11.4	NA	NA	NA	NA	6.8	11.4
Tree dead	0.1	0.1	NA	NA	NA	NA	NA	NA
Twisted bole	34.0	48.0	0.4	0.3	17.6	25.6	16.0	21.1
Total	72.4	65.8	7.9	1.3	33.4	28.6	31.0	35.3

NA = Not applicable

Fungus-inf. = fungus-infected, Large-brh. = large branch

prevalent at the middle of the trunk than at the top. Finally, only a small percent of the damaged trees were forked or had multiple leaders. This malgrowth seemed to be restricted only to the tops of trees.

Seasonal Variation in Bark-stripping

The monthly mean percent damage was 7.7% in cypress and 4.5%. in pine compartments. These differences were not significant (Mann-Whitney *U* test, $P<0.05$). Figure 3 shows the monthly percentages of trees damaged. In cypress

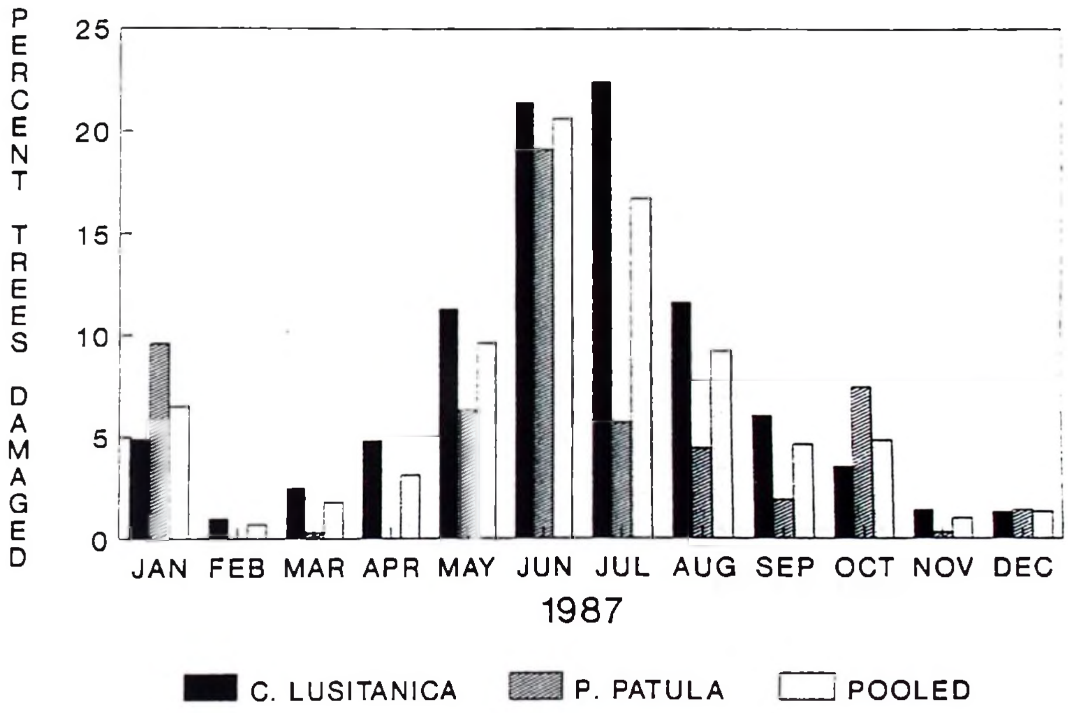

Figure 3. Seasonal pattern of bark-stripping of C. lusitanica and P. patula trees by blue monkeys

compartments, the percentage of trees debarked was lowest (0.9%) in February, and highest in July (22.4%). There was no tree damage in pine compartments in February and April whereas the highest tree damage happened in June (21.4%). Bark-stripping was generally low during the rain season months and peaked in the dry season. Strikingly, tree debarking was also relatively high in January which is usually dry.

DISCUSSION

Extent of Debarking

Proportionally more pine trees were bark-stripped than that of cypress trees, but the difference was not significant. The variation among compartments in the percentage of cypress trees damaged was greater than for pine. This variation can probably be attributed to the location of cypress compartments which were scattered throughout the plantation. In contrast, pine compartments were all, except one, contiguous to one another. Thus location could have contributed to the variation in the extent of damage between the cypress and pine trees.

The fact that there was equal damage to cypress and pine trees differs from those obtained in forest plantations in Kenya (Omar and de Vos 1970), and in South Africa (Von dem Bussche and Van der Zee 1985) where related subspecies of blue monkeys showed tree species preference in their debarking habits. In Kenya, a larger percent of *C. lusitanica* trees were damaged than either *P. patula* or *P. radiata*. However,

P. patula was more severely damaged than cypress although the part of the tree that received severe damage was not reported. Similarly, in South Africa Von dem Bussche and Van der Zee reported that monkeys displayed species preference. They debarked more P. taeda than other species of pine, but the authors did not explicitly quantify the extent each tree species was damaged.

In this study it was also found that a greater percent of dominant cypress trees were debarked than intermediate or suppressed trees. In contrast, more intermediate pine trees were debarked than dominant or suppressed trees. The reasons for such differences can only be speculated. For example, (Wilcox 1962) reported that conifers had a longer bark-peeling season (period when bark peel easily) than hardwoods, and tree vigor was related to the peeling season. Dominant trees, being vigorous, had a longer bark-peeling season than either intermediate or suppressed trees. This might be why monkeys prefer to debark the vigorous dominant cypress trees. The reason that they prefer intermediate pine trees is not as clear but may be related to the chemical and physical characteristics of the bark. The bark of dominant pine trees is probably tougher than that of intermediate trees. It is also possible that dominant trees have more plant secondary compounds; steroids and phenolics such tannins than intermediate trees.

Intensity of Debarking

In both species more trees were debarked at the middle and top of the trunks than either at the base or branches. The degree of damage was also more severe in the middle and top of the trunks. Von dem Bussche and Van der Zee (1985) also observed that most trees were damaged high up. The reasons for this pattern is probably three-fold. First, the bark at the base is tougher than the bark at the middle or top of the trunk. It is thus conceivable to expect less damage at the base because of the difficulty of peeling off the bark. Second, for monkeys to debark trees at the base they have to descend close to the ground. Blue monkeys are highly arboreal, and avoid descending to the ground, especially in a plantation forest floor that has little understory. For safety reasons, monkeys would prefer to be high up in the tree crowns where they can hide quietly to avoid being detected in case of any danger.

Third, the concentration of chemical compounds in the bark, may be different in the sections of the trunk. Sullivan et al. (1986) for example, found a similar pattern of bark stripping of hemlock (Tsuga heterophylla) by porcupines (Erethizon dorsatum). They contended that this feeding pattern was because conifers had the highest concentrations of fats and carbohydrates in the foliage and phloem of the aerial tissues. Moreover, it has also been suggested that some primates eat the inner bark to obtain sugars (Nishida 1976). Possibly the upper portions of the trunks of the cypress and pine contain more carbohydrates than the bark at the base.

More cypress trees were damaged at the base than pine trees. This can be explained by the physical difference in the nature of the bark of the tree species. The bark at the base of pine is rough and has a thick cork layer whereas the cork layer is virtually missing in cypress. This makes the tree species fairly vulnerable to debarking at the base.

Effects of Bark-stripping

Twisted boles resulting from tree damage were the most prominent defect in the middle and top sections of both tree species. This is to be expected because the highest percent of severe damage by blue monkeys in both tree species occurred at these two sections of trees. The percentages of trees with bent or crooked trunks, and excessively large branches was higher in cypress than in pine trees. The reason for this difference is unknown, but it is undoubtedly due to the differences in the growth hormone systems of the trees. For example, Wilcox (1962) reported that in some conifers ring-barking initiated autonomous growth hormone production below the ring, and that the hormone production was highest during the bark-peeling period. Since all the above defects are a function of the tree growth hormones, the growth hormone systems of the two trees may be operating differently resulting into the debarked trees of the two species to develop growth defects differently.

The percent of dead trees in both species was relatively low. This is probably because blue monkeys rarely ring-bark trees at the base or middle which could result into cutting off the translocation of compounds between the roots and the crown.

More cypress trees (11.0%) were infected by fungi than pine trees (1.2%). This could be explained by the amount and type of resin produced in the wounds. Damaged pine trees secrete very thick resin that cover the wounds. Since this is not the case with cypress trees, they probably become more susceptible to fungi infection than pine trees.

Seasonal Pattern of Bark-stripping

There was a marked seasonal pattern of tree damage by blue monkeys. Bark-stripping of both cypress and pine trees increased at the end of the long rain season (May), it reached its peak in June-July, and declined towards the onset of the short rain season (October). Omar and de Vos (1970) reported a similar trend to have happened in Kenya. In South Africa, Von dem Bussche and Van der Zee (1985) found that tree damage peaked in only one summer but the pattern was not repeated in the subsequent summer.

Seasonal bark-stripping by other non-human primates has been reported to occur even in natural forests as well. Among these are chimpanzees (e.g. _Pan troglodytes_) (Nishida 1976), some species of lemurs (e.g _Propithecus verreauxi_) (Richard 1977), and langurs (e.g. _Presbytis entellus_) (Sugiyama 1964).

Seasonality in debarking has also been observed in other mammals. For example, in Taiwan the Formosan red-bellied squirrel (Callosciurus erythraeus) debarked conifer trees less in the rainy months than in the rest of the months (Kuo and Chiang 1986).

The reasons for such patterns are not clear. The main reason animals strip bark is probably nutritional, with bark being used as supplementary food during a time of food shortage. For some primates the shortage of fruit has been proposed as the reason they eat bark or more of it at certain seasons (Sugiyama 1964, Nishida 1976). Since blue monkeys appear to eat a high proportion of fruits (Omar and de Vos 1970, Nishida 1972, Struhsaker 1978, Rudran 1978, Aldrich-Blake 1979), it might be reasonable to expect that the debarking rate of cypress and pine trees in the plantation would be related to the availability of food (fruits) in the native forest. Unfortunately, there have been few long-term studies that have investigated this relationship. Von dem Bussche and Van der Zee (1985) attempted to explore the relationship between food availability and tree damage. Such relationship seemed to exist during the first year of study but not the second year.

Another reason for seasonality in debarking by animals might be contributed by the easiness of peeling the bark. Wilcox (1962) found that the period at which bark peels easily is usually just before the leaf growing season (vegetative growth), but it may also be true for reproductive growth.

Barnes (1982) reported that the bark-stripping by elephants of some tree species occurred just before and/or during the leaf growing or flowering period. This is the period when tree trunks have much sap, and thus this season is called sap-peeling period (Wilcox 1962).

This may explain the increased debarking of cypress and pine trees by monkeys. Omar and de Vos (1970) also observed that blue monkeys in the forest plantations on the slopes of Mt. Kenya and Aberdare mountain debarked more trees between July and October. They suggested that monkeys increased their debarking because of the sap was rising in trees just before vegetative growth. Since their study areas have very similar seasons to the present study area, their speculation seems to apply to what has been observed in the present study. In addition, because this is the period of high cambial activity, and since the cambial sap is reported to be rich in sucrose and proteins (Wort 1962), monkeys may be stripping the bark and gnawing the cambium to get these nutrients.

FOOD HABITS OF BLUE MONKEYS IN RELATION TO BARK-STRIPPING

METHODS

The techniques known as scan sampling was used to gather food habits data (Altmann 1974), and has been used in several studies, for example Clutton-Brock (1975), Struhsaker (1975), and Waser (1975, 1977). Oates (1977) compared this time-interval method to frequency methods and the results from all methods were highly correlated. This suggests that under similar conditions scan sampling can yield results that do not differ significantly from results obtained by the frequency methods.

Blue monkeys were observed while feeding at the Narok and Laikinoi study sites (Figure 3) from January to December 1987. For each month, a consecutive 3-day observation period was usually allocated for each study site. At 8:00 hrs in the mornings of sampling days, monkeys were located by observing in trees and listening to any vocalization. After the monkeys were found, they were followed and observed usually until 14:00 hrs in the afternoon.

Blue monkeys were observed using a 8 x 40 binoculars at 5-minute periods (scans) that were systematically spaced at 15-minute intervals such that there were three scans per hour. During the scanning period, any individuals that were observed feeding, the plant growth form, species and part or item were recorded. The items were classified as leaf, leaf petiole, fruit, flower, shoot, and bark. Whenever it was not certain of the plant item eaten, the plant was checked, for confirmation, after monkeys had left the area. Any unknown or unidentified plant species, specimens were collected, and dried in a plant press. Specimens were later identified at the National Herbarium of Tanzania at the Tropical Pesticides Research Institute, Arusha. Most of the plant specimens collected in the field were identified at this herbarium.

