the Mpingo Conservation Project

Report of the Mpingo Survey 2000 Expedition

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Executive Summary

Previous expeditions from the Mpingo Conservation Project in 1996 and 1998 surveyed mpingo rich habitats in south-eastern Tanzania. The bias inherent in this selection of study site made extrapolation of the results to a wider area difficult. The Mpingo Survey 2000 expedition attempted to address this problem by surveying nearly 1,000km² in 6 separate sites across Lindi Region, each randomly located. The study sites ranged from degraded coastal forest at Mkanga on the Rondo plateau through secondary thicket at Mkoka and classic miombo woodland at Kilimarondo.

In contrast to the previous expeditions, Mpingo Survey 2000 found very few mpingo, and none at all in two study sites. Adult mpingo trees were found in 10% of plots at an overall density of 1.36 trees per hectare, though slightly more frequently (14.7% of plots) in plots where canopy cover was between 26% and 75%, and which reflects mpingo's designation as a woodland species. Other habitat characteristics were not found to have a significant effect on the presence or absence of mpingo.

Mpingo juveniles were noted in 19% of plots, and were totally absent from the same two study sites from which adult specimens were absent. The greater frequency of juveniles than of adults is healthier than the reverse situation which prevailed at Migeregere when surveyed by the *Tanzanian Mpingo 98* expedition. In the four sites where they were present, mpingo of any age occurred at a frequency of 36%. Mpingo juvenile presence in a sample plot showed no relationship with the presence of adult mpingo in the plot.

The frequency of juvenile mpingo was not found to increase when local canopy cover (within a 5m radius) was less than 40% as had been found by the *Tanzanian Mpingo 98* expedition. However estimated canopy height for the whole sample plot was found to be a significant factor in mpingo juvenile presence, with the likelihood of encountering mpingo juveniles almost doubling from 23% to 43% in plots where the estimated canopy height was 6m or less in the four study sites where any mpingo at all were found.

The mpingo surveyed were more likely to have multiple stems than those observed by the *Tanzanian Mpingo 98* expedition in the mpingo rich habitat at Migeregere, perhaps a reaction to growing in less suitable conditions. However in this case the presence of multiple stems is not correlated with recent burning.

The expedition measured basal circumference as well as at breast height (CBH) and have derived a simple model to allow estimation of CBH from stumps, although it needs further refinement from a data set containing more large trees.

The size structure of adult mpingo showed a distribution highly skewed towards smaller, pole-size trees, which accounted for 74% of adult mpingo recorded. The expedition followed the practice of *Tanzanian Mpingo 98* in estimating the straight length of trunk for each adult mpingo, and found that 54% of trees had a sufficiently straight bole or bole-section that they might potentially be harvestable at some point now or in the future, but only 6% of trees also had a girth sufficient to justify harvesting now. Total harvestable worth of mpingo found in the survey amounted to a negligible $0.0075 m^3 ha^{-1}$.

Calculations based on this figure have refined the stocks estimations of previous expeditions, roughly halving the maximum estimate. However further research on harvesting practices, the effects of fire and heart-rot, and variation in timber colour is needed to produce a more precise, usable estimate. For the present, and following the consensus of local experts which triggered the mounting of the expedition, we conclude that current harvesting is unlikely to be or remain sustainable in the long term when infrastructure improvements facilitate cheaper logging on a large-scale throughout the region. Management of mpingo should thus be based on the precautionary principle until more detailed information is available.

Muhtasari (kwa Kiswahili)

Misafara ya nyuma ya wanafunzi ya mradi wa mpingo mwaka 1996 na 1998 ilitafiti maeneo yenye wingi wa mpingo kusini mashariki mwa Tanzania. Matokeo ya utafiti huu ulipelekea ugumu wa kutumia taarifa za utafiti huo katika eneo kubwa. Msafara wa utafiti wa Mpingo Survey 2000 ulijaribu kutatua tatizo hili kwa kutafiti kiasi cha 1,000km² katika maeneo sita (6) tofauti katika mkoa wa Lindi yaliyochaguliwa bila mfumo maalum. Maeneo ya mafunzo yalikuwa katika misitu ya pwani iliyo-haribiwa kutoka Mkanga kwenye vilima vya Rondo hadi maeneo ya vichaka vilivyofunga maeneo ya Mkoka na maeneo ya miombo.

Tofauti na misafara ya utafiti ya nyuma, utafiti wa Mpingo Survey 2000 uligundua mpingo kidogo, na katika maeneo mawili ya mafunzo mpingo haukupatikana kabisa. Miti mikubwa ya mpingo uliokomaa ilipatikana kwa asilimia kumi (10%) ya vitalu vyote kwa hectare, ingawa kwa kiasi kikubwa zaidi (14.7% ya vitalu) katika vitalu ambapo msitu ulifunika kwa 26% na 75%, ambayo ni kielelezo cha mpingo kama moja ya jamii ya mimea katika uoto wa miombo. Sifa za maeneo mengine haziku-patikana kuwezesha kuonyesha kuwepo au kutokuwepo kwa mpingo.

Machipukizi ya Mpingo yalikuwa 19% ya vitalu,na hayakuwepo kabisa katika maeneo yaleyale mawili ya mafunzo ambapo mpingo iliyokomaa haikupatikana. Kiasi kikubwa cha upatikanaji wa machipukizi kuliko mpingo iliyokomaa ni tofauti na matokeo ya msafara ya utafiti wa *Tanzanian Mpingo 98* yaliyopatikana Migeregere. Katika maeneo manne ambapo mpingo ulikuwepo, mpingo wa umri wowote ulionekana kwa kiasi cha 36%. Kuwepo kwa machipukizi ya mpingo katika vitalu vya majaribio ilionyesha hakuhusiani na kuwepo kwa mpingo mikubwa iliyokomaa katika kitalu.

Kiasi cha upatikanaji cha machipukizi ya mpingo iligundulika kutokuongezeka wakati ufunikaji wa miti (katika kipenyo cha mita 5) ilikuwa chini ya 40% kama ambavyo iligunguliwa na *Tanzanian Mpingo 98.* Hata hivo makadirio ya urefu wa kivuli cha mti kwa vitalu vyote ilionyesha kutokuwa na madhara katika upatikanaji wa mpingo. Kulikuwepo na uwezekano wa upatikanaji wa mpingo machi-pukizi kuongezeka mara mbili kutoka 23% hadi 43% katika vitalu ambapo kadirio la urefu wa kivuli ilikuwa 6m au chini katika maeneo yote manne ya mafunzo ambayo hayakuwa na mpingo kabisa.

Mpingo uliopatikana ulikuwa na mashina mengi kuliko ilvyoonekana kwenye msafara wa utafiti wa *Tanzanian Mpingo 98* katika maeneo yenye mpingo mwingi kwenye maeneo ya Migeregere, labda unaweza kuota katika maeneo yasiyo ukanda wake. Hata hivo kuwepo kwa mashina mengi hakuhusiani na uchomaji moto wa mara kwa mara. Msafara ulipima kimo na mzunguko urefu wa kifua na wakatengeneza modeli kwa ajili ya makadirio ya mzunguko wa katika kimo cha kifua kutoka kwenye shina, ingawa inahitaji marekebisho zaidi toka taarifa zilizoandaliwa kutoka kwenye miti mikubwa.

Kimo cha mpingo uliokomaa kilionyesha mgawanyiko mkubwa kuegemea kwenye mpingo mdogo, miti midogo yenye kimo cha nguzo ilihesabika kwa 74% ya mipingo mikubwa iliyoorodheshwa. Msafara wa wanafunzi ulifuatilia zoezi la *Tanzania Mpingo 98* kwa kukadiria urefu ulioonyooka katika shina kwa kila mpingo uliokomaa, na kuona kwamba 54% ya miti ilikuwa inayo urefu ulionyooka au shina la kati ambalo linaweza likavunwa wakati wowote au baadae, lakini 6% tu ya miti pia ilikuwa na mzunguko ambao ulitosheleza kuvunwa kwa wakati huo. Idadi ya mipingo ilyoonekana tayari kuvunwa ilikuwa kiasi kidogo $0.0075m^3ha^{-1}$.

Hesabu zilizoambatanishwa kutoka kwenye tarakimu hizi zimerekebisha kiwango cha miti iliyokadiriwa kutoka misafara ya wanafunzi iliyopita, kwa makadirio ya haraka inaleta nusu ya makisio ya juu. Ingawaje utafiti zaidi kwenye njia za uvunaji, madhara ya moto na kuoza kwa kiini na mabadiliko katika rangin ya mbao inahitajika kupata jibu la uhakika kwa makadirio ya matumizi. Kwa wakati huu, na kufuatia uamuzi wa watalaam wa ndani ambao umelenga malengo ya msafara wa wanafunzi, tunahitimisha kuwa kiwango cha kuvuna kwa sasa hakitabakia au kitabakia endelevu kwa muda mrefu wakati njia za mawasiliano zitakapokuwa zimeimarika na kufanya uvunaji uwe rahisi katika kiwango kikubwa kwa eneo lote la mkoa. Usimamizi wa mpingo utatakiwa ufanyike kwa makini hadi hapo taarifa muhimu zitakapokuwa zimepatikana.

Contents

Background

Mpingo is the Swahili name for *Dalbergia melanoxylon*, the East African Blackwood. The tree is often referred to as ebony although it is not a member of the Ebenaceae family. It is one of the most valuable timbers in the world, with cut billets fetching up to $18,000 per cubic metre on the export market (Jenkins *et al.* 2002). Its main use is in the manufacture of musical instruments. Domestically within range states it is used to make wood carvings, and is the medium of choice for many carvers (West & Malugu 2003). The tree is under threat from over-exploitation and has already reached commercial extinction in Kenya (Cunningham 1998). Although this is unlikely to lead to biological extinction, that pattern could be repeated further south in Tanzania if steps are not taken to ensure the harvest is sustainable (Gregory *et al.* 1999). As a result of its high economic and cultural value it has been proposed as a flagship species for nascent community forest management programmes (Ball 2004).