Several problems were encountered in the field work which other workers of forest-dwelling primates have experienced (e.g. Aldrich-Blake 1979). The foremost problem was locating monkeys. It was usually not easy to spot monkeys especially in the early mornings because they were fairly inactive, and generally did not start to feed actively until around 9:00 hrs. McKey and others (1981) reported a similar behavior in black colobus monkeys (Colobus satanas) in Cameroon. The period of inactivity of blue monkeys was extended on rainy or cold and foggy days, and moreover, visibility on such days was very poor.

Poor visibility is an inherent problem in a forest and so not all monkeys in a group were visible during sampling scans due to obstruction by foliage. Also in some cases it was not possible to observe monkeys continuously for one or two hours before they were out of site. Whenever the group moved away, quite some time would be spent to relocate it especially if there was no vocalization. In addition, at noon hours of most sampling days, monkeys usually descended into the thick vegetation of the stream valleys. Consequently, the actual contact hours when monkeys were observable was reduced.

The food habits data for each study site was summarized by plant species and parts eaten. The monthly and annual contributions of plant species and parts in the diet of blue monkeys were determined by expressing the number of feeding records for each species and plant part as percentages of the total feeding records. The relationship between the feeding of blue monkeys and the bark-stripping in the plantation was determined by correlating the monthly percentages of plant parts eaten and the monthly percentages of trees debarked. This was performed for each study site and each tree species.

RESULTS

Plant Species Eaten by Blue Monkeys

For the entire year of sampling, a total of 1,757 feeding records were obtained; 790 from Narok and 967 from Laikinoi site. The various plant items included in the annual diet of blue monkeys were recorded from 38 species for both sites (Appendix II). More than half (20) of the species were trees, eight species were non-woody climbers, whereas the remaining species belonged to other growth forms. Interestingly, 26 plant species were eaten at each study site, and 14 species were commonly fed on by monkeys both at Narok and Laikinoi.

Plant species that contributed 1.0% or more to the total feeding records of blue monkeys for the year are presented in Table 8 (Narok) and Table 9 (Laikinoi). There were 10 plant

Table 8. Percent feeding records of plant species included in the diet of by blue monkeys at Narok in 1987 (only species that contributed ≥ 1.0% of the total records are listed)

Species (parts eaten)	Percent in diet
Ficus thonningii* (fruits)	62.4
Allophylus sp.* (fruits)	7.3
Zehneria scabra (flowers, leaves)	7.0
Basella alba* (leaves)	3.0
Neoboutonia macrocalyx (bark, leaves)	2.4
Tabernaemontana holstii (flowers, leaves)	1.8
Turrea holstii (bark, leaves)	1.8
Maesa lanceolata* (fruits)	1.5
Englerina holstii* (fruits)	1.4
Cussonia spicata (bark, leaves)	1.0
Total	89.6

* Denotes plant that also contributed ≥ 1.0% at Laikinoi

species at Narok which accounted for 89.6% of the total feeding records. At Laikinoi 15 plant species accounted for 95.2% of the feeding records in the area.

Only four species were used in common by monkeys at both sites; Ficus thonningii ranked first and accounted for over half of the total feeding records at each study site. The ranking of the remaining three species was very different for each site with the exception of Basella alba which was the

Table 9. Percent feeding records of plant species included in the diet of blue monkeys at Laikinoi in 1987 (only species that contributed ≥ 1.0% of the total records are listed)

Species (parts eaten)	Percent in diet
Ficus thonningii,* (fruits)	52.7
Schefflera volkensii, (fruits)	8.7
Galiniera coffeiodes (fruits)	6.4
Basella alba* (leaves, shoots)	4.4
Maesa lanceolata* (fruits)	3.4
Urera hypselodendron (fruits)	3.3
Parquetina nigrescens (leaves, shoots)	3.1
Hagenia abyssinica (petioles)	2.8
Allophylus sp.* (fruits)	2.6
Prunus africana (fruits)	2.3
Englerina holstii* (flowers, fruits)	1.8
Xymalos monospora (leaves)	1.6
Cyphostemma kilimandscharicum (shoots)	1.1
Hypoestes aristata (leaves)	1.0
Nuxia congesta (leaves)	1.0
Total	96.2

* Denotes plant that also contributed ≥ 1.0% at Narok

fourth most preferred species at both sites. In addition, the percentages of feeding records of _B_. _alba_ in the two study sites were comparatively similar (3.0% at Narok and 4.4% at Laikinoi). _Allophylus_ sp. was the second in preference at Narok but it was ninth at Laikinoi and accounted for less than half of what it contributed at Narok. The differences in the number of species that contributed 1.0% or more of the feeding records and their relative ranks at each site is most likely a reflection of the differences in floristic composition between the two areas.

Plant Parts Eaten by Blue Monkeys

Plant species and items eaten throughout the year in the two study sites are listed in detail in Appendices III and IV. The actual plant parts fed on by monkeys during the sampling period are shown in Table 10. Fruits were the most frequently used item throughout the year both at Narok (76.8%) and Laikinoi (81.6%). However as noted, most of the fruits consumed were from only one tree species, _F_. _thonningii_. The monthly average of fruits from all species was 76.2% and 77.7% of feeding records at Narok and Laikinoi, respectively. By contrast, the monthly mean of _F_. _thonningii_ fruits at Narok was 63.4% and 53.5% at Laikinoi. Therefore, on the average fruits of other plant species in a month accounted for only 12.8% at Narok and 24.2% at Laikinoi.

Leaves were the next most heavily food item consumed by monkeys at both study sites. The remaining plant parts

Table 10. Proportions (percentages) of feeding records of plant parts or items eaten by blue monkeys at Narok and Laikinoi in 1987

Plant parts	Narok		Laikinoi	
	Annual	Mean*	Annual	Mean*
Bark	1.39	2.01	0	0
Flowers	3.54	2.57	0.83	1.00
Fruits	76.84	76.16	81.59	77.71
Leaves (blades)	14.81	14.23	11.38	12.55
Petioles	2.28	3.99	2.79	3.66
Shoots (terminal)	1.14	1.03	3.41	2.98
Total	100.00		100.00	

* Monthly mean

(Table 10) formed a relatively small portion of the diet at both sites. Monkeys were observed to feed on the bark of three trees species (*Cussonia spicata*, *Neoboutonia macrocalyx* and *Turrea holstii*) only at Narok but they were not observed to eat bark at Laikinoi.

There was a seasonal variation in the abundance of the food items in the forest. Since the forest is generally evergreen, the variation in the abundance of leaves of trees and shrubs was not great because in such forests senescent leaves are constantly replaced by new leaves. However, the variation in the abundance of flowers and fruits was quite noticeable since trees have different fruiting periods; some of which are relatively brief. The abundance of fruits, particularly of F. thonningii which were the principal fruits consumed by monkeys, fluctuated during the study period. These fluctuations of fruits may have influenced the pattern of blue monkey feeding on the other plant parts or items.

Feeding Pattern of Plant Parts

The extent at which blue monkeys fed on each plant part or item varied monthly, and therefore their proportions in the monthly diet also varied from one month to another. There was generally a similar trend at Narok and at Laikinoi in terms of the part of the plant fed on. Figures 4 and 5 show the monthly percentages of the feeding records of the various food items that were included in the diet of blue monkeys. Flowers, shoots, petioles and bark were combined because the monthly percentages of the total feeding observations of each item were relatively low.

At both study sites, more fruits were eaten between January and May, and declined between June and July when only 34% (at Narok) and 37% (at Laikinoi) of the feeding records were accounted for by fruits. Thereafter, the percent of feeding on fruits increased until the end of the year. The slight increase in the proportion of fruits in June at Laikonoi (Figure 5) is due to monkeys feeding on fruits of Prunus africana tree which were ripe then.

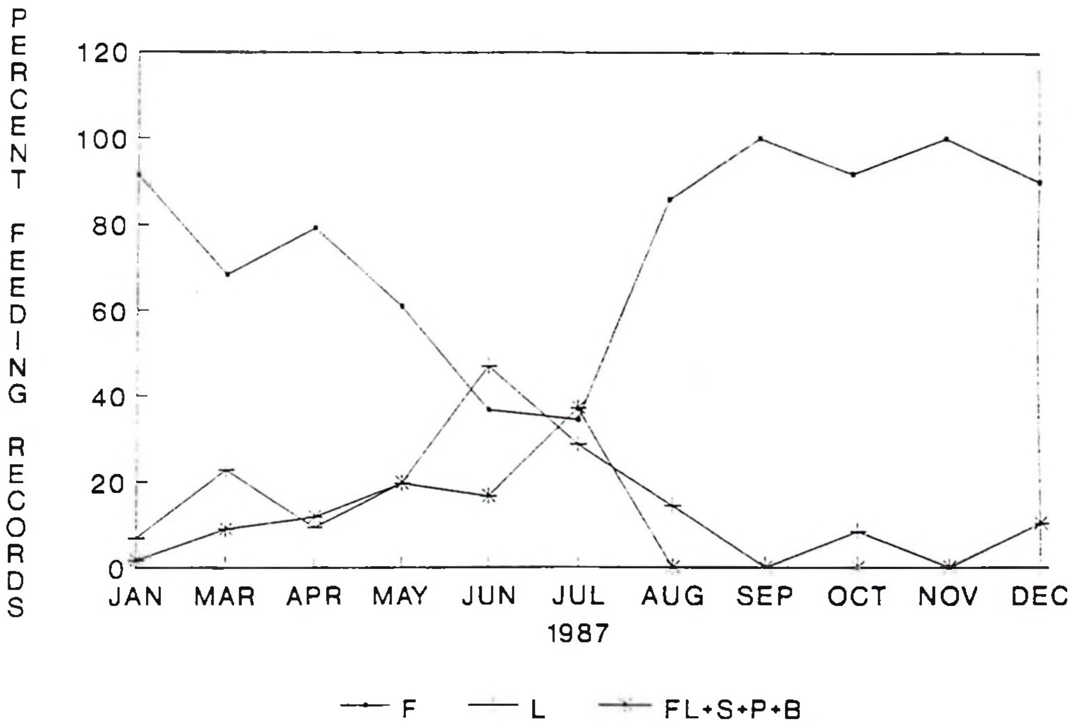

Figure 4. Monthly percent feeding records of the plant parts eaten by blue monkeys at Narok (F = Fruits; L = Leaves; Fl = Flowers; S = Shoots; P = Petiole; B = Bark)

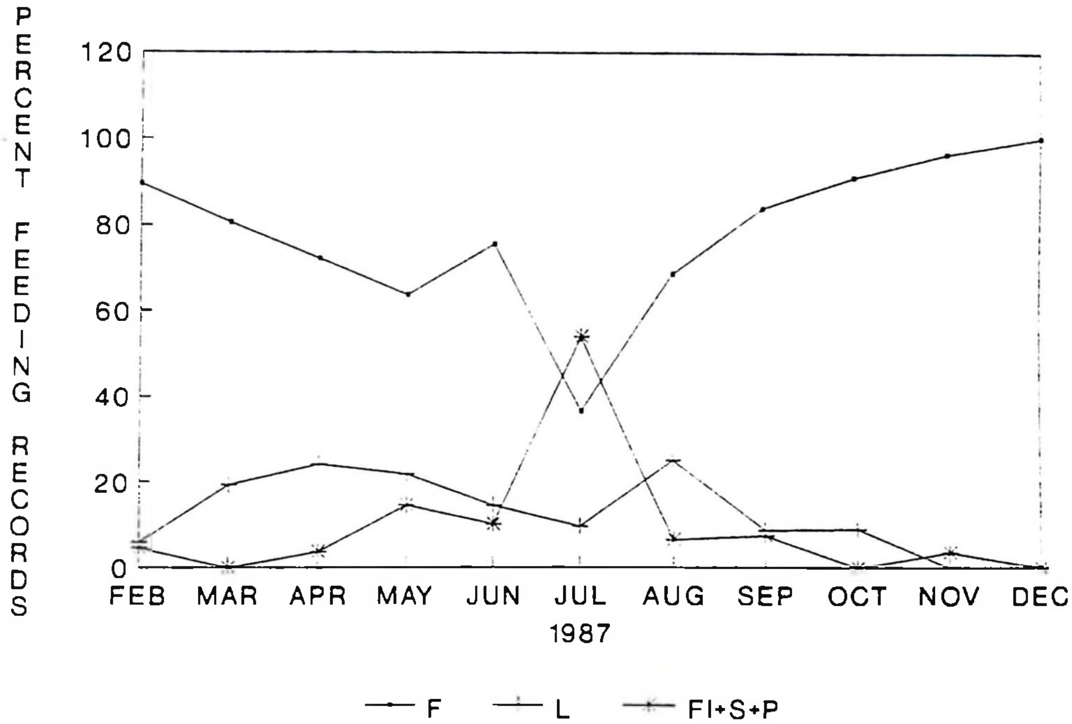

Figure 5. Monthly percent feeding records of the plant parts eaten by blue monkeys at Laikinoi (F = Fruits; L = Leaves; Fl = Flowers; S = Shoots; P = Petiole)

The pattern of feeding on leaves (blades) at Narok (Figure 4) was opposite to that of fruits such that feeding on leaves was low during the first months of the year (January to May) when monkeys fed more on fruits. The contribution of leaves to the total monthly feeding records was highest (about 47%) in June, a period when feeding on fruits was low. The feeding on leaves again declined as the feeding on fruits increased.