A much fuller review of the literature is presented in Gregory *et al.* (1999) along with a detailed examination of an mpingo rich site at Migeregere in southern Tanzania. Bevan & Harrison (2003) explore the socio-economic context, while details of the trade in mpingo can be found in Jenkins *et al.* (2002).

Within Tanzania most harvesting currently takes place in the coastal miombo, that is miombo woodland within the coastal forests belt as defined by Burgess & Clarke (2000), in Lindi region in south-eastern Tanzania. It has thus been the destination of three previous expeditions from the Mpingo Conservation Project to investigate the ecology and exploitation of the tree (Ball *et al.* 1998, Gregory *et al.* 1999, Bevan & Harrison 2003). However no widespread survey has been completed in recent times, and thus attempts to estimate current stocks in the region have been frustrated by the limitations when extrapolating results from a small study area (Gregory *et al.* 1999). The issue has become more urgent with new infrastructure improvements in the region including a new bridge over the River Rufiji, and signs that harvesting pressure has moved south of the river in recent years (Milledge & Kaale 2003).

This report sets out the results of the *Mpingo Survey 2000* expedition. It was the first attempt to assess mpingo stocks over a wide area since the issue was first investigated in the 1980s (Moore & Hall 1987), and a significant step up in scale for the Mpingo Conservation Project. Importantly, the expedition selected study sites at random to give the first unbiased picture of mpingo distribution in the region.

Aims & Objectives

The first two expeditions from the Mpingo Conservation Project established a solid base-line set of data on both the tree and its ecology. However those expeditions, *Tanzanian Mpingo 96 & 98*, were limited by the narrow geographical scope of their surveying. Although both expeditions included visits to other parts of Lindi Region, each time the surveying was confined to two relatively small areas close to the coast, both of which were known to be rich in mpingo.

Mpingo Survey 2000 aimed to reduce the uncertainties inherent in trying to extrapolate the information from these small samples across the whole of Lindi Region.[1] This area was already targeted by a wide-ranging forest conservation programme designed to protect its substantial natural resources from the unrestricted illegal logging which is anticipated on a massive scale once the imminent road improvements are completed. Following in the footsteps and building upon the work of its predecessors, the expedition aimed to provide vital data for the establishment of a successful management plan for mpingo.

To accomplish this aim required a much larger expedition; and so Mpingo Survey 2000 comprised 3 distinct teams of mixed British and Tanzanian membership. Each team surveyed 2 separate sites randomly located in Lindi Region. Data from these 6 sites, together with that from the first two expeditions, were statistically analysed in an attempt to answer the following key two questions:

- How much harvestable wood is there in Lindi region?
- Is it regenerating?

which are contributory factors to the overall goal of determining how severe exactly is the ‘ mpingo problem’. How many years stocks may Lindi Region possess if harvesting continues at current rates? Is present harvesting sustainable? What is a sustainable yield for any particular area?

[1] See Gregory *et al.*, 1999; Ball *et al.*, 1998

Methodology

The methods employed followed closely those developed by the *Tanzanian Mpingo 98* expedition.[2] Differences are outlined below.

Study Site Selection

The *Tanzanian Mpingo 98* expedition worked in one study site only, previously identified as having substantial stocks of mpingo. On this expedition a total of six study sites were surveyed, each randomly located within Lindi region. The expedition divided into three teams, and each team surveyed two study sites.

The whole region was stratified by distance from the sea into three zones: 20km-100km, 100km-180km, and 180km-260km. Then areas were excluded on the following bases:

- Within the Selous Game Reserve, the southern part of which was considered too remote to suffer from poaching of mpingo.[3]
- Too close (< 25km) to a town. If the site included a village, then plots were not located within 1km of standing houses.
- Too far from a town; for safety reasons sites more than 4 hours drive from the nearest town with a hospital and air-strip were not considered.[4]
- Too low – all areas predominantly under 200ft.
- Too high – all areas predominantly over 1500ft.[5]
- Too close (<50km) to the main study sites of *Tanzanian Mpingo 96* and *Tanzanian Mpingo 98*, or another study site previously determined.

Several study sites for each strata were thus generated in a set order, and the allotted to the teams according to logistical considerations. If a study site was deemed impractical to survey for logistical reasons the team would move to the next site on their list within the strata. The study sites actually surveyed are listed in Table 1.

Strata (distance from coast)	Name of Nearest Village	Centre of Site	No. Plots
1 : 20km-100km	Mkanga	10° 12.5' S 39° 16.6' E	42
…	Nangaro	09° 53.8' S 39° 25.8' E	37
2 : 100km-180km	Kimambi	09° 24.6' S 38° 27.8' E	42
…	Mkoka	10° 10.6' S 38° 44.0' E	42
3 : 180km-260km	Barikiwa	09° 30.5' S 37° 54.1' E	34
…	Kilimarondo	10° 33.1' S 38° 03.2' E	43

Table 1. Location of study sites and number of plots per site.

Each study site was a 7km radius circle about the randomly located centre. Hence each site had an area of 154km², and the total area of all sites surveyed was 924km².

2 See Gregory *et al.*, 1998
3 This is no longer true, see Milledge & Kaale, 2003.
4 Qualifying towns were Lindi, Mtwara, Ndanda, Masasi, Kilwa, Ikwiriri, Nachingwea and Liwale.
5 *Tanzanian Mpingo 98* surveyed only between the 250ft and 500ft contours, so this was a deliberate widening of the survey parameters.

Plot Location

At each site the teams surveyed at least 34 plots, see Table 1 above, which were situated randomly within each study site and reached by applying orienteering techniques; walking at a standardized speed along a bearing for a predetermined period of time.[6] Each plot was of 20m radius, and hence covered an area of 1260m². Total area surveyed per site was thus around 5.28ha, or 0.034% of each study site. In total, 240 plots were surveyed across all sites with an aggregate area of just over 30 ha.

Each plot was categorised as either being riverine, i.e. containing a seasonal water course (which took priority), burnt (since the start of the dry season) or unburned. The degree and direction of slope was estimated where not flat. Additionally the percentage tree canopy cover was estimated for each plot along with canopy and grass height.

Survey Components

The first three main components followed closely the methods described in the *Tanzanian Mpingo 98* report, with some slight variations.

Adult Mpingo Trees

Mpingo trees with at least one stem with a Circumference at Breast Height (CBH) of 10cm or greater were termed adult mpingo, and all such mpingo in each plots were surveyed in detail. CBH and Estimated Straight Length (ESL) was recorded on a per stem basis (minimum qualifying CBH 10cm). Other measurements taken were basal circumference, tree height by way of a clinometer, and canopy area. Subjective indices for termite infestation and fire scorching were also noted as per previous expeditions.

Other Tree Species

All other trees were identified where possible although less emphasis was placed on identification of rarer or more obscure species. Family was recorded where species or genus could not be determined. Trees were allotted to one of the size classes: pole, tree, big tree and very big tree, according to the definitions in Gregory *et al.* (1999). This report does not contain analysis of this component, which may follow in a subsequent addendum or supplementary report.

Juveniles

Juveniles were surveyed by use of a sub-plot located exactly as per 1998 expedition, centred on the nearest mpingo seedling or sapling to the centre of the plot, or around the nearest juvenile of any species if young mpingo is absent. All mpingo and other seedlings and saplings were counted in a 2m radius, and canopy cover of different tree and shrub species estimated in a 5m radius.

[6] This method differed from that used by the *Tanzanian Mpingo 98* expedition in one important point: there was use of plot category as a stratification, so the different categories of plot were encountered with varying frequencies, unlike the 1998 expedition which enforced equal proportions of the three categories.

Study Area

Thanks to Canisius Kayombo for his descriptions of Mkoka and Kilimarondo in this section.

Mkanga

Site Centre: 10° 12.5' S 39° 16.6' E (Strata 1) – Surveyed by teams B & C [7]

Mkanga is located on the Rondo plateau one of the most important fragments of East African Coastal Forest, and at the heart of the Lindi regional sub-centre of endemism (Burgess & Clarke, 2000). The forest at Mkanga was highly degraded and dominated by thickets with some abandoned cashew nut fields. The site is crossed by many small streams making the terrain extremely rough. Surveying was further hampered by the dense vegetation.

Nangaro

Site Centre: 09° 53.8' S 39° 25.8' E (Strata 1) – Surveyed by teams B & C

The site at Nangaro was characterised by a mixture of miombo vegetation, some thickets and attended cashew nut fields. The vegetation was more open than at Mkanga and was dominated by magnificent *Sterculia* and *Adansonia digitata*. The topography was hilly, but less so than at Mkanga. Vegetation was also sparser, making field work was easier.

Kimambi

Site Centre: 09° 24.6' S 38° 27.8' E (Strata 2) – Surveyed by teams B & C

The terrain at Kimambi was notably flatter and drier than at either Mkanga or Nangaro, with some small swampy areas. Much of the forest was dominated by thickets, though sparser than Mkanga and Nangaro. The site is within 10km of the border of the Selous Game Reserve, and game, including elephant, was abundant. Large bush fires were frequently witnessed in the evenings, reportedly started by poachers.

Mkoka

Site Centre: 10° 10.6' S 38° 44.5' E (Strata 2) – Surveyed by team A

A large part of the Mkoka study site was thicket growing in abandoned farms surrounding cashew nut plantations. Much of the natural woodland was also disturbed, and dominated by *Combretum* spp., *Diplorhynchus condylocarpon*, *Balanites*, *Dalbergia*, *Pteleopsis*, *Bauhinia thonningii*, *Vernonia* spp., *Markhamia* spp. and *Grewia* spp., and grass up to 3m high. Other habitats found were:

- Acacia and *Tamarindus indica* woodland, disturbed by fire
- Acacia woodland with bamboo.
- *Adansonia digitata* and *Kigelia africana* woodland, disturbed by cultivation.
- Seasonally waterlogged Acacia woodland with *Mucuna gigantea*, disturbed by cultivation.