At Laikinoi (Figure 5) the trend was slightly different. The percentages of feeding records of leaves varied between 20% and 24% for the months of March through April. In July, observations of monkeys feeding on leaves were quite low (about 10%) though not the lowest in the year as it was case with fruits. This low level of feeding on leaves and fruits was compensated by a high percentage of feeding on other plant food items (flowers, leaf petioles and shoots). Feeding on leaves peaked again in August (25%) and then declined for the remaining months.

The monthly pattern of feeding on flowers, petioles, shoots and bark was essentially similar at both sites. The monthly percentages of feeding records increased and was highest in July both at Narok (37%) and Laikinoi (54%). At Narok there was no feeding records of these items for the remaining months whereas at Laikinoi the feeding on the items declined beginning from August through December.

Feeding on Plant Parts and Bark-stripping

The correlation between the feeding records in the natural forest and the tree debarking in the plantation are shown in Table 11. The amount of time monkeys spent feeding on fruits at both sites in the native forest was negatively correlated to the amount of cypress and pine trees debarked in the plantation. This relationship is also depicted in Figures 6 (Narok) and 7 (Laikinoi).

Bark-stripping of both tree species increased during months when feeding on fruits was lowest. This was concurrently the period when feeding on leaves, flowers, shoots and petioles was proportionately high. Hence the feeding percentages of these items were positively correlated to tree damage (Table 11). At Laikinoi tree damage of cypress and the combined percent of feeding on flowers, shoots, petioles and bark were significantly correlated (r_s = 0.76, $P<0.01$). Similarly, the correlation coefficients between the feeding on leaves and cypress tree damage at both sites were relatively high but not significant. Although other correlations were also not significant, the correlation coefficients for cypress were generally relatively high suggesting that the bark damage of cypress trees was related to the pattern at which blue monkeys feed on fruits and leaves.

Table 11. Spearman's rank correlation coefficients between percent feeding records of plant parts eaten and percent tree damage by blue monkeys in the plantation (n = 11)

Site		Fruits	Leaves	Fl+P+S+B
Laikinoi	TDCL	-0.78**	0.59	0.76**
	TDPP	-0.31	0.19	0.41
Narok	TDCL	-0.48	0.56	0.27

** Significant at 1% level;

Fl = Flowers; P = Petioles; S = Shoots; B = Bark;

TDCL = Tree damage of _C_. _lusitanica_; TDPP = Tree damage of _P_. _Patula_.

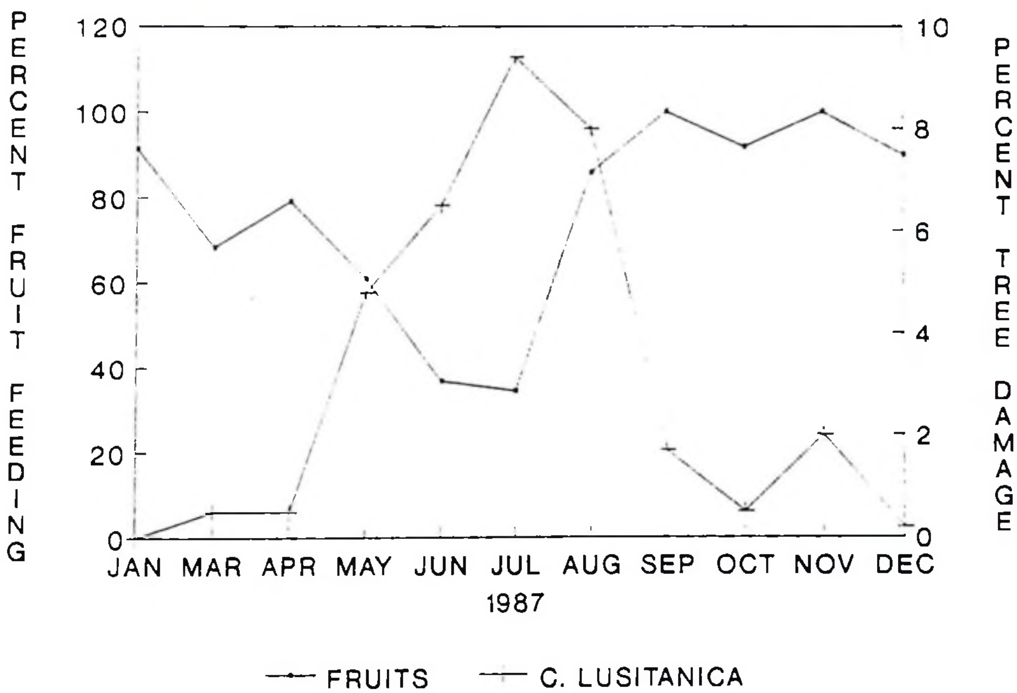

Figure 6. Relationship of percent feeding records of fruits and percent plantation tree damage at Narok

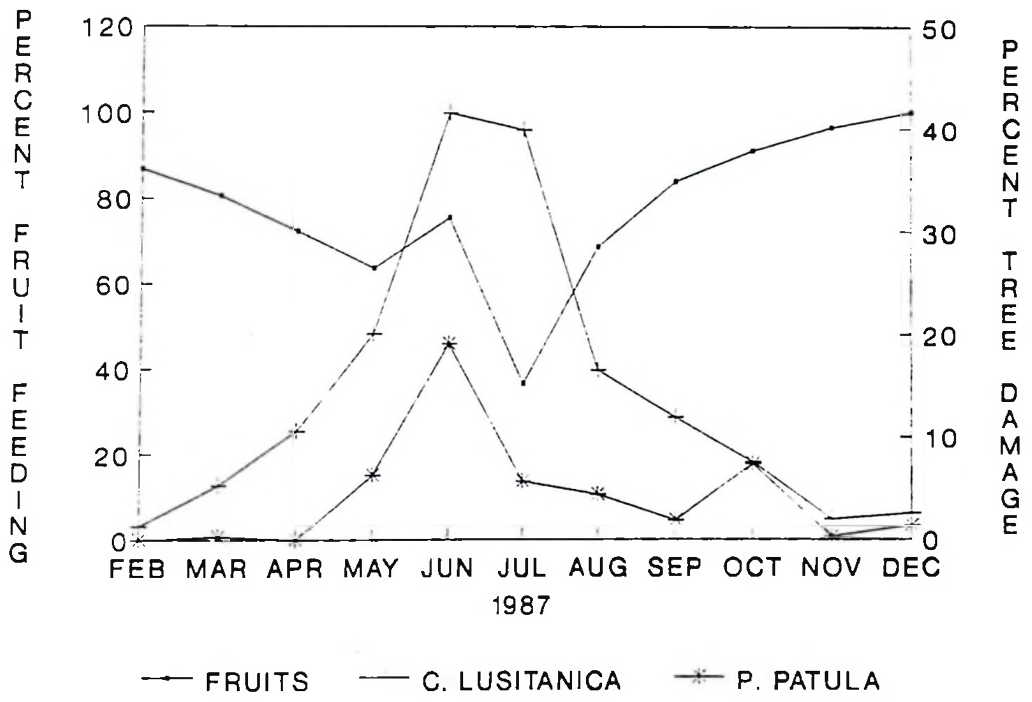

Figure 7. Relationship of percent feeding records of fruits and percent plantation tree damage at Laikinoi

DISCUSSION

Plant Species in the Diet

The number of plant species that contributed 1.0% or more to the monkey feeding observations over the year was higher at Laikinoi than at Narok. This difference is most likely due to differences in the floristic composition of the two study sites primarily because the two areas were at different elevations. It may also be a result of the degree of forest disturbance by human activities. These have been more intense at lower elevations (Narok) than at higher elevations (Laikinoi). Consequently, the native forest at Narok is more impoverished than the forest at Laikinoi. For example, Laikinoi had more fruit tree species for monkeys to feed on than at Narok. Tree species such as *Schefflera volkensii* and *Galiniera coffeoides* were more abundant at Laikinoi than at Narok.

Most of the plant items eaten by blue monkeys were from either trees or climbers. Since blue monkeys are arboreal, they feed more on food items of trees and climbers than on plants on the ground. In both sites, all plant species contributing 8.0% or more to the total feeding records were fruit trees, with *F. thonningii* accounting for over half the total annual feeding records in each area. This is because the tree was abundant in both sites and its fruits were included in the diet of monkeys each month.

There has been several studies on the food habits of blue monkeys (see Schlichte 1975, Rudran 1978, Struhsaker

1978a). The number of plant species found to be eaten by blue monkeys in this study (38) generally correspond to those found in these studies, for example, 30 species in Budongo Forest, Uganda (Aldrich-Blake 1970 cited in Rudran 1978), 36 species in Kahuzi-Beiga National Park, Zaire (Schlichte 1975), and 59 species in Kibale Forest, Uganda (Rudran 1978).

There was little overlap of the plant species consumed by blue monkeys in this study and at Kibale Forest. Only (Basella alba and Neoboutonia macrocalyx) were eaten at both places. Five plant species out of the 36 species eaten by monkeys at Kahuzi-Beiga National Park in Zaire were also eaten by monkeys in the present study. These were B. alba, Hagenia abyssinica, Maesa lanceolata, Urera hypselodendron and Xymalos monospora. Notably, B. alba, a non-woody climber with soft and succulent leaves and shoots, was eaten in all three countries. Its fourth ranking in terms of proportion of feeding records both at Laikinoi and Narok study sites might not only be related to its nutritive value but to its succulent parts as well.

Plant Parts in the Diet

Fruits were the most highly utilized food item by blue monkeys. They contributed over 75% of all the annual feeding records and were included in the diet each month throughout the year. Food habit studies of blue monkeys in Budongo and Kibale Forests in Uganda (Rudran 1978, Struhsaker 1978a), and in Zaire (Schlichte 1975) have also shown that fruits accounted for a larger portion of the items included in the monkey diet than other items.

The second item in terms of frequency of utilization were leaves. The monthly percent feeding observations of leaves were inversely related to fruits. Struhsaker (1978a) and Rudran (1978) found a similar relationship, and Rudran suggested that leaves become important during periods of fruit shortage. Rudran's suggestion seems to be consistent with the results of this study in that the feeding on fruits by monkeys was low during the dry months of May/June through August/September. During this period some deciduous fruit trees shed their leaves and usually have no fruits. For example, F. thonningii is deciduous and because its fruits were the most highly utilized, the decline of the total feeding records of fruits could probably be explained by its phenological pattern.

The inverse pattern of feeding on fruits and feeding on leaves or other items is not unique to blue monkeys, but is exhibited by other primates as well. Hladik (1977) reported that chimpanzees (Pan troglodytes troglodytes) in Gabon ate more leaves and stems during the dry season, and the trend was reversed in the wet season. Howler monkeys (Alouatta palliata) on Barro Colorado Island of Panama were also observed to include more leaves in their diet when fruits were scarce than when fruits were abundant (Milton 1979). Leighton and Leighton (1983) found a similar feeding pattern in frugivorous primates in Borneo. This feeding pattern implies that primates probably eat large proportions of leaves to compensate for nutritional substances usually supplied by fruits.

Studies have shown that fleshy fruits included in the diets of some primates usually contain high concentrations of total nonstructural carbohydrates (TNC) that serve as an important and quick source of energy for these primates (Chivers and Hladik 1980, Milton 1981, Leighton and Leighton 1983, Waterman 1984). During fruit shortages, monkeys must seek for alternative food to obtain their daily minimum energy requirement. To minimize energy expended in search of scarce fruits and to obtain the required energy, monkeys switch to other food items such as leaves, petioles and shoots. These parts have low TNC and low available energy because most of the energy is tied up in the structural carbohydrates of the cell walls that are highly lignified (McKey et al. 1981, Baranga 1982). Since high lignin content reduces the digestibility of the items, and for monkeys to obtain enough energy, they have to consume larger volumes of these items as arboreal folivores usually do (McNab 1986).

Feeding Pattern of Plant Parts and Bark-stripping

This study showed that blue monkeys increased their bark-stripping of plantation trees when feeding on fruits was low. Similarly monkeys included more leaves, and other food items (flowers, petioles, shoots and bark) in their diet during the same period. One can hypothesize that the role of the bark in the diet of monkeys is probably similar to that of fruits; that is providing monkeys with energy. The fact that monkeys were noted to eat the bark of two tree species in the natural forest at Narok (Neoboutonia macrocalyx and Cussonia spicata, Appendix III) in July when feeding on fruits was low may support this hypothesis.

The habit of eating bark of native trees by blue monkeys has been reported in Zaire (Schlichte 1975), but it was not observed in Kibale Forest in Uganda (Rudran 1978, Struhsaker 1978a). This habit has been noted in other primates too (Petter 1965, Nishida 1972, 1976, Richard 1977, Waser 1977). Nishida (1976) observed that this feeding habit in chimpanzees occurred mainly at times when fruits in the habitat were low. This food habit has also been noted in a species of lemurs (Propithecus verreauxi) of Madagascar (Richard (1977), and in orang-utan in Borneo (Rodman 1977).

Nishida (1972, 1976) has suggested that primates eat the bark as a substitute or supplementary food to meet nutritional requirements. Since primates usually eat the phloem and the cambium which, and at certain times, are said to contain high concentrations of carbohydrate (Kramer and Kozlowski 1960, Zimmermann and Brown 1971, Waterman 1984), energy seems to be the most likely currency sought by these primates. However, other chemical constituents such as minerals could be an important factor in influencing the bark-stripping behavior of primates. Nevertheless, the most probable reason of blue monkeys debarking cypress and pine trees is to obtain energy from the carbohydrates in the phloem and cambium. Because the extent of bark-stripping increased in the dry season, the hypothesis of primates seeking for carbohydrates during fruit shortage may deserve further investigation.

PHENOLOGY OF A FRUIT TREE USED BY BLUE MONKEYS

METHODS

The abundance and availability of a preferred food item in a habitat will generally affect the pattern of animal feeding on that item. Forest primates feed on a variety of plant foods including leaves, flowers, fruits and shoots. Because of this, when studying the food habits of forest primates, it is not always possible to accurately quantify the plant food items eaten. Other factors that complicate this determination are the variation in the sizes of plant species, size of the food items eaten, and the temporal variation in the food items on the plants (Clutton-Brock 1977, McKey _et al_. 1981). Because of these difficulties, the phenology of food plants, particularly trees, is sometimes used as measure of the availability of certain food items.

This study examined the occurrence of fruits of _Ficus thonningii_ at Narok and at Laikinoi. During the preliminary study two other tree species, _Galiniera coffeoides_ and _Schefflera volkensii_, were selected for inclusion in the phenology studies. However, a closer examination revealed that _F. thonningii_ was the principal food tree and the major fruit eaten by monkeys throughout the year. For this reason, only the phenological information for this tree species is presented here.

In each study site, 10 _F. thonningii_ trees were randomly selected ensuring that trees were well distributed over the entire study area. Trees were numbered with white paint for easy identification during the recording of phenological data. The amount of fruits in the crowns of these trees were assessed over an 11 month period. It was difficult to accurately quantify the amount of fruit in the crowns. Therefore, to make this assessment, the crown of each tree was scanned using a binoculars and the portion of the crown covered by fruits was estimated. Two classes were used to record the amount of fruits on the crowns; scarce - fruits covering less than one third of the crown, and ample - fruits covering one third and more of the crown. Additional information such as the yellowing, shedding of leaves, and flowering, was also noted.

Since ripe fruits of this tree species were eaten by monkeys every month and on the average these fruits contributed to 50% of the total monthly feeding records, it was assumed that these fruits were preferred by monkeys in this area. It was therefore assumed that the feeding records should vary with the abundance of fruits. The monthly percentages of trees that had ample fruits were correlated with the corresponding monthly percentages of the fruit feeding records. A similar test was performed to determine if the debarking of trees in the plantation was independent of the fruits of *F. thonningii* in the area.

RESULTS

Annual Phenological Cycle

The monthly number of F. thonningii trees which had ample fruits is presented in Figure 8, and additional information on fruiting and other phenological data are shown in Table 12. Between January through March most trees had what was classed as ample fruits. In April the amount of fruits started to decline, and at Narok there were no trees with ample fruits from April through September. At Laikinoi this situation occurred from June through October. New fruits appeared in October and continued until December. Generally, the months that most F. thonningii trees had very few or no fruits corresponded with the long and cool dry season when deciduous trees shed leaves.

The shedding of leaves of some of the F. thonningii trees begun in March at Narok and in April at Laikinoi (Table 12); months when leaves were noted to start yellowing. About half of the trees had completely shed their fruits in the months of May and June. In July a few trees had already started to grow new leaves, and this was followed by the flowering/fruiting period between August and October.

Because of the variations in individual trees and the local variations in environmental conditions, the various phytophases did not usually begin and end at the same period for all trees. Nevertheless, the overall trend was that F. thonningii trees had ample fruits during the first three months of the year, shed their leaves and fruits in the middle

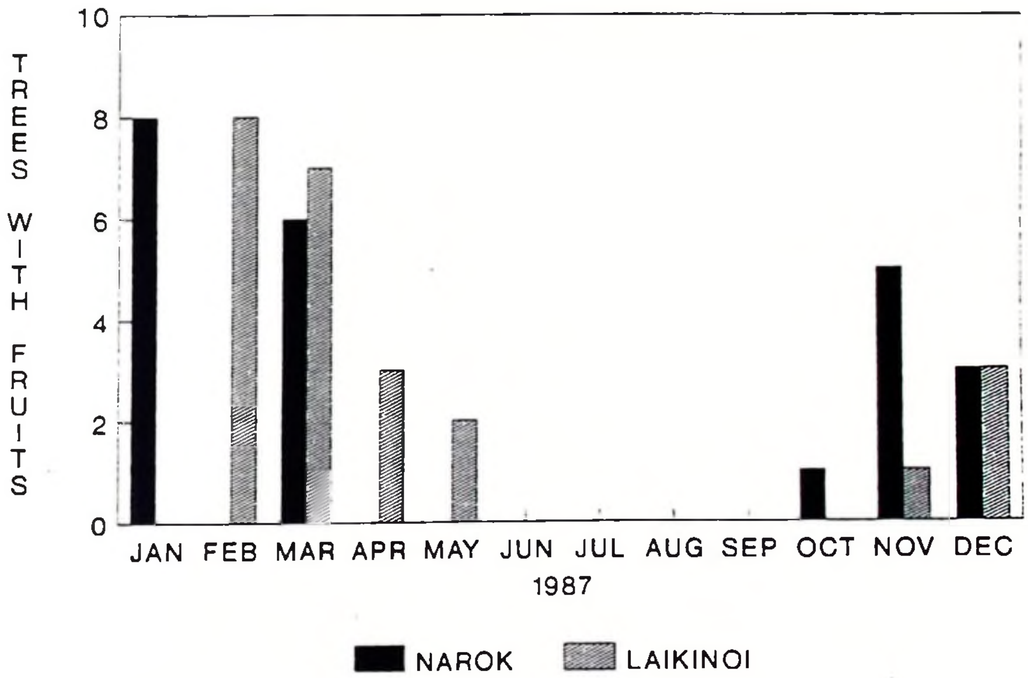

Figure 8. Monthly number of F. thonningii sample trees with ample fruits at Narok and Laikinoi (n = 10 for each site)

Table 12. Description of some phytophases of F. thonningii sample trees at Narok and Laikinoi in 1987 (n = 10)

	Study site	Phenological notes
Jan	Narok	Eight trees with ample ripe fruits
Feb	Laikinoi	Same as Narok
Mar	Narok	Two trees showed yellow leaves
Apr	Narok	One tree shed some leaves
	Laikinoi	Two trees showed yellow leaves
May	Narok	Five trees without fruits at all
	Laikinoi	On tree shed most leaves
Jun	Laikinoi	Five trees without fruits at all
Jul	Narok	Eight trees shed all leaves; two trees in new leaves
	Laikinoi	Seven trees shed all leaves; one tree grew some new leaves
Aug	Narok	Nine trees with in new leaves; two trees with green fruits
	Laikinoi	Five trees in new leaves noted
Sep	Narok	Same as August
	Laikinoi	Eight trees in new leaves
Oct	Narok	One tree with ample green fruits
	Laikinoi	Flowers/fruits in some trees
Nov	Laikinoi	Ample fruits one tree, some green
Dec	Narok	Five trees with some fruits
	Laikinoi	Same as Narok

months during the long dry season, and finally grew leaves and fruits towards the end of the year.

Variation in Fruits in Relation to Debarking

At both study sites there was an inverse relationship between the percent of F. thonningii trees having ample fruits and the bark-stripping of trees in the plantation as depicted in Figures 9 and 10. As the amount of fruits on most trees declined, a larger percent of trees in the plantation were debarked by blue monkeys. Bark-stripping at Laikinoi and Narok started to increase in May and reached its peak in June and July when there were no F. thonningii trees with ample fruits. The situation was reversed in October when these trees were fruiting again.

The correlation of the monthly percentages of trees with ample fruits and trees debarked at Laikinoi was significant (r_s = -0.67 $P<0.05$ for cypress; r_s = -0.76 $P<0.05$ for pine). Similarly, the correlation at Narok was significant (r_s = -0.75 $P<0.05$). This suggests that the increase in the debarking of trees in the plantation by monkeys during this period was due to the scarcity of fruits. The correlation of the percentages of feeding records and trees with ample fruits for both sites were low and not significant (r_s = -0.12 $P<0.05$ at Laikinoi, r_s = 0.21 $P<0.05$ at Narok).

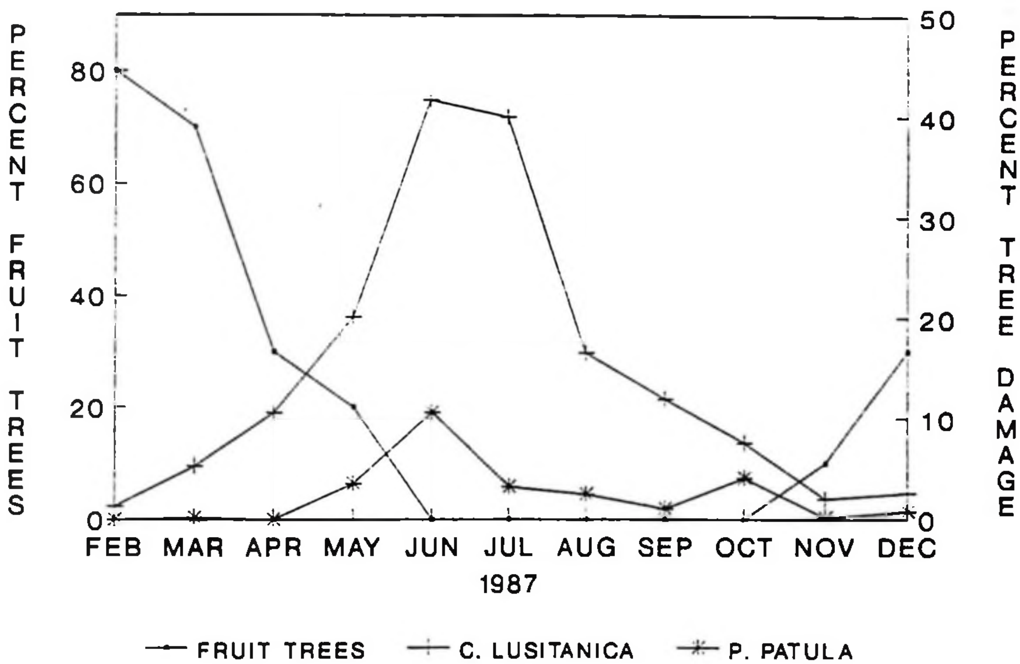

Figure 9. Monthly percent F. thonningii trees with ample fruits and percent bark-stripping of plantation trees at Laikinoi