Barikiwa

Site Centre: 09° 30.5' S 37° 54.1' E (Strata 3) – Surveyed by teams B & C

The site at Barikiwa was typical *Brachystegia* dominated miombo woodland. Fire burning is widespread in the area. Topography is gently hilly. Magnificent tall, dense miombo woodland in places gave way to moist, riverine forest. The area was exceptionally rich in game.

[7] Teams B & C combined together early on for logistical reasons.

Kilimarondo

Site Centre: 10° 33.1' S   38° 03.2' E (Strata 3)   –   Surveyed by team A

The Kilimarondo study site was predominantly miombo (*Brachystegia*) woodland with very scattered termite mounds; common tree species were *Acacia lahai, Albizia* spp., *Sclerocarya birrea, Commiphora abyssinica, Julbernardia globiflora, Lannea* and *Combretum* spp. Also common was riverine wooded grassland dominated by *Kigelia africana*, *Syzygium guineense*, *Diplorhynchus condylocarpon*, *Pseudolachnostylis maprouneifolia*, *Vitex doniana*, and *Psorospernum febrifugum*. Less common habitats encountered were:

- *Brachystegia* woodland with abundant bamboo.
- Rocky, miombo woodland additionally containing frequent *Annona* spp., *Tamarindus indica*, *Diplorhynchus condylocarpon* and *Xeroderris stuhlmannii*.
- Seasonal streams with riverine woodland dominated by *Syzygium guineense* and *Brachystegia* spp.

There were also areas of rocky shrub land with *Xerophyta sp.* which did not feature in any of the sampled plots.

Results

Before proceeding with the results of the data analysis it is incumbent upon us to note some of the deficiencies in the data. Despite a training day in which all teams were taken through the methodology together, certain elements of the methodology were carried out inconsistently by the three field teams, and some sections of the data exhibit a significant number of gaps. Substantial effort on the data entry and cross-checking resolved some of these issues, but elsewhere analysis had to proceed based on incomplete records. For instance 13 sample plot numbers appear to have been skipped, or the data for those plots lost. In some cases, the total *n* remains large enough that the analysis is largely unaffected. Explanatory footnotes are provided where data quality issues impinge on the results presented below. Two important assumptions underlie all the analysis:

1. Missing data does not follow any distorting pattern, i.e. such instances are randomly distributed, and are not a source of bias.[8]
2. All mpingo trees growing in the sample plots were correctly identified and recorded.[9]

A third assumption is commonly invoked when computing averages of data across all sites:

3. The variation between sites in number of plots for which data exists[10] is not a significant source of bias.

The most important results from this survey, such as mean harvestable worth, do not require sophisticated statistical analysis. To complement this, a data-mining or exploratory approach was taken similarly to that adopted by Gregory *et al.* (1999), with many of the analyses the result of *post-hoc* testing. Many of the statistical differences thus reported should not be over-relied upon unless subject to further testing. Nonetheless the differences so noted are valid for this data set, and throw an interesting light on some aspects of mpingo distribution.

Habitat Characteristics

Plot Type

The sample plots in four of the study sites were made up of around 40% unburned plots, with the remainder split roughly evenly between riverine and burned plots. However two of the study sites – Nangaro and Mkoka – had a much higher proportion (around 75%) of unburned plots, no riverine plots were surveyed at all at Mkoka. Figure 1 below shows the percentage split between plot types for each of the six study sites.

[8] In fact there is some bias evident in that the majority missing data points occur in the data collected by teams B and C, and thus the data from Mkoka and Kilimarondo is more complete than the other two sites.

[9] One tree was recorded with a CBH of 80cm and a basal circumference of 12cm which is clearly wrong. A CBH of 8cm would fit the model derived below quite closely, and also fits the recorded height of 2.5m, but this would exclude it from the surveying methodology, contradicting assumption 2. The ESL was recorded as 0.4m making the tree unharvestable, so the major findings on harvestable timber are not distorted by the individual, and the CBH was left blank in all other analyses.

[10] The aim was to survey 42 plots per site. Two sites were underrepresented with 34 and 37 plots for which data exists, and one site had 43 plots surveyed.

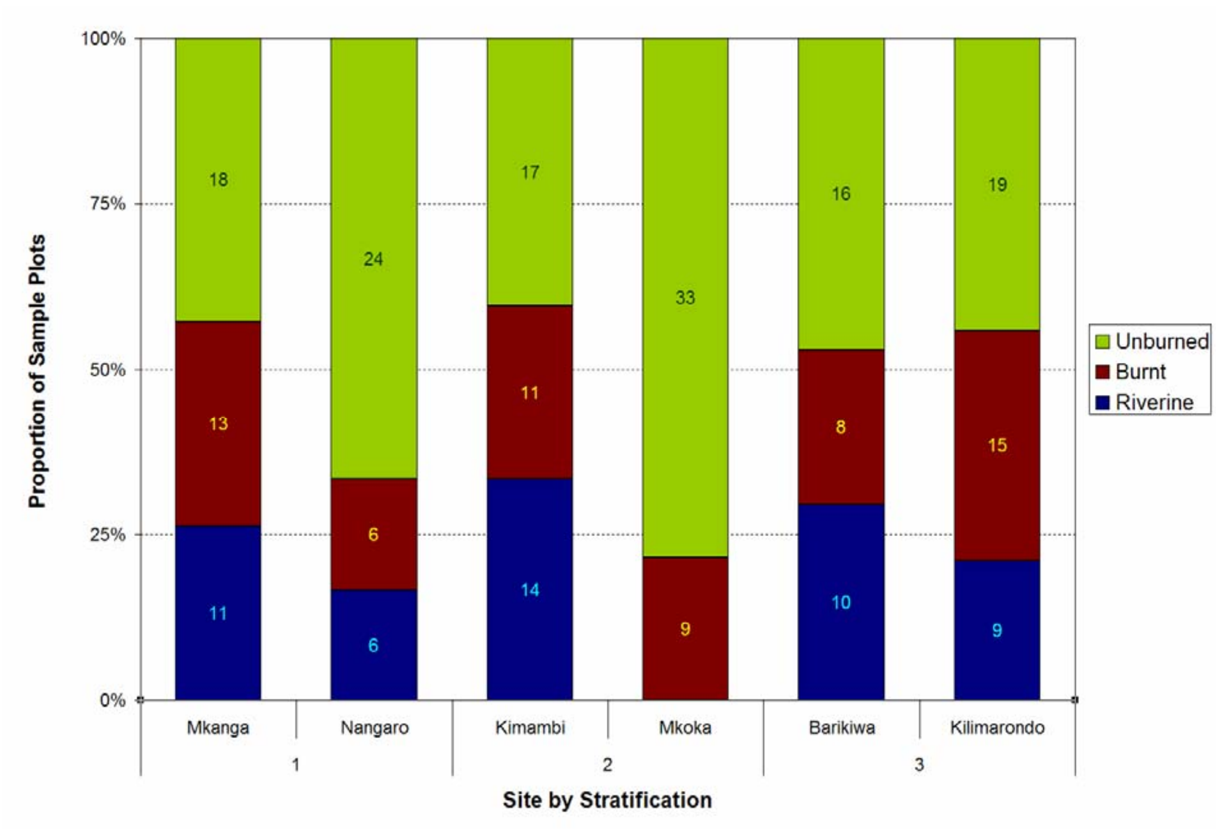

Figure 1. Variation in plot type between study sites. Numbers indicate total number of plots surveyed.

Plot Slope

Some study sites were hillier than others, and this is reflected in the statistics for plot slope, see Table 2. 84% of plots in the important sites in strata 2 and 3 were flat. Variation in slope, both proportion flat[11] and direction[12], is confounded with the original stratification by distance from the sea, so any analysis by that stratification must be checked against plot slope as an alternative causal or correlated factor.

Study Site	% Plots Flat	% Low Slope (1-15°)	% Medium Slope (16-30°)	% High Slope (31°+)	Prevailing Slope
1 : Mkanga	46	26	21	8	NE – N – NW (37%)
1 : Nangaro	53	28	8	11	N (17%)
2 : Kimambi	90	10	0	0	
2 : Mkoka	95	5	0	0	
3 : Barikiwa	62	32	6	0	E – SE (12%)
3 : Kilimarondo	81	16	2	0	E (15%)

Table 2. Slope variation between study sites.

[11] By visual inspection only, *n* is too small for analysis by ANOVA.
[12] Chi-squared test: $\chi^2 = 52.6$, $p < 0.01$

Canopy & Grass Cover

Percentage tree canopy cover and grass cover data are presented in Figure 2 and Figure 3 below. Data for grass cover is only available for 4 out of the 6 study sites, and for approximately half of the plots in those 4 sites.