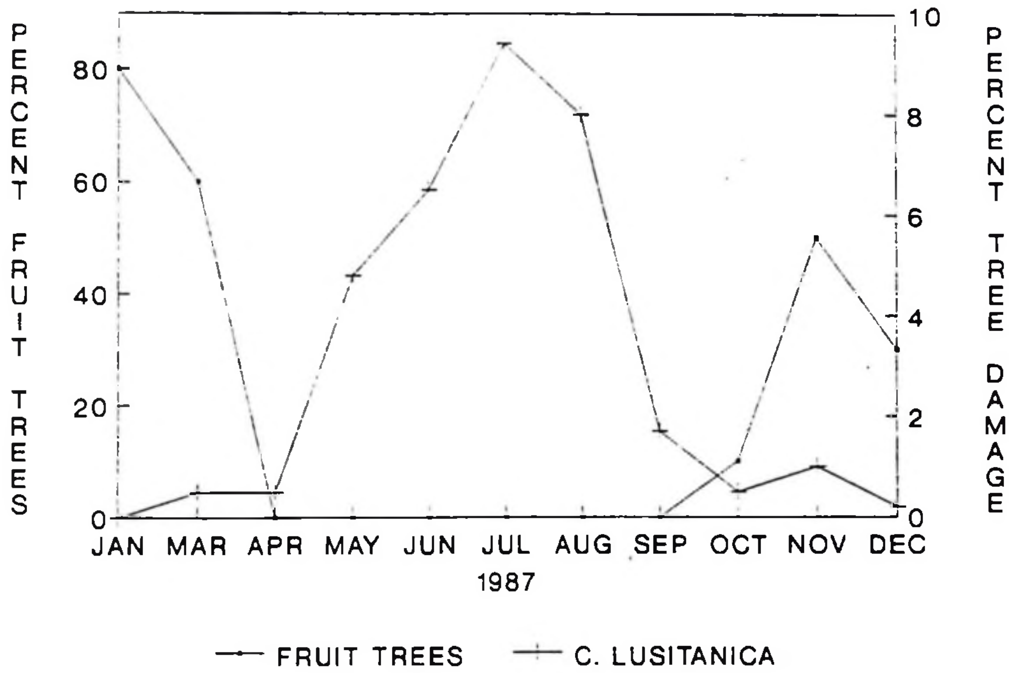

Figure 10. Monthly percent F. thonningii sample trees with ample fruits and percent bark-stripping of plantation trees at Narok

DISCUSSION

Phenological Cycles

Sample *F. thonningii* trees were well distributed over the study sites and therefore were assumed to represent the population of trees in the two areas. At Laikinoi, the phytophases occurred a month later compared with Narok. This might be attributed to the elevational differences that create microclimates at the two areas. Narok is at lower elevation (average 1,800 m), is warmer and becomes drier much earlier than Laikinoi (average 2,100 m). It is possible that the time lag at Laikinoi in the shedding of leaves and fruits, and the flowering/fruiting cycles is caused by this difference. Since the phenological monitoring was carried out only for a year, the cycles could be different in the subsequent years.

Variation in Fruits and Debarking

Blue monkeys increased their feeding on bark of the plantation trees during the dry season when fruits on trees in the natural forest were generally scarce. As discussed earlier, energy seems to be the principal component monkeys are seeking in the bark of not only the exotic coniferous trees but in the indigenous trees as well since the bark of these trees are also eaten mainly during the dry season.

These results are contrary to those reported by Von dem Bussche and Van der Zee (1985), who found that samango monkeys (*C.* (*m.*) *albogularis* debarked pine trees in summer months when fruits in the native forest were available. Von dem Bussche and Van der Zee further stated that tree damage was positively rather than negatively correlated to availability of food. Since they did not describe how the availability of fruits was measured or assessed, or the degree of correlation, their conclusions cannot be easily compared with the results obtained in this study. Conversely, de Vos and Omar (1970) suggested that blue monkeys damaged cypress and pine trees in the dry season probably because of the fluctuation in the availability of food materials. Although they were not specific with respect to the food items or materials, their suggestion concurs with what has been found in this study.

Stripping and eating of bark of indigenous trees has also been reported in other species of non-human primates and it occurs usually in the dry season (Sugiyama 1964, Nishida 1976, Richard 1977). Bark eating has been attributed to its nutritive value and/or because it provides water which is ordinarily obtained by eating fruits. These arguments support the fairly strong correlation between the availability of fruits and the extent of bark-stripping in the plantation.

Finally, there are two reasons for the weak correlation of the percent feeding records of F. thonningii fruits and the percentage of trees with ample fruits. First, monkeys fed on the fruits of a few trees for a long time if they had relatively many fruits. Consequently a large proportion of fruit feeding score was obtained from a few trees, and thus do not really reflect the percentage of trees with ample fruits. Secondly, monkeys particularly at Laikinoi, also spent some time feeding on fruits of other species such as _Allophylus_ sp., _Galiniera coffeiodes_, and _Schefflera volkensii_ when they were available despite the availability of _F. thonningii_ fruits. This may explain the poor correlation of feeding on these fruits with the proportion of trees with ample fruits.

BARK WATER AND CARBOHYDRATE CONTENT IN RELATION TO BARK-STRIPPING

METHODS

Collection and Treatment of Bark

Starting in January 1987 and continuing every second month for a period of six months, samples of bark were collected from trees in the eight compartments selected for the monitoring of tree damage (Appendix I). Within each compartment and month, five trees were randomly selected, and three pieces of bark were peeled off from the base, middle, and top sections of the tree trunks. During the period, 720 pieces of bark were collected; 450 from cypress and 270 from pine trees.

After the pieces of bark were peeled, they were labeled and immediately placed in polyethylene bags to prevent excessive loss of moisture. Within a few hours, the bark samples were transported to the nearby laboratory at the Arusha based Tropical Pesticides Research Institute. They were weighed and placed in an oven for drying at 75°C., a value within the range recommended for drying plant materials prepared for chemical analysis (Evans 1972). After samples attained constant weights, they were removed from the oven and cooled in a desiccator. They were reweighed and stored in polyethylene bags to await chemical analysis.

Chemical Analysis

The cost of the total chemical analysis of all bark samples proved to be prohibitive. To minimize the cost, bark samples from only two compartments for each tree species (5a and 9a of cypress, and 10a and 11a of pine) were selected for chemical analysis. The analysis was to determine the total nonstructural carbohydrates (TNC) in the bark.

The pieces of bark for each tree species were grouped by compartment, month, and trunk part or section (base, middle, top). Thus each group was composed of five pieces of bark from only one trunk section (e.g. base) of the five trees sampled in one compartment and month. The five pieces of bark were ground together in a mill and sieved in a No.20 mesh to prepare them for chemical analysis. Ground samples were kept in polyethylene bags before chemical analysis.

The ground samples of bark were sent to the Nutritional Analysis Laboratory of the Department of Range Science at Colorado State University for carbohydrate analysis. The acid extraction method as described by Smith et al. (1964) was used to determine the total nonstructural carbohydrates in the bark. These include only the mono- and disaccharide sugars, and storage polysaccharides (e.g. starch); the structural carbohydrates, that is cellulose and hemicellulose of the cell walls, are not included.

Statistical Analysis

The water or moisture content in the bark was calculated as a percent of the oven dry weight. For each tree species, analysis of variance was performed using SAS program (Freund and Littell 1981, SAS 1982). The design was conceptually a split-plot design in which compartments were main plots, months were subplots, trees were experimental units replicated and nested within compartments and months, and tree sections were treatments. The mean moisture content among months and tree sections were compared using Duncan's New Multiple Range test. This comparison method was selected because it is less conservative and has a higher probability of detecting differences among means if some means are actually different (Ott 1984).

Spearman's rank correlation was used to test the hypothesis of no relationship between the water content in the bark and the damage to plantation trees by blue monkeys. This was done by calculating the monthly percent of trees debarked at each trunk section in each compartment monitored, and from these percentages monthly means of percent damage at each trunk section for each tree species were computed. The mean percentages were correlated with the mean percentages of water content at the corresponding sections.

Similarly, analysis of variance of TNC was performed for each tree species to detect if there were significant differences in the TNC among months and trunk sections. Duncan's New Multiple Range procedure was used to compare means. The correlation of monthly means of percent TNC and monthly means of percent tree damage at the trunk sections were determined by Spearman's rank correlation procedure.

RESULTS

Variation in Water in the Bark

The results of the analyses of variance of water content in the bark of cypress and pine are presented in Tables 13 and 14, respectively. For both tree species, the effects of compartments and months on the water content in the bark were significant, but their interaction was not significant. The interaction of compartments with trunk sections was also highly significant, whereas the interaction of trunk sections with months, and compartments and months were not significant.

The high significant differences among cypress compartments can possibly be accounted for by the age of trees in the compartments sampled. Bark samples were collected from five compartments with trees aged between four to twelve years (see Appendix I). On the other hand, the low significance among pine compartments is probably because the pieces of bark were obtained from three compartments with trees only four and eight years old. The significant difference of water in the bark among months in both tree species is undoubtedly due to changes in the climatic conditions which influence the physiological activities of trees in various months. The moisture in the bark of the tree trunk also varies accordingly.

Table 13. Analysis of variance of water content (percent oven dry weight) in the bark of *C. lusitanica*

Source of variation	df	F
Compartments (Cpts)	4	6.80 ***
Months (Mths)	5	11.29 ***
Cpts x Mths	20	0.89 NS
Trunk sections (Trse)	2	48.04 ***
Cpts x Trse	8	9.48 ***
Mths x Trse	10	0.50 NS
Cpts x Mths x Trse	40	1.13 NS

*** Significant at 0.1 % level

NS Not significant at 5 % level

Table 14. Analysis of variance of water content (percent oven dry weight) in the bark of *P. patula*

Source of variation	df	F
Compartments (Cpts)	2	4.88 *
Months (Mths)	5	14.57 ***
Cpts x Mths	10	2.16 NS
Trunk sections (Trse)	2	14.93 ***
Cpts x Trse	4	3.35 *
Mths x Trse	10	1.24 NS
Cpts x Mths x Trse	20	0.82 NS

*** Significant at 0.1 % level

* Significant at 5 % level

NS Not significant at 5 % level

Results of the comparison of means of water content in the bark of cypress trees are shown in Tables 15. The monthly water content in the bark of cypress at each portion of the tree trunks (columns of Table 15) generally did not differ significantly except for November. The mean moisture content at the base of the trunk was however consistently and significantly higher than either at the middle or the top (rows of Table 15).

Table 15. Mean water content (percent oven dry weight) in the bark of *C. lusitanica* in 1987

	Trunk sections		
Month	Base	Middle	Top
January	241.9^{a}	227.5^{a}	215.1^{a}
March	231.4^{a}	214.9^{a}	214.6^{a}
May	245.6^{a}	226.9^{a}	217.6^{a}
July	237.2^{a}	223.9^{a}	212.9^{a}
September	225.4^{a}	215.7^{a}	206.5^{a}
November	201.4^{b}	187.4^{b}	174.4^{b}

For each month n = 25 trees

Rows: Values underlined in the same way do not differ significantly, and double-underlined values do not differ significantly from the other two values at 5% level.

Columns: Values with the same letter are not significantly different at 5% level.

The moisture content in the bark decreased from the base to the top for all months although the difference between the middle and top for most months was not statistically significant. Overall, the amount of water in the bark at all levels of the trunk was highest in May and lowest in November.

Table 16 shows the results of the comparison of mean water content in the bark of pine trees. These results were slightly different from those of cypress in that the monthly mean moisture content was significantly different at all sections of the trunk (columns Table 16). This is reflected in the analysis of variance by the highly significant difference in the moisture content among months.

Similar to cypress, the water content generally was significantly higher at the base than at the middle or top of the bole (rows of Table 16). However, in contrast to cypress, the bark at the top portion of the trunk for most months had consistently a greater amount of moisture than the middle section though for most of the months the differences were not significant as was the case with cypress.

The analysis of variance for each tree species showed that the interaction of compartments and trunk sections were highly significant but not the interaction of the sections with months. The nonsignificance of the interaction of months and sections is most likely because the monthly mean moisture content in the trunk sections did not differ significantly except the moisture content at base differed significantly from the other two sections. The significant interaction of

Table 16. Mean water content (percent oven dry weight) in the bark of *P. patula* in 1987

	Trunk sections		
Month	Base	Middle	Top
January	238.1^{ab}	224.2^{ab}	234.3^{ab}
March	250.7^{a}	233.9^{a}	240.2^{a}
May	236.6^{abc}	216.0^{abc}	217.6^{bc}
July	221.0^{bcd}	207.5^{b}	211.8^{cd}
September	216.1^{bd}	196.9^{c}	222.2^{abc}
November	217.4^{bcd}	198.0^{c}	193.8^{d}

For each month n = 15 trees

Rows: Values underlined in the same way do not differ significantly, and double-underlined values do not differ significantly from the other two values at 5% level.

Columns: Values with the same letter are not significantly different at 5% level.

trunk sections with compartments was most likely due to the significant difference in the bark water content in trees among compartments and not because of the difference in the sections.

Bark Water Content and Bark-stripping

Table 17 shows the correlation coefficients between the percentages of bark tree damage and the water content in the bark at the three trunk sections of cypress trees. Generally, the correlation coefficients at all sections of both tree species were fairly low and not significant. The percent of trees damaged at the base was negatively correlated ($\underline{r}_s$ = -0.29) to the amount of moisture in the bark at the base. At the middle section, the percent damage was positively correlated to moisture content ($\underline{r}_s$ = 0.49), and was the highest of the three coefficients. The correlation coefficient at the top section was positive but weak ($\underline{r}_s$ = 0.31).