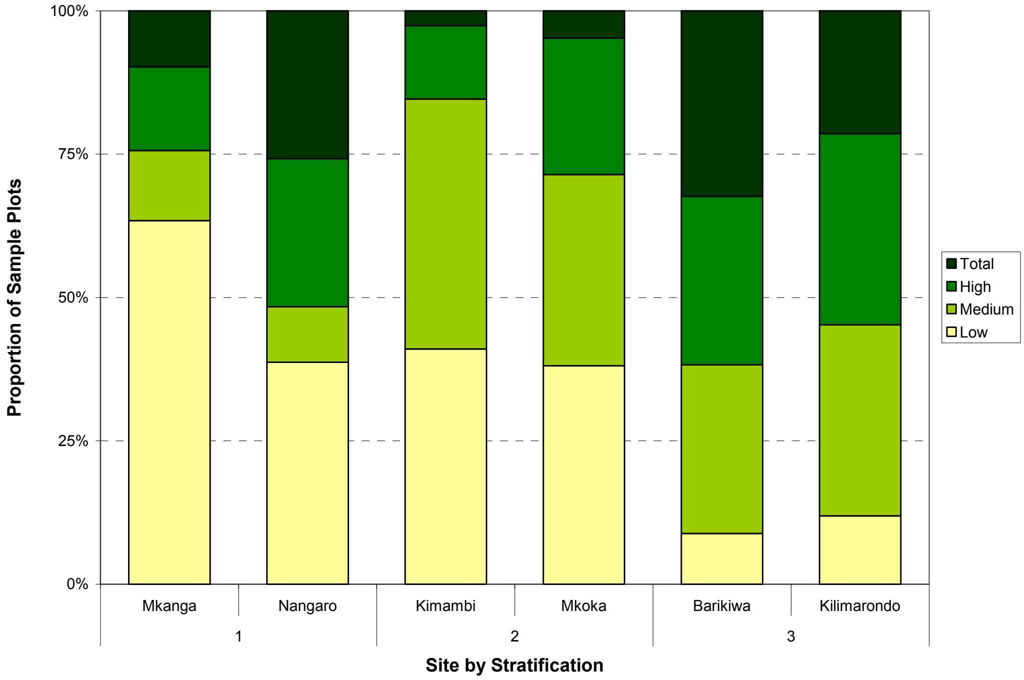

Figure 2. Variation in tree canopy cover:
low (0 – 25%), medium (26 – 50%), high (51 – 75%), total (76 – 100%).

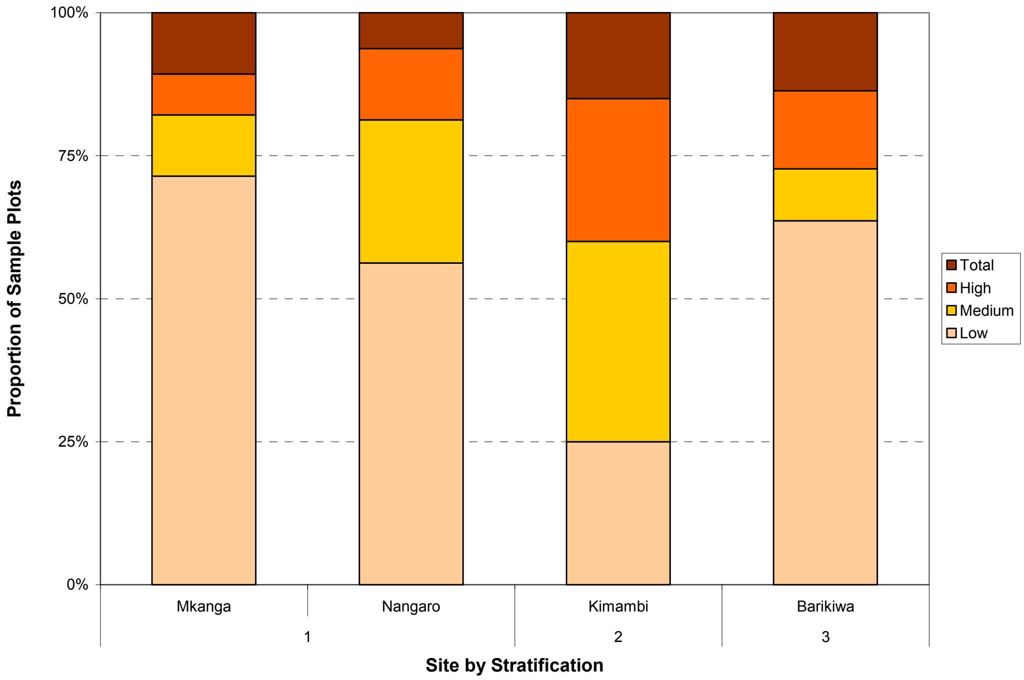

Figure 3. Variation in grass cover where data available:
low (0 – 25%), medium (26 – 50%), high (51 – 75%), total (76 – 100%).

Canopy height varied little by site and canopy cover as set out in Table 3 below. Nangaro and Kimambi were surveyed by the same joint team which surveyed Mkanga and Barikiwa, so the higher mean canopy height for those two sites cannot be explained by perceptual differences between teams. Grass height follows a similar pattern as indicated in Table 4.

Study Site	Low Cover (0 – 25%)	Medium Cover (26 – 50%)	High Cover (51 – 75%)	Total Cover (76 – 100%)	Overall Mean
1 : Mkanga	8.8	8.7	8.8	6.8	8.2
1 : Nangaro	11.5	11.4	11.5	13.4	12.3
2 : Kimambi	12.1	13.2	12.1	none	11.1
2 : Mkoka	7.6	9.1	7.6	7.3	8.1
3 : Barikiwa	8.7	8.1	8.7	8.2	8.3
3 : Kilimarondo	7.6	8.4	7.6	7.4	8.3

Table 3. Variation in mean canopy height (m) by study site and canopy cover.

Study Site	Low Cover (0 – 25%)	Medium Cover (26 – 50%)	High Cover (51 – 75%)	Total Cover (76 – 100%)	Overall Mean
1 : Mkanga	0.1	0.9	1.5	1.8	0.7
1 : Nangaro	0.1	0.8	0.7	0.5	0.6
2 : Kimambi	0.4	0.8	1.6	1.2	1.0
2 : Mkoka					0.7
3 : Barikiwa	0.2	0.5	0.9	1.4	0.5
3 : Kilimarondo					0.8

Table 4. Variation in mean grass height (m) by study site and grass cover. Team A which surveyed Mkoka and Kilimarondo collected grass height data but not percentage grass cover.

Study Site Characterisation

The above data complements the textual descriptions of each study site. Further detail can be deduced by looking at two most variable characteristics, plot type and canopy cover, in combination on a site by site basis. That eludes the following results:

- The sites at Mkanga and Barikiwa had mostly low canopy cover riverine plots[13], whereas a large majority of the riverine plots at Nangaro had high to total tree canopy cover.
- Burned plots were strongly associated (70%+) with low (0-25%) canopy cover at the Mkanga, Nangaro and Kimambi sites, while canopy cover on burned plots at Mkoka, Barikiwa and Kilimarondo was more or less in line with the overall canopy cover distribution for each of those sites as given in Figure 2 above.
- Canopy cover in unburned plots at each site reflected the overall site canopy cover in each case.

Adult Mpingo Population

Distribution

41 adult mpingo trees were recorded in 24 different plots over the course of surveying at an overall frequency of 10% of plots and an overall density of 1.36 trees per hectare. This compares with 40% of plots surveyed and 8.5 trees ha^{-1} found by the *Tanzanian Mpingo 98* expedition in the mpingo-rich

[13] Only 20% of riverine plots at Mkanga had tree canopy cover > 50%, 30% of riverine plots at Barikiwa had in excess of 50%.

habitat around Migeregere.[14] The highest density of 7 trees in a plot (55.7 trees ha^{-1}) found in a burned plot at Mkoka is also lower than the maximum 87.5 trees ha^{-1} at Migeregere.[15] However this is an outlier, with the next highest density observed being 4 trees in a unburnt plot at Mkoka (31.8 trees ha^{-1}). Those two plots account for 58% of the adult mpingo seen at Mkoka.

No adult mpingo at all were found in sample plots at either of the strata 1 sites, although some mpingo were observed outside sample plots at Nangaro. The variation in frequency and density of mpingo at the other study sites is set out in Table 5 and Table 6 below. Only in the burnt areas at Mkoka do the figures appear similar to those found at Migeregere. Unfortunately further statistical analysis of the distribution of the trees is constrained by the low sample size in all strata.

Study Site	Unburned	Burnt	Riverine	Overall Mean
2 : Kimambi	6%	0%	21%	10%
2 : Mkoka	9%	56%	–	19%
Strata 2 Overall	8%	25%	21%	14%
3 : Barikiwa	6%	25%	30%	18%
3 : Kilimarondo	16%	7%	22%	14%
Strata 3 Overall	11%	13%	26%	16%
All study sites	**6%**	**13%**	**16%**	**10%**
Migeregere	*24%*	*53%*	*40%*	*40%*

Table 5. Frequency (%) of encountering adult mpingo in survey plots by plot type and study site, with totals for strata and for all sites, and the *Tanzanian Mpingo 98* data from Migeregere for comparison.

Study Site	Unburned	Burnt	Riverine	Overall Mean
2 : Kimambi	1.4	0	1.7	1.1
2 : Mkoka	1.4	9.7	–	3.2
Strata 2 Overall	1.4	4.4	1.7	2.2
3 : Barikiwa	1.5	2.0	4.0	2.3
3 : Kilimarondo	1.7	0.5	2.7	1.5
Strata 3 Overall	1.6	1.0	3.4	1.9
All study sites	**1.0**	**1.8**	**1.7**	**1.4**
Migeregere	*4.3*	*10.7*	*10.3*	*8.5*

Table 6. Density of adult mpingo (trees per hectare) by plot type and study site, with totals for strata and for all sites, and the *Tanzanian Mpingo 98* data from Migeregere for comparison. The figure for burnt plots at Mkoka is distorted by the above mentioned outlier.

When the above-noted outlying plot with 7 adult mpingo is excluded, the density appears higher for riverine plots than other types of plot, but this is not significant ($t = -1.28$, $df = 158$, $p > 10\%$). Figure 4 which illustrates the variation in mpingo density for plots in study strata 2 and 3 by both plot type and

[14] Gregory *et al.*, 1999
[15] The fact that this one single plot accounts for over one-sixth of the adult mpingo recorded in the surveys has negative consequences for statistical analysis of the data set as noted below.

canopy cover. Other than the above-mentioned case of the riverine plots, unburnt plots with a high (51-75%) canopy cover is a possible peak, but this is also insignificant ($t = -1.01$, $df = 154$, $p > 10\%$), perhaps due to a low sample size. The general character of the graph, showing higher mpingo density in medium to high canopy cover areas is better explained in terms of mpingo frequency rather than density, see below.

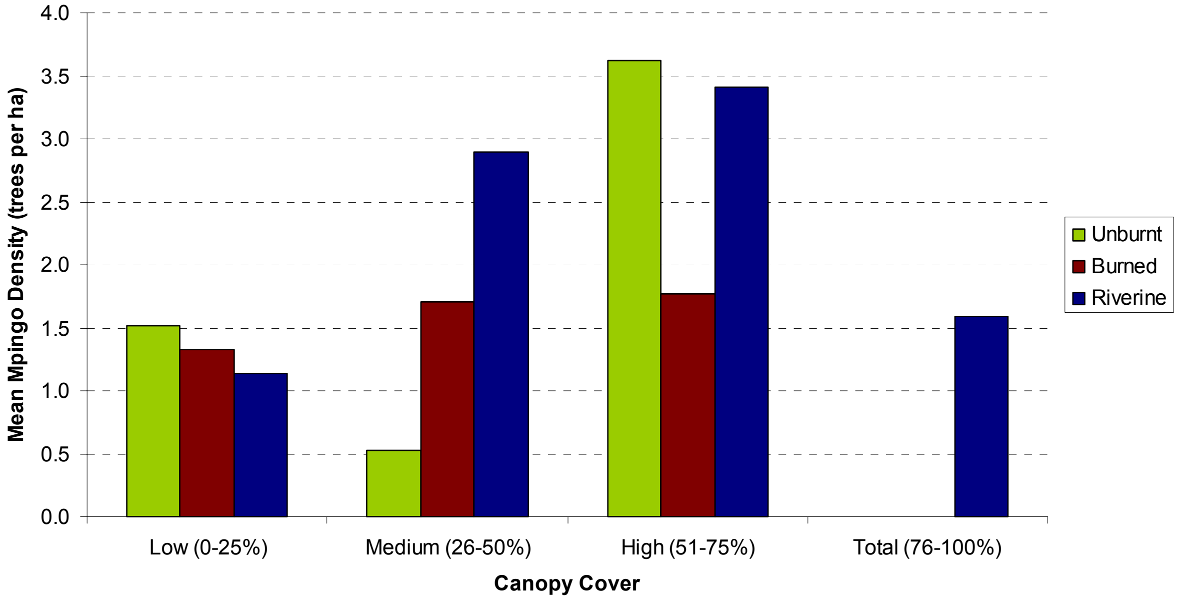

Figure 4. Variation in adult mpingo density in plots in site strata 2 & 3 according to different classes of canopy cover, showing variation by plot type. Excludes outlying plot at Mkoka with 7 mpingo, next maximum was 3.

All the adult mpingo were seen in plots with a canopy height of between 5m and 15m. The number seen showed a marked jump between 7m and 10m canopy height, but this range also accounted for a large number of the plots surveyed as Figure 5 makes clear.

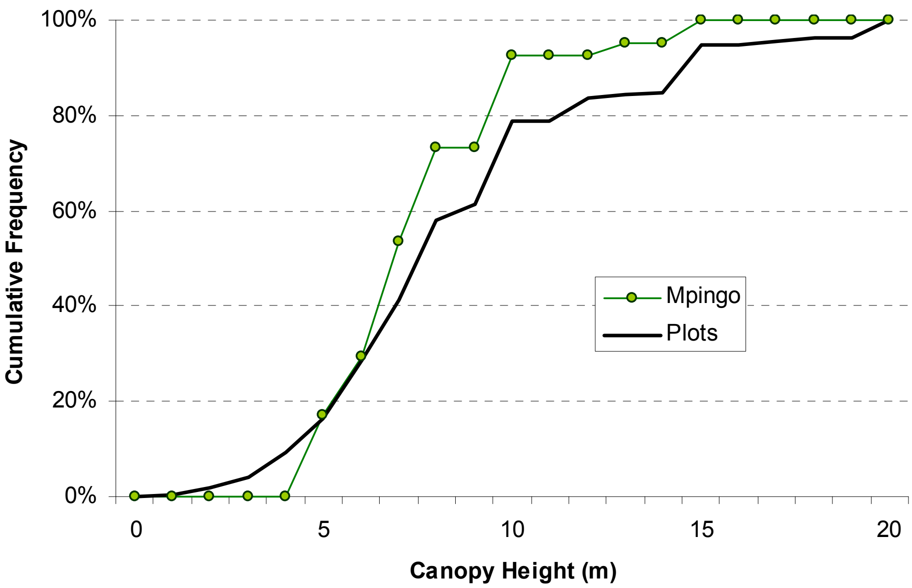

Figure 5. Comparative cumulative frequency of mpingo seen and plots surveyed by canopy height.

Due to the low frequency of mpingo encounters, the density of adult mpingo is not readily susceptible to analysis by variations in plot characteristics.[16] However habitat preferences can be detected in the mpingo frequency. Adult mpingo were more likely to be found in plots where the canopy cover was medium to high (i.e. between 26% and 75% inclusive, frequency 14.7%) than elsewhere (frequency 5.3%) (binomial test, n = 229, r = 10.0%, p < 5%), and see Figure 4 above. Other plot classifications, including slope, did not show evidence substantial variations. All attempts to construct any kind of general linear model to predict the presence of mpingo failed, at least partly as a result of the low total number seen.

Size Structure

The girth at breast height of the thickest stem (maximum CBH) is the simplest indicator of the age of a tree that can be obtained without cutting it down. Many mpingo trees have multiple stems, but usually there are only one or two large ones, while the others are much smaller.

Max CBH (cm)	**Unburned**	**Burnt**	**Riverine**	**All plots**
Mean	22	40	22	28
Standard error	*8*	*41*	*9*	*25*
Max	35	127	46	127

Table 7. Comparative thickness by plot type of stem size of adult mpingo to the nearest cm, qualifying requirement CBH ≥ 10cm.

Figure 6 below repeats the analysis by size group performed on the data collected at Migeregere in 1998, however the results are strikingly different, with a highly skewed size structure in favour of the smaller trees, and echoing the size structure seen by *Tanzanian Mpingo 96* at Mchinga, where 75% of adult mpingo were poles, i.e. CBH < 30cm (Ball *et al.* 1998).

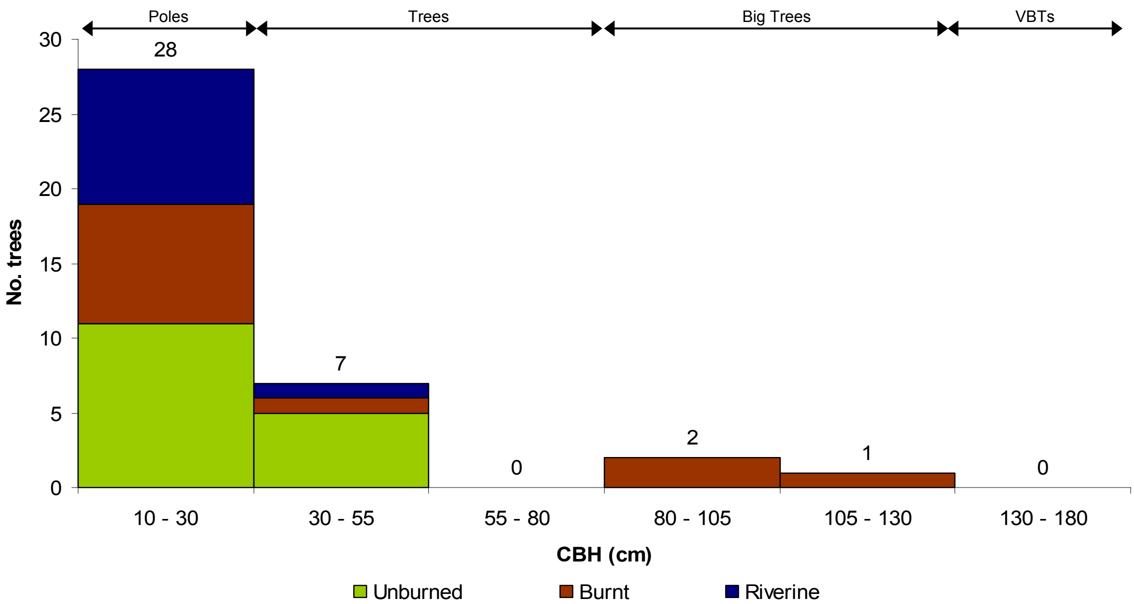

Figure 6. Mpingo frequency by size group and plot type. Note the change in the span of size groups for the end columns. VBTs = Very Big Trees – see methodology. Two middle groups split as per Figure 5, page 32 in Gregory *et al.* (1999(.

[16] Additionally mpingo density will be strongly influenced by those two plots in Mkoka with 4 and 7 adult mpingo respectively, such that any observable pattern is likely to be a result of at least one of those two plots.

Other measures of tree size showed the following variation:

Plot Type	Height (m)	Canopy Area (m^2)	Estimated Straight Length (m)	Estimated Straight Volume (dm^3)
Unburned	5.4	26.8	1.1	4.7
Burnt	6.5	37.1	1.1	23.7
Riverine	5.1	33.7	1.3	9.4
All plots	5.7	32.0	1.1	11.9
Standard Error	*2.6*	*36.4*	*1.2*	*29.7*

Table 8. Variation in measures of tree size for mpingo. Estimated Straight Volume, ESV = ESL x (CBH^2 / 4π), where ESL = Estimated Straight Length. Except for the final line all figures are means.