The correlation coefficients for pine are shown in Table 18. Because there was no damage at the base of trees in all pine compartments for the six month period, the variables were correlated only at the middle and top sections. The correlation of percent tree damage and water content at the middle was negative ($\underline{r}_s$ = -0.14) and the correlation at the top was low and positive ($\underline{r}_s$ = 0.26).

Variation in Carbohydrates in the Bark

The amount of TNC in the bark of both cypress and pine were not significantly different between compartments and among months as indicated by the analysis of variance Tables 19 and 20. The TNC among trunk sections in both tree species was significant but their interactions with compartments and

Table 17. Spearman's correlation coefficients ($\underline{r}_s$) between monthly mean water content (percent oven dry weight) and mean percent damage of C. lusitanica trees (n = 6)

Percent tree damage	Percent water content		
	Base	Middle	Top
Base	-0.29		
Middle		0.49	
Top			0.31

Table 18. Spearman's correlation coefficients ($\underline{r}_s$) between monthly mean water content (percent dry weight) and mean percent damage of P. patula trees (n = 6)

Percent tree damage	Percent water content	
	Middle	Top
Middle	-0.14	
Top		0.26

Table 19. Analysis of variance of the total nonstructural carbohydrates (percent dry weight) in the bark of *C. lusitanica*

Source of variation	df	F
Compartments (Cpts)	1	0.05 NS
Months (Mths)	5	0.68 NS
Trunk sections (Trse)	2	34.50 ***
Cpts x Trse	2	2.02 NS
Mths x Trse	10	1.30 NS

*** Significant at 0.1 % level

NS Not significant at 5 % level

Table 20. Analysis of variance of the total nonstructural carbohydrates (percent dry weight) in the bark of *P. patula*

Source of variation	df	F
Compartments (Cpts)	1	0.00 NS
Months (Mths)	5	0.93 NS
Trunk sections (Trse)	2	49.35 ***
Cpts x Trse	2	0.89 NS
Mths x Trse	10	1.72 NS

*** Significant at 0.1 % level

NS Not significant at 5 % level

months were not significant.

The reason that there was no significant difference in the TNC between compartments is unclear. It is possible that the small sample size could have contributed to these results since TNC in the pooled bark samples of trees from only two compartments of each species were analyzed. This may also be the reason for the nonsignificance of TNC in the bark among months.

Multiple comparison results for bark TNC in the trunk sections of cypress are given in Table 21. Bark from the top section had significantly higher TNC than the bark at the base or middle sections for all months except January and November. The difference in the amount of TNC in the bark between the middle and top sections for most months was significant. In general, the TNC in the bark increased progressively from the base towards the top of the bole. However, there were no real differences in the intermonth variation of TNC in the bark at all three sections.

Results for pine trees (Table 22) were different from those of cypress. The TNC at either the middle or top portions, except in March, were significantly lower than at the base. The significant difference of TNC among trunk sections in the analysis of variance was because the bark at the base section generally contained a higher percentage of TNC than the bark at the middle or top sections. Apart from September, the percent TNC at the middle did not differ significantly from the top.

Table 21. Mean total nonstructural carbohydrates (TNC) (percent dry weight) in bark of C. lusitanica in 1987

Month	Trunk sections		
	Base	Middle	Top
January	11.21	10.85	11.88
March	9.23	10.07	13.12
May	8.95	10.77	12.25
July	10.64	11.77	13.05
September	7.96	8.44	11.54
November	8.48	10.36	12.39

Rows: Values underlined in the same way do not differ significantly, and double-underlined values do not differ significantly from the other two values at 5% level.

Table 22. Mean total nonstructural carbohydrates (TNC) (percent dry weight) in the bark of P. patula in 1987

Month	Trunk sections		
	Base	Middle	Top
January	18.87	15.50	16.55
March	19.56	17.18	17.10
May	22.73	18.06	19.32
July	24.00	18.60	18.70
September	22.55	18.09	15.42
November	22.04	18.81	18.36

Rows: Values underlined in the same way do not differ significantly, and double-underlined values do not differ significantly from the other two values at 5% level.

Carbohydrates in the Bark and Bark-stripping

There was a weak positive correlation between the percent TNC and the percent debarking at each of the three trunk levels in cypress compartments (Table 23). Figure 11 further depicts the relationship between TNC and debarking by blue monkeys. Debarking of all three trunk sections peaked in July. The TNC in the bark in the middle section was also slightly high in July. There were two peaks of TNC in the bark of the base and top sections; one of the which occurred in July.

Correlation coefficients for pine are shown in Table 24. The base portion was excluded because there was no damage. The reason for the low correlation between TNC in the bark and pine tree damage can be seen in Figure 12. Generally, the pattern of monthly variation of the two variables were not similar. For example, the TNC in the bark at the middle section was approximately constant throughout the six month period whereas the extent of bark-stripping varied.

Table 23. Spearman's correlation coefficients ($\underline{r}_s$) between monthly total nonstructural carbohydrates (TNC) (percent dry weight) and mean percent damage of *C. lusitanica* tree (n = 6)

Percent tree damage at:	Percent TNC		
	Base	Middle	Top
Base	0.23		
Middle		0.31	
Top			0.31

Table 24. Spearman's correlation coefficients ($\underline{r}_s$) between monthly mean total nonstructural carbohydrates (TNC) (percent dry weight) and mean percent damage of *P. patula* trees (n = 6)

Percent tree damage at:	Percent TNC	
	Middle	Top
Middle	-0.09	
Top		0.09

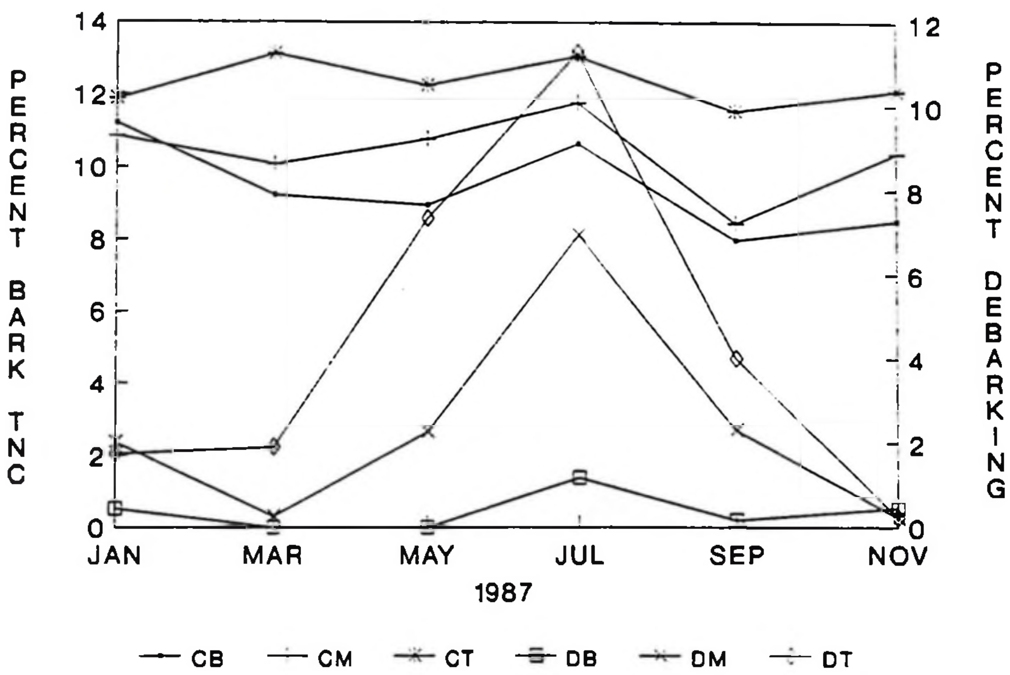

Figure 11. Total nonstructural carbohydrates in the bark and percent bark-stripping of C. lusitanica trees (CB, CM, and CT stand for carbohydrates at the base, middle and top respectively; DB, DM and DT stand for debarking at the base, middle and top respectively)

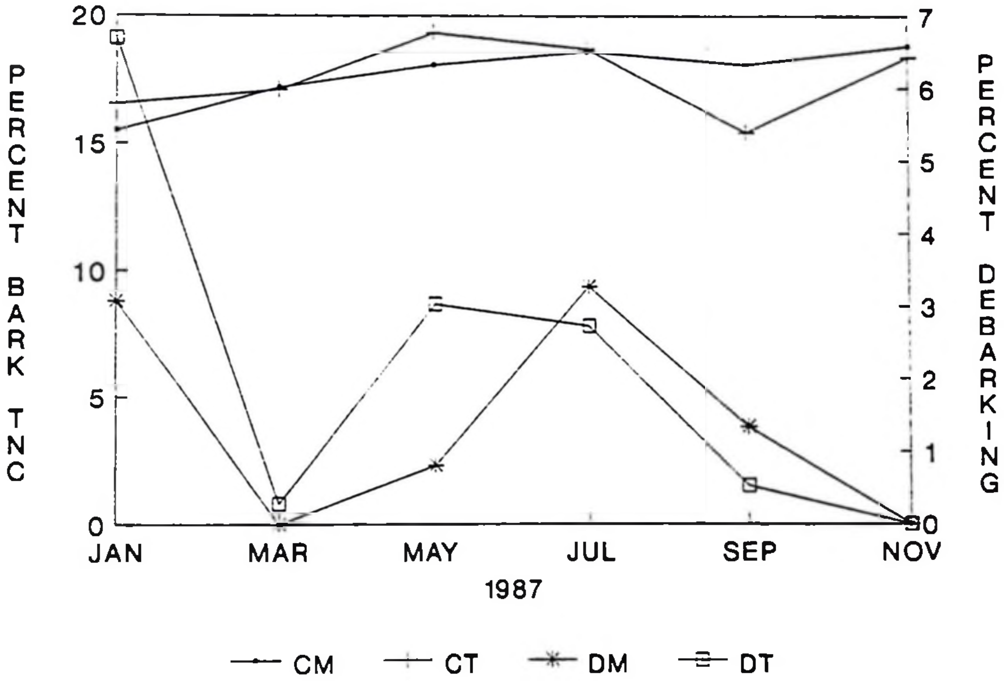

Figure 12. Total nonstructural carbohydrates in the bark and percent bark-stripping of *P. patula* trees (CM and CT stand for carbohydrates at the middle and top respectively; DM and DT stand for debarking at the middle and top respectively)

DISCUSSION

Water Content in the Bark

The amount of water in a plant item affects the succulence of that item. Succulence, in combination with required nutrients, in turn influences how the item is selected and utilized by animals. Several studies have illustrated that primates, including the blue monkey, probably select plant food items based on succulence and nutrient content (Waser 1977, Rudran 1978, Milton 1979, McKey et al. 1982, Baranga 1982).

The amount of water in the bark or the succulence of cypress and pine trees may therefore be an important factor influencing monkeys in stripping the bark. Since bark-stripping requires energy, it might be expected that tree debarking by monkeys would be at the highest rate when bark can peel easily and contain enough sap to satisfy the monkeys' nutritional needs.

If the above argument is true, then the extent of tree damage by monkeys should correlate with the moisture content in bark particularly at the middle and top sections of the tree trunk. This relationship has been implied by Omar and de Vos (1970) who speculated that blue monkeys debarked trees when sufficient sap was raising through the trunk from roots to leaves making the bark to peel easily. The same reason was also suggested to explain the seasonal bark-stripping of trees by elephants (Barnes 1982), and black bear (Ursus americanus) (Radwan 1969).

Results of this study, however, show that the water content in the bark of both tree species was poorly correlated to tree damage by blue monkeys. This is probably because the water in the bark was monitored every other month and thus reduced the sample size. There could have been great variation in water in the months that water content in the bark was not assessed.

In addition, the pattern of debarking by blue monkeys, and certainly by other animals, may change from one year to another because of the yearly random variations of other factors also, such as climate, alternative food availability, and other compounds in the bark. These factors may greatly influence the foraging behavior of the monkeys. For example, the yearly fluctuations of the alternative food resources that may be important in supplying monkeys with the required nutrients will certainly influence the food habits of blue monkeys, and hence the debarking of trees.

Such variation in bark-stripping by blue monkeys was observed in South Africa (Von dem Bussche and Van der Zee 1985). The extent of debarking was highest in the summer of one year but the pattern was not repeated in the subsequent summer. However, it is not possible to draw any conclusions from their study because they only stated that most fruit was available in the summer months. It is possible there could have been some differences in the availability of fruit between the two summers. Similarly, because the duration of this study was only for one year, the period may not be long enough to establish a clear relationship between tree damage and moisture content in the bark.

Another relevant observation was the trend of water content in the bark of the three sections of the tree trunk. In both tree species the base section had a higher moisture content than the middle or top sections. Because of this trend, one would probably expect monkeys to debark trees more at the base than higher up the tree but the opposite occurred. Bark at upper sections is younger, thinner, and thus easier to strip than at the base causing monkeys to direct their debarking activity on the upper sections of the trunk. Thus ease of peeling the bark may be more important than water content.