The patterns of variation are not consistent with those evidenced in the larger data set obtained at Migeregere. Interestingly while tree height and ESL are about 60% of those found on adult mpingo at Migeregere, canopy area is 30% higher than at Migeregere. Estimated Straight Volume per tree is 12% of that found at Migeregere! However statistical testing of these differences is not appropriate since the low sample size, skewed data set and high variability[17] precludes any meaningful analysis of the variation between the plot types. Moreover the fact that one plot at Mkoka accounts for over one-sixth of all adult mpingo seen by the expedition means that any such analysis by plot characteristics is likely to be extremely sensitive to the conditions in that one plot.

The distance to the nearest competitor of different size classes was not found to be a significant determinant of tree size at Migeregere, and this result was repeated with the data collected on this expedition.

Harvestable Timber

The Estimated Straight Length varied from 0 to 5m. Figure 7 is analogous to Figure 6 in showing the variation in ESL between different plot types, and, given the highly skewed size structure, exhibits the expected exponential decline in frequency of ESL above a certain threshold; 1.0m in this case.

Following the terminology of Ball (2004) 54% of the adult mpingo were potentially harvestable at some point in the future, i.e. they had an ESL >= 75cm, but only 6% (2 trees, both in burnt plots) were harvestable now, i.e. they also had a CBH >= 70cm. This compares with 82% and 50% respectively at Migeregere. The extremely low number of trees harvestable now unfortunately makes the calculation of any statistics of harvestable worth almost meaningless, but for the sake of comparison the mean currently harvestable volume is $0.0075m^3\ ha^{-1}$, which is less than 1% of the $1.03m^3\ ha^{-1}$ found at Migeregere.

[17] Except for tree height the standard error is greater than the mean of the measure indicating a highly variable data set skewed by some large outliers but otherwise dominated by smaller trees.

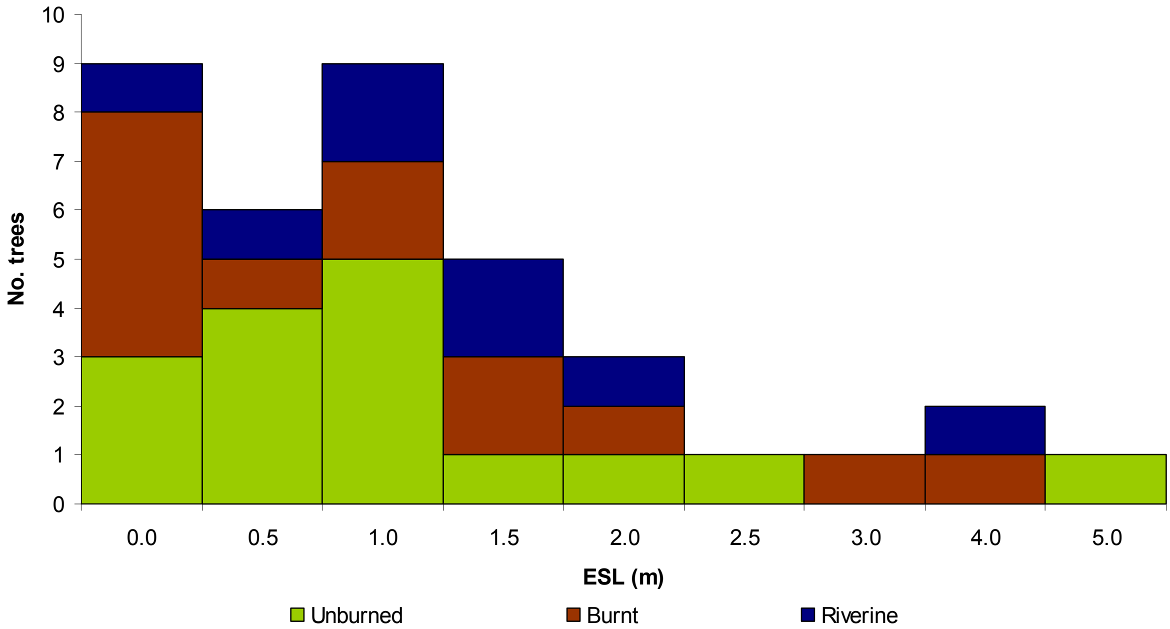

Figure 7. Mpingo frequency by Estimated Straight Length. Note the larger spans of the classes for ESL above 2.5m.

Mpingo Morphology

Mpingo coppices well and is frequently multi-stemmed, but trees with more than one stem are often less suitable for harvesting since the individual stems will not grow so large. 59% of adult mpingo recorded in the survey had a single stem against 77% found by *Tanzanian Mpingo 98* at Migeregere. The overall mean number of stems was 1.83 per tree against 1.51 at Migeregere and 2.5 at Mchinga, study site of the *Tanzanian Mpingo 96* expedition, and where 57% of trees had more than one stem. Figure 8 summarises the contrasting data sets graphically.

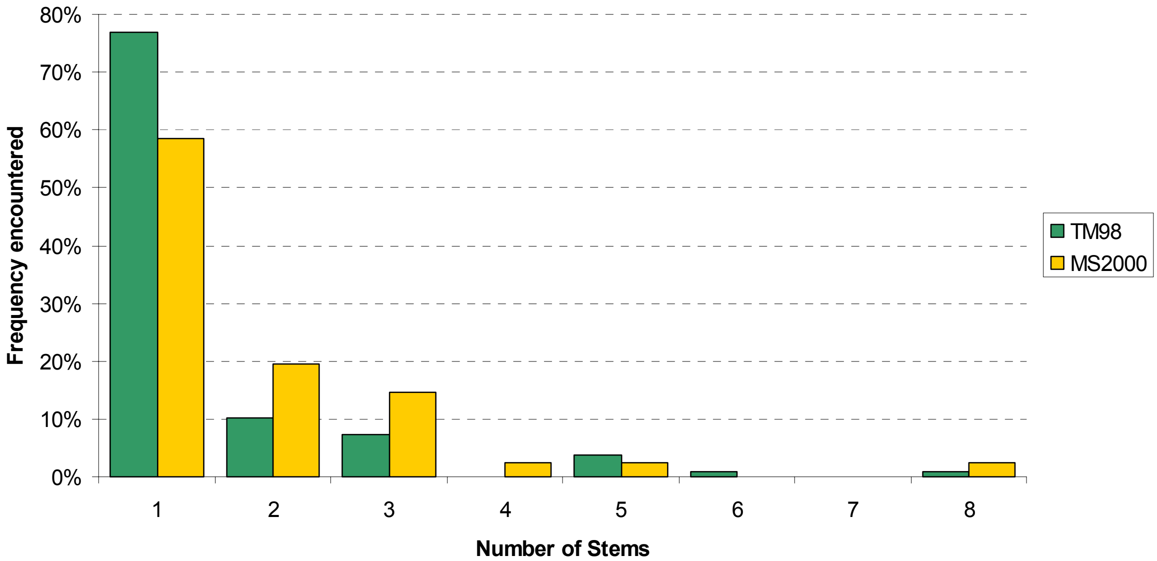

Figure 8. Varying frequency of different number of stems on mpingo trees encountered by the *Tanzanian Mpingo 98* (TM98) expedition at Migeregere, and this expedition at various study sites (MS2000).

The difference between the likelihood of multiple stems in the two samples, one in low mpingo density sites scattered over the whole region, and the other in an mpingo rich habitat, is significant ($\chi^2 = 4.06$, n = 149, df = 1, p < 5%). However a test of the number of stems per tree does not exhibit significant differences between the samples (T = 1.30, n = 149, df = 64, p > 10%), since the average number of stems for trees with more than one at 3.0 is less than the 3.2 stems per multiple-stemmed tree at Migeregere.

The data presented here contradict the findings of *Tanzanian Mpingo 98* which noted multi-stemmed trees were more frequent in burnt plots. The number of stems per mpingo surveyed by this expedition also varies by plot type, but here the major difference is between unburned plots where 60% of adult mpingo were multi-stemmed, and the other plot types where 22% of adult mpingo were multi-stemmed (F = 3.25, n = 41, df = 2, p < 5%). However the above noted precaution about the influence of those two outlying plots at Mkoka with many mpingo applies here; all 4 mpingo in the unburnt plot have multiple stems.[18]

When evaluating harvesting by stumps CBH is not available so the researcher must rely on basal circumference. To check the accuracy of this approach the expedition also measured the basal circumference of all adult mpingo, and regressed CBH of the thickest stem against basal circumference. Figure 9 shows the result. Basal circumference accounts for only 58% of the variation, but this is distorted by the two outliers either side of the line which are so extreme as to defy explanation.[19] Excluding these two points produces a much better fit, with adjusted $R^2 = 85\%$. The refined model is:

$$CBH = 0.737 \times BC$$

where BC is basal circumference, the intercept has been forced to zero, and CBH is that of the thickest stem.

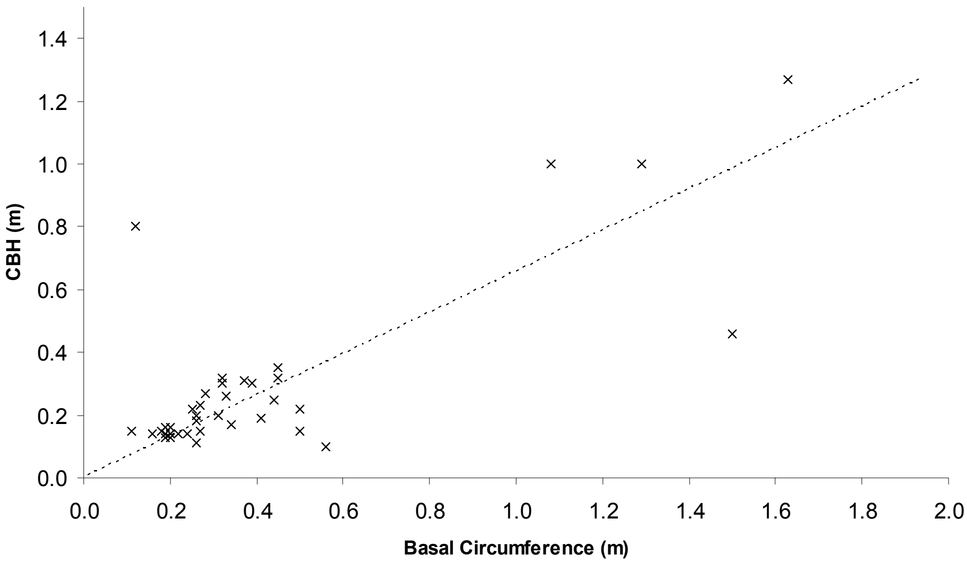

Figure 9. CBH of the thickest stem regressed against basal circumference of adult mpingo.

A possible explanation for variation either side of the model is that individual mpingo under the best fit line, i.e. where the CBH is substantially lower than would be expected from the basal circumference are branched below breast height, while those above the best fit line may be branching just above breast height or swollen from infection or insect activity. However a chi-squared test does not show any relationship between multiple stems and an under- or over-estimate (by at least 10%) of CBH from the model ($\chi^2 = 1.83$, n = 37, df = 2, p > 10%).

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[18] Though of the 7 adult mpingo in the burnt plot, only 4 are single-stemmed.
[19] See footnote 9 at the start of this chapter.

Gregory *et al.* (1999) observed that the height v girth ratio of the great majority of adult mpingo at Migeregere lay between 7 and 22, but only 39% of the trees surveyed by this expedition fitted that pattern. Gregory *et al.* (1999) also regressed ESV against predictor variables of girth and height, but the skewed data set of very low ESVs collected here means that any further analysis is unlikely to add anything useful to those previous computations.

Tree Health

The two indicators of damage to trees recorded: termite infestation and trunk scars from fire, are subjective, and so less susceptible for comparison between different expeditions, and the different study sites, which were surveyed by different teams. However it is worth remarking that this expedition only recorded scorch marks on 17% of the adult mpingo seen, and never more than light scarring (1 on a scale of 0 to 3), and that this was not noticeably more prevalent in burnt plots than unburnt plots. By comparison, the *Tanzanian Mpingo 98* expedition found scorch marks on 53% of adult mpingo, the majority in burnt plots, and of these 28% exhibited moderate to severe scarring (2 or 3 out of 3).

Mean termite infestation on adult mpingo was 1.39 on our scale, as opposed to 1.87 at Migeregere. The distribution of levels of infestation is illustrated in Figure 10. The expedition also recorded the presence or absence of climbers, and found them on 18% of adult mpingo encountered.

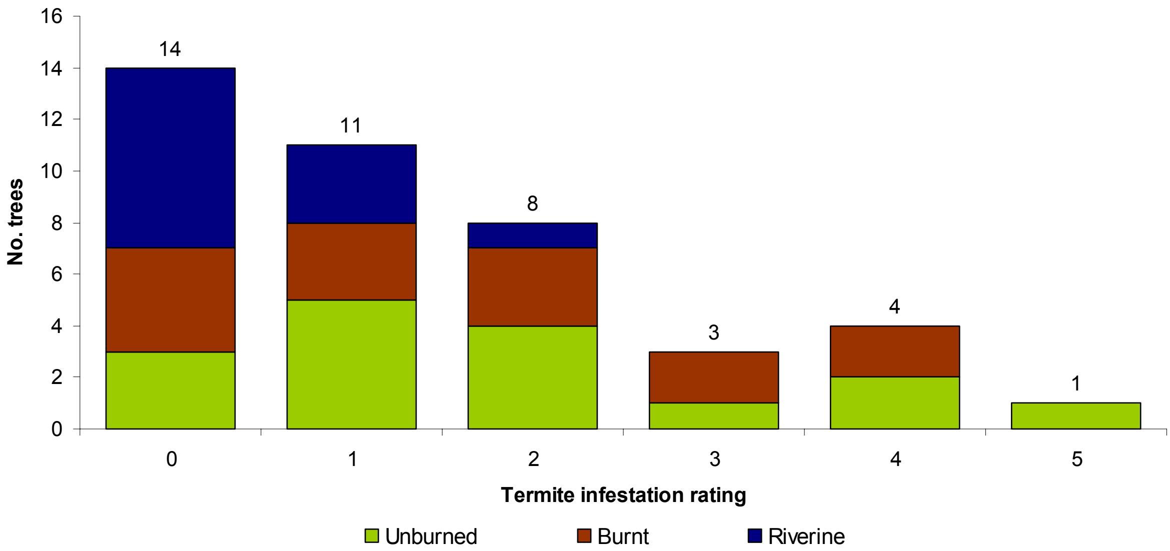

Figure 10. Frequency of different levels of termite infestation of adult mpingo.

Regeneration

85% of plots contained one or more juvenile trees of any species[20], but only 19% of plots surveyed contained juvenile mpingo. Just as for adult mpingo, this figure varies considerably. No juvenile mpingo were found in either of the strata 1 study sites, and differing frequencies in the other 4 sites. Table 9 summarises the situation and lists the *Tanzanian Mpingo 98* data for comparison. As at Migeregere the variation between plot types in mpingo juvenile presence is not significant (Binomial test – burnt / riverine, n = 62 / 50, p > 10%). Also as at Migeregere no strong association between presence of juvenile and adult mpingo is noticeable in the four study sites where it was present at all ($\chi^2 = 3.05$, n = 140, df = 1, p > 5%). Mpingo of any age occurred with an overall frequency of 36% in the four sites in strata 2 and 3.

[20] This is comparable with Migeregere where 87% of plots had at least one seedling or sapling of any species.

Study Site	Unburned	Burnt	Riverine	Overall Mean
2 : Kimambi	0%	0%	15%	6%
2 : Mkoka	42%	0%	–	33%
Strata 2 Overall	31%	0%	15%	22%
3 : Barikiwa	20%	14%	60%	33%
3 : Kilimarondo	24%	57%	25%	36%
Strata 3 Overall	22%	43%	44%	35%
All study sites	**19%**	**16%**	**22%**	**19%**
Any spp. juvenile	92%	75%	83%	85%
Mpingo at Migeregere	*21%*	*33%*	*37%*	*30%*

Table 9. Frequency (%) of encountering juvenile mpingo in survey plots by plot type and study site, with totals for strata and for all sites, and the totals for all juveniles of all species and *Tanzanian Mpingo 98* data from Migeregere for comparison.

Mpingo juveniles accounted for only 4.6% of woody juveniles counted in the 2m radius sub-plots. Where mpingo juveniles were found, saplings accounted for 73% of juveniles as against 48% for all other species and a roughly even split at Migeregere. This is reflected in the increase in mean height for the centre juvenile which is 1.81m for mpingo, but 1.53m on average for all species.[21]

Ball (2004) found the likelihood of mpingo juveniles being present at Migeregere doubled where the total tree canopy cover in the surrounding 5m radius sub-plot was 40% or less, but the likelihood remains almost constant for sub-plots thus surveyed by this expedition.[22] In fact this result is reversed when canopy cover over the entire 20m radius plot (not available for the Migeregere data) is considered; now the likelihood of mpingo juveniles being present rises from 17% in plots where canopy cover over the whole plot is equal to or less than 40%, to 24% mpingo juvenile presence where canopy cover over the entire is plot exceeds 40%, although this result is not significant (Binomial test, n = 90, p > 10%). Juveniles of other species appear to follow a similar pattern but gaps in the data prohibit statistical analysis.

Figure 11 shows in more detail the variation between categories of canopy cover of the presence of mpingo juveniles for study sites in strata 2 and 3. Riverine plots which do not have total (76-100%) canopy cover are generally on smaller ephemeral water courses which do not harbour the distinctive thicker ground-water forest. Mpingo juvenile were found there with a significantly greater frequency of 50% as against the average encounter rate of 30% in site strata 2 & 3 (Binomial test, n = 25, p < 5%), but the associated test for riverine courses with total canopy cover is not significant due to a low sample size (n = 5, p > 10%). Burnt plots with a low canopy cover also appear to exhibit an extremely low frequency of mpingo juvenile presence, and this is significant (n = 10, p < 5%).

[21] Owing to the deliberate location of sub-plots around mpingo juveniles where present, the presence or height of other species cannot be said to be independent of the presence or height of mpingo, and so these differences in the data do not readily present themselves to statistical analysis.

[22] Mpingo juvenile presence varies slightly from 34% where the canopy cover is less than or equal to 40%, to 36% where canopy cover is over 40%. The inconsistency with Table 9 is a result of a much reduced data set (n = 91 compared to 240) for canopy cover within the 5m radius sub-plot. This inconsistency is statistically significant (p < 0.1%), though there is no obvious explanation and illustrates the hazards of working with partial data sets.