Total Nonstructural Carbohydrates in the Bark

It has been found that the bark of most trees contain greater concentrations of carbohydrates than wood, and that the simple sugars and starch (TNC), may reach high concentrations in the phloem (Kramer and Kozlowski 1960, Waterman 1984). Nishida (1976) has attributed the high concentration of available carbohydrates in the bark to the utilization of bark by some primate species, mainly by chewing the inner bark to extract the sap and spitting the fiber.

This study assumed that TNC was one of the main reasons blue monkeys stripped bark of cypress and pine trees, and that changes of TNC levels in the bark would accordingly influence the debarking. The results have revealed that the TNC in the bark of both tree species was relatively constant over the year, and as a result there was little correlation between the TNC and debarking. There is only a minor indication that TNC may influence stripping of the bark of cypress, especially at the middle and top sections of the trunk. This is shown by the fact that the TNC in the bark of cypress was lowest at the base and highest at top. Blue monkeys debarked more trees at these positions also; possibly to obtain the carbohydrates from the cambium and the inner bark.

Nishida (1976) pointed out that bark could be a substitute food for primates at times of food shortage in a habitat. This may be the case with blue monkeys where fruits comprise a large percent of their diet. Fruits have been identified to be a poor source of proteins but an important source of simple sugars that are easily hydrolysed to provide energy for most primates (Chivers and Hladik 1980, Waterman 1984). Sugars in fruits pulp may be as high as 35% of the dry weight (Milton 1981). Because fruits are generally very seasonal in most habitats as has been shown in this study, monkeys have to search for other sources of food that will provide energy.

Phloem, part of the inner bark, contain substantial concentrations of simple sugars and starch (Kramer and Kozlowski 1960). Kramer and Kozlowski also pointed out that among the simple sugars, sucrose is very abundant in phloem of trees. For example, Kuo and others (1982) found that in some months the amount of sucrose in the cambium and phloem of three tree species reached a level of up to 25.2 mg/g. In addition, sucrose may contribute up to over 95% by dry weight of the substances translocated in the phloem (Zimmermann and Brown 1971). The cambium, which monkeys gnaw, is also reported to be rich in sucrose and proteins (Wort 1962). It is likely that blue monkeys feed on the bark as a source of carbohydrates.

To date there is a paucity of long-term studies that have investigated the stripping or eating of bark by primates in relation to the content of carbohydrates or specific sugars in the bark. However, examples with other mammals do illustrate that sugars in the bark may be a driving force for animals to debark trees. Kuo and others (1982) reported that sucrose was the main component of the sugars found in three tree species in Taiwan, and in two tree species the sugar in the bark was significantly correlated with the debarking by the Formosan red-bellied squirrel. They also found that the third tree species that had no significant correlation between bark sugar and bark damage had low sugar content in the bark. Similarly, in a study of black bear Radwan (1969) suspected that the sapwood of four tree species was a good source of sugars, and hence the bear's preference for the sapwood.

This study showed that the bark TNC was relatively constant in the months sampled, and thus failed to clearly identify a relationship between TNC in the bark and the debarking by monkeys in the plantation. Since the amount of TNC was not monitored monthly, it is possible that significant variations in the bark TNC occurred in some months in which no sampling was done. However, these results do suggest that blue monkeys debark cypress and pine trees to obtain the carbohydrates in the bark. The highest damage occurred during the dry season when food becomes scarce. Because blue monkeys are largely dependent on fruits in most habitats, during fruit shortage they perhaps feed on bark to meet their daily energy requirements.

SYNTHESIS, CONCLUSIONS AND RECOMMENDATIONS

GENERAL DISCUSSION

Bark-stripping

This study has found that blue monkeys cause considerable amount of damage from bark-stripping of cypress and pine trees in the plantation. Damage occurs more in the dominant or intermediate than suppressed trees. The debarking was more severe at the middle and top sections of the tree trunks than at the base. Possible reasons for this bark-stripping pattern have been covered in detail in the previous sections. The question that remain is: Why is the damage directed primarily to softwood or coniferous trees that are exotic to this area, whereas the exotic hardwoods and indigenous trees are rarely debarked.

It has been generally suggested that the major reason for bark-stripping by blue monkeys and primates is probably nutritional. However, Von dom Bussche and Van der Zee (1985) disagree arguing that nutrients cannot be a problem because monkeys have evolved in forests without exotic trees and monkeys do not seem to have nutritional problems. One point to consider is that forest plantations are established by clearing the natural forests which, obviously, reduces the food plants for the monkeys. Under such circumstances, therefore, monkeys look for alternative food sources to meet their nutritional requirements. Because the exotic softwood trees replace the native trees, monkeys may use these trees as an alternative food source, and in the process damage them.

The mechanism monkeys use first to determine the nutrient content in the bark of these trees is not known, but it may be olfactory as has been demonstrated in other animals (Krueger et al. 1974, Longhurst et al. 1968). Krueger and others suggested that possibly the smell of some compounds associated with the nutrients in the plant part could be a cue for selecting and feeding on the part. Smell in combination with taste may be the means monkeys first used to detect the nutrients and started bark-stripping the cypress and pine trees. After monkeys became familiar with the trees, sight was enough to recognize them, and the debarking habit was passed on to subsequent generations.

Two factors may explain why monkeys limit their bark-stripping activity primarily to the exotic conifers. One is that the period in which the bark can be easily peeled differs between conifers and hardwoods, being longer in conifers than in hardwoods (Wilcox 1962). Although these findings were for temperate forests, it may apply to the softwoods in this study.

The second and most likely factor is the difference in the amount of secondary compounds, particularly alkaloids and phenolics, contained in the bark of indigenous and the exotic softwood trees. Phenolics (phenolic acids, flavonoids and tannins), are the most widespread compounds among plants (Waterman et al. 1978). Tannins are more widespread in flowering plants than alkaloids (see Gartlan et al. 1980).

Waterman (1983) also pointed out that more than 70% of the tree species in tropical rain forests produce significant amounts of tannins. On the other hand, alkaloids are either absent or infrequent in gymnosperms (Harborne 1973). Both phenolics and alkaloids are known to influence the feeding behavior and food selection of herbivores (Oates et al. 1977, Waterman et al. 1978). Phenolics lower the digestibility of food items because they are toxic to the gut microorganisms and may chemically react with other organic compounds in animals. Because herbivores usually have an innate capacity to avoid or accept plants containing certain secondary chemicals (Chapman and Blaney 1979), plants containing secondary compounds with concentrations exceeding threshold levels are usually avoided.

Swain (1979) pointed out that high concentrations of tannins are found in the bark. Gartlan and others (1980) also reported high levels of phenolics in the bark of many tree species of two African rainforests. Since alkaloids either do not generally occur or are not common in gymnosperms whereas phenolics are common in angiosperms, this may be one explanation why monkeys prefer the bark of conifers over indigenous tree species or hardwood plantation trees. Kuo and Chiang (1986) similarly found that conifers were more frequently debarked by squirrels than hardwoods. Exotic conifers were also more frequently bark-stripped than native conifers.

This trend could possibly be due the to plant-herbivore evolutionary interactions (Rhoades 1979). Native plants that evolve with the animals may develop more and higher levels of secondary compounds than exotics because the compounds act as a defense system against over-utilization by herbivorous animals. When exotic tree species are introduced to an area, they are heavily used by animals because their defense systems are not as well developed as the native species. They consequently become more prone to animal damage than the indigenous species.

Food Resources and Bark-stripping

Although the food resources in the habitat of blue monkeys were not quantified, there is some evidence that monkeys experience food shortage (principally fruits) in the dry season. It is during this critical period that monkeys increase their consumption of coniferous tree bark in the plantation. The clearing of the natural forest in this area had probably a profound impact not only on blue monkeys but other wildlife species. For example, part of this plantation (at Laikinoi) is on land which had Hagenia woodland that was cleared for pyrethrum (Chrysanthemum cinerariifolium) farming (Lind and Morrison 1974). This clearing reduced the abundance of many plant species, particularly fruiting species that blue monkeys depend on.

Fruits of species such as F. thonningii, S. volkensii, Allophylus sp., and others are important food sources of blue monkeys. Prior to clearing the natural forest, fruits of these species were probably available at different seasons. The reduction of certain specific fruit trees such _F. thonningii_ could have had a dramatic effect on the food habits of blue monkeys. Monkeys were, for example, noted to feed on the fruits of this tree monthly, and searched for its fruits in the remnant trees that are interspersed in the plantation. This suggests that fruit trees in the remnant patches of natural forest may not be sufficient to satisfy the fruit requirement of these monkeys.

The process of searching for fruit in the _F. thonningii_ trees remaining in the plantation could have probably initiated bark-stripping of the cypress and pine trees. As monkeys moved through the plantation, especially during fruit shortage, monkeys detected the nutrients in the bark and thus stripped some trees. This habit was perpetuated and eventually cypress and pine bark became an alternative food item during periods of food shortage. The food shortage period probably coincide with the season when the bark of these conifers peels easily rendering them more susceptible to debarking by monkeys.

Implications of Bark-stripping

Results also showed that bark-stripped trees developed growth defects and some were attacked by other damage agents especially fungi. All these defects and the secondary fungal infection in totality affect the quality and quantity of the wood harvested. For example, twisted trunks do not yield good lumber because of twisted wood grains. Bent boles cannot be used in sawmills, and logs that have large branches produce lumber with large knots. The large knots become weakpoints reducing the strength of the lumber. Thus large logs may end up being used as fuelwood, which is not the intended primary use. In addition, the infection of wood rotting fungi not only reduces the wood production, but also reduces the strength properties of the wood.

The reduction of the quantity and quality of wood produced caused by blue monkey damage is an economic loss. However, many studies of wildlife damage to trees in plantations quantify the loss only by area and proportion of trees damaged. This may be because the process of quantifying the wood loss in terms of volume becomes complicated when damaged trees are also attacked by secondary damage agents. For example some insects have been found to feed on or attack animal damaged trees more than the undamaged trees (Katerere 1982, Danell and Huss-Danell 1985). It is thus not easy for the assessors to be certain that the defects or effects found on damaged trees were caused by the animal in question.

Despite this complication, there has been some attempts to evaluate the monetary loss caused by wildlife damage elsewhere (Arner and Dubose 1978, Broodie et al. 1979, Tee and Rowe 1985, Droomer 1985). There are however only a few studies in Tanzania that have so far attempted to estimate such losses in forest plantations. Afolayan (1975) estimated the revenue lost through elephant damage in forest plantations on the northern slopes of the Kilimanjaro mountain although the method used to arrive at the monetary figure was not shown. A study to assess wood and economic loss caused specifically by blue monkeys has not been carried out in Tanzania. In South Africa Droomer (1985) evaluated the economic loss caused by the samango monkeys, a subspecies of blue monkeys, that damaged pine trees. The study revealed that there was a significant financial loss due to bark damage by the monkey. Although the volume of wood lost through blue monkey debarking in the present study is unknown, the amount of wood and monetary loss could be considerable.

During the survey, trees with only visible effects of debarking were assessed. Because wounds on trees heal after a certain period, it is possible some trees had healed wounds that enclosed dry or rotten portions of wood. Therefore such trees were not included in the assessment. It is therefore likely that the estimate of damage, and the various effects given here may be an underestimate.

OVERVIEW OF PREVENTIVE OR CONTROL METHODS

Methods of controlling bark damage by arboreal animals such as the blue monkey may prove difficult to implement because a combination of two or more methods may be necessary. Only a few workers studying bark-stripping by blue monkeys have suggested or tried various control or preventive methods (Omar and de Vos 1970, Von dem Bussche and Van der Zee 1985). Some of the control methods and their relevance to the present study area are reviewed.

Shooting

Shooting may be done either to eradicate the populations of monkeys in the area or it can be control shooting which is aimed at reducing numbers of blue monkeys. The former may not be desirable because apart from the aesthetic value of monkeys, these primates are part of the forest ecosystem, and play a very important role in sustaining such tropical forest ecosystems (see Struhsaker 1978b, 1981, Bourlière 1985). In addition, the blue monkey on Mt. Meru represent an isolated population of one of the many subspecies of this primate group. The subspecies is endemic only to the northwestern Tanzania and its status is currently unknown. In view of this, shooting to eliminate blue monkeys in the area should not be considered as a control method.

Control shooting is the most common control method implemented. It was attempted in this area but was reported to work only in pine because their crowns are less dense than those of cypress (Anonymous 1962). Control shooting was also carried out in Kenya (Clark 1968, Omar and de Vos 1970), and South Africa (Von dem Bussche and Van der Zee 1985). In both areas, results were not very satisfactory. Omar and de Vos reported that bark-stripping increased instead of decreasing. Shooting may deter some groups but not all groups. Furthermore, if a large portion of the population is killed, other groups from adjacent areas may move in to occupy the empty territories and so they may continue damaging trees. Lastly, because the method is labour-intensive, it may prove to be very expensive but not necessarily effective.

Trapping and Poisoning

It is reported that blue monkeys were trapped in this area but the impact it had on monkeys in unknown. In Kenya, trapping of monkeys resulted into temporary relief of damage (Clark 1968). On the other hand, poisoning of blue monkeys has not been documented. This is probably because of its major disadvantage of the possibility of killing non-target species. Although the goal of the two methods may be to depress the population of blue monkeys and to reduce the extent of the bark-stripping, animals killed may be replaced by other groups from nearby areas.

Silvicultural Treatment

Extra high pruning also has been suggested as a way to relieve monkey bark damage. Von dem Bussche and Van der Zee (1985) reported that extra high pruning reduced damage in one compartment and did not in another compartment and thus these observations are not conclusive. Unfortunately, the drawback of extra high pruning is that it reduces the tree crowns. This in turn reduces the area for photosynthesis, and consequently the wood volume increment is reduced.

Other Methods

Electric fencing, buffer zones, and instruments which frighten animals are other control methods recommended or tried. The electric fence has been experimented with in South Africa (Von dem Bussche and Van der Zee 1985) but there are no details on the way the electric fence was installed. The fence may not be effective unless the clearing of trees on the natural forest/plantation boundary is a wide enough to prevent monkeys from jumping over the fence from tall tree crowns in the natural forest directly to tree crowns in the plantation. One major disadvantage is that electric fences are very expensive to install and maintain particularly in large plantations.

Another form of fencing may be called live fencing, and it involves the use of plant species which have thorns or spikes preventing easy access of monkeys through them. Shrubby or bushy species could probably be the best suited for this purpose. This also has to be done in combination with a clearing similar to the one suggested for the electric fence. The plant species could be planted in rows or they could be planted in wide strips as a buffer zone. This method has not been documented as a way of preventing monkeys from entering plantations probably because it has not been tried.

Omar and de Vos (1970) recommended similar buffer strips of grassland of about 10 feet to surround plantations. Unless there are no tall trees adjacent to the plantation, the strips may be too narrow to prevent monkeys from jumping from the native forest to the plantation as pointed out above for the electric fence. During this study blue monkeys were seen jumping between tree crowns that were up to approximately six meters (about 20 ft) apart. Therefore wider strips could probably work better than the recommended width.

This method is possibly only suitable in areas where soils are not very fragile and susceptible to erosion. The soils on Mt. Meru are easily erodible and thus the ground has to be covered with deep-rooted and thicker vegetation than grass to prevent erosion. This has to be considered particularly on the steep stream banks which form a large portion of the natural forest/compartment boundaries in the plantation. Maintenance of these grass strips may also be impractical and very expensive due to the many stream valleys in the plantation that are inhabited by blue monkeys.

Animal frightening instruments may include placing dummies of for example predators and/or distress sounds to scare monkeys from the plantation. This method is also very impractical in large plantations apart from being expensive. In addition, monkeys may get used to the devices and prove to be ineffective.

One method that has been suggested is the changing of species to be planted by planting species that are less preferred by blue monkeys (Omar and de Vos 1970). This is a long term method, and in this plantation completely new species may be required since the both cypress and pine are equally debarked. It may therefore involve conducting long-term trials of completely new species which are fast-growing with similar yields of wood.

CONCLUSIONS AND RECOMMENDATIONS

Several points emerged from this study. An equally high percent of cypress and pine trees were debarked by blue monkeys, and that bark-stripping was highest in the dry season. More dominant and intermediate trees were damaged than suppressed trees. Severe damage was more frequent at the middle and top sections of the tree trunk than at the base. Among the defects arising from the bark-stripping, the twisting of trunks was the most common, and occurred correspondingly at middle and top sections of the trunk. In contrast, tree mortality was fairly low but relatively more trees had dead tops.

Blue monkeys fed on several plant food items, but fruit was the most consumed item, and leaves was the next item to fruits. During the dry season when fruits were scarce, the bark damage in the plantation increased. Bark was assumed to be used as a supplemental food item primarily supplying energy during this critical period. However, the amount of TNC in the bark of cypress and pine tress was found to be almost constant over year and showed no significant relationship with the bark-stripping.

Considering the duration of the study, results obtained are illustrative rather than conclusive, and there are many areas of problem yet to be investigated. Thus for making specific management steps to be taken, further research is required. Recommendations that follow reflect this need.

1. An evaluation of the volume of wood and the revenue lost through bark-stripping by blue monkeys in the plantation should be conducted. The rationale for instituting any control method(s) has to be based on this information.
2. The status of blue monkey population in the plantation has to be investigated. The study has to determine the number, sizes, and structure of monkey groups, and their territories and/or home ranges in the natural forest along the stream valleys including at least a kilometer from the plantation boundary towards the mountain.
3. Some preventive/control methods should be started on experimental basis. Among the methods that could be tried are buffer zones of thorny shrubs or bushes, and silvicultural treatments especially the high pruning.
4. Because monkeys do not damage very young trees, the planting of trees should start at the center of the plantation radiating outwards toward the boundary. This might minimize the damage in that when trees at the center reach the age susceptible to blue monkey damage they will be surrounded by younger trees.
5. Remnant fruit trees that are interspersed in the compartments should be cut down. These attract monkeys into compartments and may increase the probability of debarking of trees in the plantation.

6. Control shooting may be carried out as a temporary and expedient measure while awaiting suitable control method(s). If ever carried out, it should be more extensive and intensive during the dry season when blue monkeys increase the bark-stripping.

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Appendix I. Details of the compartments sampled in the plantation and the mean diameters (dbh) of the three types of trees

Cptment number	Tree species	Year planted	Area (ha)	Tree type mean dbh (cm)		
				Dom	Int	Sup
2a	Cl	1973	12.0	27.4	19.0	13.6
5a*	Cl	1975	18.4	27.8	20.9	15.7
9a*	Cl	1979	11.3	24.2	19.6	14.2
10a*	Pp	1979	6.7	20.7	16.7	12.8
11a*	Pp	1981	4.4	20.6	15.9	11.5
12a	Pp	1977	18.6	22.8	17.3	12.2
12b*	Pp	1979	7.7	22.6	16.8	11.5
12c	Pp	1979	5.2	22.8	17.0	11.2
18a*	Cl	1977	10.2	24.7	19.4	14.9
21a	Cl	1979	12.6	25.3	18.5	13.0
23a*	Cl	1975	6.6	29.2	21.6	14.8
33a*	Cl	1983	9.9	17.1	13.8	10.7

* Indicate compartments in which tree damage was monitored and bark samples were collected

Cptment = compartment; Cl = *C. lusitanica*; Pp = *P. patula*; dbh = diameter at breast height; Dom = dominant; Int = Intermediate; Sup = suppressed

Appendix II. List of plant species recorded to be eaten by blue monkeys from January to December 1987

	Species (Growth form)	Family
1.	Acalypha psilostachya (H)	Euphorbiaceae
2.	Allophylus sp. (T)	Sapindaceae
3.	Basella alba (C)	Basellaceae
4.	Caesalpinia decapetata (B)	Caesalpiniaceae
5.	Cheilanthes concolor (F)	Sinopteridaceae
6.	Croton macrostachyus (T)	Euphorbiaceae
7.	Cussonia spicata (T)	Araliaceae
8.	Cyphostemma kimandscharicum (C)	Vitaceae
9.	Dombeya leucoderma (T)	Sterculiaceae
10.	Englerina holstii (P)	Loranthaceae
11.	Ficus thonningii (T)	Moraceae
12.	Galiniera cofeoides (T)	Rubiaceae
13.	Garcinia sp. (T)	Guttiferae
14.	Gouania longispicata (C)	Rhamnaceae
15.	Hagenia abyssinica (T)	Rosaceae
16.	Hypoestes aristata (H)	Acanthaceae
17.	Ipomea wightii (C)	Convolvulaceae
18.	Maesa lanceolata (T)	Myrsinaceae
19.	Mimulopsis solmii (H)	Acanthaceae
20.	Neoboutonia macrocalyx (T)	Euphorbiaceae
21.	Nuxia congesta (T)	Loganiaceae
22.	Parquetina nigrescens (C)	Asclepiadaceae
23.	Periploca linearifolia (C)	Asclepiadaceae
24.	Prunus africana (T)	Rosaceae
25.	Rubus steudneri (S)	Rosaceae
26.	Schefflera volkensii (T)	Araliaceae
27.	Senecio syringifolia (C)	Compositeae
28.	Tabernaemontana holstii (T)	Apocynaceae
29.	Thelypteris magascariensis (F)	Thelypteridaceae
30.	Turrea holstii (T)	Meliaceae
31.	Urera hypselodendron (L)	Urticaceae
32.	Urtica massaica (H)	Urticaceae
33.	Xymalos monospora (T)	Monimiaceae
34.	Zehneria scabra (C)	Cucurbitaceae
35.	Unknown 1 (T)	?
36.	Unknown 2 (T)	?
37.	Unknown 3 (T)	?
38.	Unknown 4 (T)	?

Growth forms: C = Climber; B = Bush F = Fern; H = Herb;

L = Liana; P = Parasite; T = Tree; S = Shrub.

Appendix III. Monthly feeding records of plants and parts eaten by blue monkeys at Narok in 1987 (No data in February)

Species	J	M	A	M	J	J	A	S	O	N	D	TOTAL
Allophylus sp.,* f		2							32	24		58
*B. alba** l		3		5	9				7			24
C. decapelata, l						3						3
C. concolor, l							1					1
C. kimandscharicum, f				3		2						5
C. kimandscharicum,* s						2						2
C. macrostachyus, l		5										5
C. spicata, l						6						6
C. spicata, b						2						2
E. holstii,* f									11			11
F. thonningii,* f	51	60	32	25	38	8	54	45	9	74	97	493
G. longispicata, l					6							6
H. abyssinica,* p			3									3
H. aristata,* l		7										7
I. wightii, l					2							2
I. wightii, s					1							1
M. lanceolata,* f									12			12
N. macrocalyx, b						4						4
N. macrocalyx, p	1			7		7						15
P. africana,* f		5				4						9
P. linearifolia, l			2									2
R. steudneri, f		2										2
S. syringifolia,* l								6				6
T.[1] *holstii*, l	3											3
T.[1] *holstii*, fl											11	11
T.[2] *holstii*,* l	1	8										9
T.[2] *holstii*, b		5										5
U. hypselodendron,* f	2			2								4
U. hypselodendron, s				2								2
X. monospora,* l							3					3
X. monospora, s		4										4
Z. scabra,* l				4	34							38
Z. scabra,* fl				2	15							17
Unknown 1, l			2									2
Unknown 3, f									13			13
Total												790

* Indicates the plant part also eaten by monkeys at Laikinoi

Plant parts: b = bark; f = fruit; fl = flower; p = petiole;

s = shoot

T.[1] = Tabernaemontana

T.[2] = Turrea

Appendix IV. Monthly feeding records of plants and parts eaten by blue monkeys at Laikinoi in 1987 (No data in January)

Species	F	M	A	M	J	J	A	S	O	N	D	TOTAL
A. psilostachya, l*								6				6
Allophylus sp.,* f										13	12	25
B. alba,* l	4	8			10		11			8		41
B. alba, s	2											2
C. kimandscharicum,* f						10		1				11
D. leucoderma, f				6								6
E. holstii,* f								4	7			11
E. holstii, fl							2	4				6
F. thonningii,* f	45	27	54	18	38	19	47	59	45	69	89	510
G. coffeoides, f	34						9	4	13		2	62
Garcinia sp., f											6	6
H. abyssinica,* p	5		2		7	12		1				27
H. aristata,* l			10									10
M. lanceolata,* f					4		7		22			33
M. solmii, l						2						2
N. congesta, l							10					10
P. nigrescens, l				7				1	3			11
P. nigrescens, s				8		4	4		3			19
P. africana,* f					10				2			12
S. volkensii, f	43	9	3	11					11			84
S. syringifolia,* f							2					2
T. magascariensis, l									1			1
T.[2] holstii,* l		1										1
U. hypselodendron,* f	14	18										32
U. massaica, l*			9									9
X. monospora,* l	5			5		5						15
Z. scabra,* l		4										4
Z. scabra, s			1									1
Unknown 2, f									2			2
Unknown 4, f									6			6
Total												967

* Indicates the plant part also eaten by monkeys at Narok

Plant parts: b = bark; f = fruit; fl = flower; p = petiole;

s = shoot;

T.[2] = Turrea