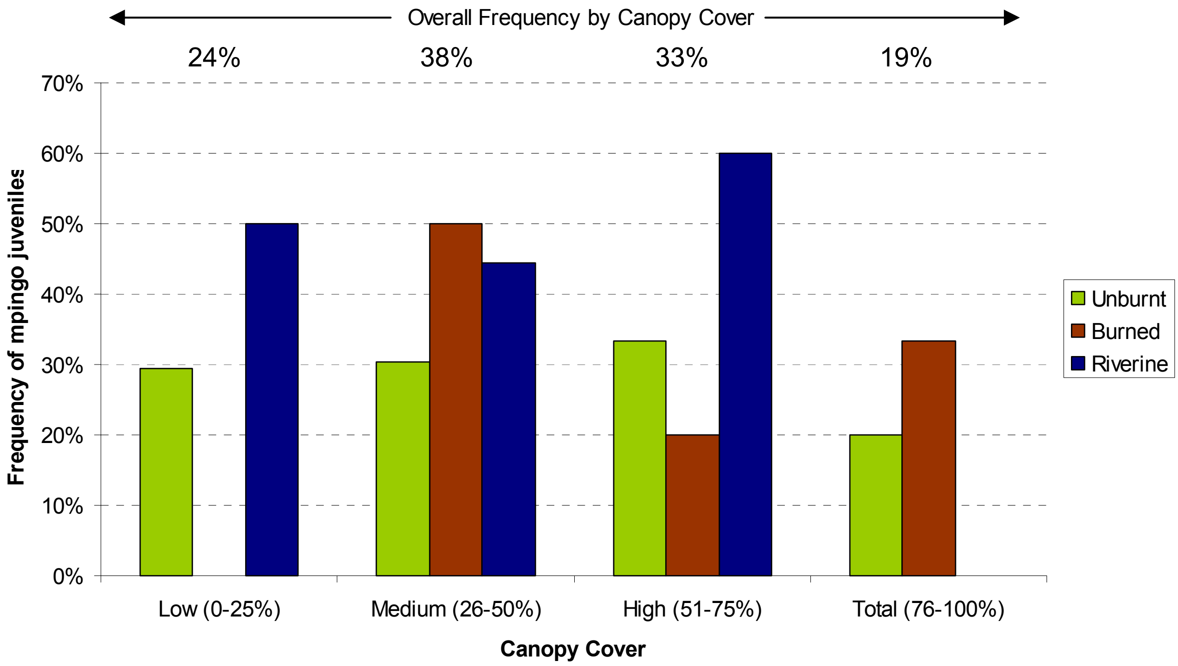

Figure 11. Frequency of juvenile mpingo in plots in site strata 2 & 3 according to different classes of canopy cover, showing variation by plot type. Overall frequency for each canopy cover class is noted at the top of the figure.

In addition to canopy cover, canopy height was found to play a significant part with mpingo juvenile presence in plots in strata 2 and 3 rising to 43% where the plot canopy height was 6m or less[23], compared to 23% where it exceeded 6m ($\chi^2 = 4.38$, $n = 136$, $df = 1$, $p < 5\%$). Plot slope was not found to be a significant factor in the distribution of mpingo juveniles. Sample size prevents any constructive analysis of the effect of grass cover or height on juvenile mpingo presence. As for adult mpingo, attempts to construct a general linear model predicting the presence of juvenile mpingo failed.

[23] 21.5% of plots in those four sites had a canopy height of 6m or less.

Conclusions

Habitat Characteristics

The expedition surveyed nearly 1,000km² across six widely differing study sites. This fact alone highlights the danger of attempting to extrapolate stock estimates from small study sites across the whole region. A simple division between miombo and coastal forest habitats is not sufficient for such purposes.

The division of plot types adopted in this research reflects two separate factors; the presence of a water course does not preclude it from being burned. There are essentially two types of habitat included in the riverine classification. First is the more-or-less closed canopy thick evergreen forest existing in deep river valleys with close to year-round ground water.[24] This type of forest rarely burns due to the higher moisture content of the vegetation. Second are ephemeral water courses with sparser, dryer flora often little different to the surrounding habitat. This second type of riverine habitat will burn in the same way that other non-riverine areas do. Thus the site at Kimambi has the highest proportion of riverine plots (33%) of any of the study sites but the lowest proportion (16%) of plots with 50% or higher canopy cover. Many of those riverine plots are thus likely to be ephemeral water courses. As noted above the sites at Mkanga and Barikiwa also exhibited mostly low canopy cover riverine plots, whereas a large majority of the riverine plots at Nangaro had high to total tree canopy cover. The riverine plots

Burned plots act as a proxy indicator for areas which may have been burned in the past (Ball 2004). However the extent to which past burning correlates with recent burning[25] is unknown. Where fires are lit for hunting purposes the correlation is likely to be quite good. However if an area has been burned to create new fields for farming, then it may only recently have been cleared, and not burned for several years previously. Fires spreading from farms around a village are as much an indicator of local human impacts, as areas further from the road or settlement are less likely to be affected by such uncontrolled fires. The effectiveness of burnt plots as a proxy for past frequency of fires may decline when comparisons are made across multiple study sites, which have been subjected to multiple different pressures and local environmental factors, from its effectiveness on a single study site as was the case at Migeregere. For example the habitat at Mkoka, although exhibiting a relatively low proportion (21%) of burnt plots, was highly degraded woodland recovering on abandoned farmland, which was probably frequently burned in the past.

A further note of caution should be sounded over the class boundaries used to analyse canopy cover. The field methodology called only for the percentage canopy cover to be estimated, and the data was put into classes subsequently. This helps avoid problems caused by some surveyors tending to estimate higher than others.[26] However the boundaries of these classes are common percentages to use when estimating; on 25 occasions the tree canopy cover in a plot was estimated at 50%, and in total 22.3% of canopy cover estimations fall on one of the boundaries. This problem can partly be alleviated by determining the classification in advance and forcing surveyors to select from one of the classes, although class selection of plots judged close to the boundary by the surveyor still becomes something of a lottery. Unfortunately the solution of choosing unlikely figures for the class boundaries leads to an obfuscated analysis, and is even less desirable.

[24] cf. 60-90% tree canopy cover described for wet miombo, Araki, 1992.
[25] I.e. Burning earlier in the dry season during which surveying is taking place.
[26] These sorts of sensitivities mean this variable would make a poor correlate in a general linear model.

Mpingo Distribution & Morphology

One of the most striking results is the total absence of mpingo from sample plots in either of the study sites in strata 1. However explanations other than distance from the sea must be sought since the study sites of both the *Tanzanian Mpingo 96* and *Tanzanian Mpingo 98* expeditions contained plentiful mpingo, and fell within strata 1. Clearly the site at Nangaro was not completely unsuitable for mpingo as it was observed in other areas of the site, outside of the sample plots, but its non-appearance in any of the plots suggests the density of mpingo there was very low.

Study sites in strata 1 were noticeably hillier than the others with only around 50% of plots flat, as compared to 80%+ in 3 of the other 4 sites, and substantially more plots with a medium to high angle of slope, but plot slope was not found to be a significant affecting mpingo presence in the other sites. The fact that far more of these slopes faced north is probably irrelevant, since 5 out of the 12 mpingo spotted on sloping sites were in north or north-east facing plots. A more likely explanation lies around differences in soil and geology or elevation. The Rondo plateau is probably too moist and cold for mpingo, despite it being within the reported altitudinal range for the species.

Other than the total absence in study sites in strata 1 little pattern can be deduced in the distribution of mpingo. Mpingo were found to be more prevalent in plots where canopy cover was between 26% and 75%, which reflects mpingo's designation as a woodland species. However other Mpingo Conservation Project expeditions have observed plentiful mpingo in relatively open areas (Ball *pers. obs.*), and so this may indicate preference in marginal habitats which is not reflected in the density of mpingo in core areas. A similar argument may account for the lack of morphological fit with the height v girth ratio observed by the *Tanzanian Mpingo 98* expedition, and the fact that the average canopy area per tree was larger while other measures of tree size were smaller than at Migeregere.

While the scattered mpingo found by this expedition were more prone to have two or more stems than those in the mpingo rich habitat at Migeregere, the data is less clear cut when considering the variation in average number of stems per tree. One possible explanation is that trees are more likely to have multiple stems in poorer conditions. This is not contradicted by the findings of the *Tanzanian Mpingo 96* expedition at Mchinga since although that site had plentiful mpingo few were large enough for harvesting (Ball *et al.* 1998). In the absence of fire or herbivory damage, the leading stem will exert apical dominance as per Chidumayo (1997, p. 68-9), i.e. it will suppress the growth of other, later stems which will not grow larger than 3-5cm CBH. Conversely in less suitable habitat, the leading stem is repeatedly damaged, and struggles to exert apical dominance, allowing additional stems to keep pace. When the tree experiences respite from these adverse factors, all the stems mature together.

Fire is likely to be one major determinant of the length of time to reach pole-size (at which point the stem might be considered safe from fire), and the above explanation therefore fits with the relationship noted by Gregory *et al.* (1999) that trees in burnt plots were more likely to have one or more stems. This finding is flatly contradicted by the smaller but more wide-spread data set collected by this expedition. However burnt plots are only a proxy for past frequency of fires, and the above noted limitations of this approach across multiple sites apply.[27]

The relationship established between basal circumference is useful but needs further refinement for larger size trees which were almost completely absent from the data set. The present model is based primarily on trees with a basal circumference of 0.6m or less, and is probably not safe at all for trees with a basal circumference over about 1.4m. However once refined the model should allow for a much better estimation of harvested volumes from stump surveys.

The variation in termite infestation is roughly consistent with that observed by the previous expeditions. Riverine plots appeared to have a lower infestation rate than other plot types, although the subjective nature of the index prohibits serious analysis. Specific targeted research is needed to identify whether termites have any particular affinity for mpingo, or whether there is a high rate of infestation

[27] For example 47% of adult mpingo at the highly disturbed, but less burned site at Mkoka were multi-stemmed compared to 40% overall, although this difference is not significant.

on many tree species in the region. Such research should also consider any possible causal mechanisms; do termites come to mpingo trees or does mpingo grow well on termite mounds?

The difference in scorch mark frequency can partly be explained when one considers that the *Tanzanian Mpingo 98* expedition found the majority of such scorch marks in burnt plots which made up over 33% of plots, while only 27% of plots in strata 2 and 3 were burned, and less than 25% of mpingo recorded were observed in a burnt plot, suggesting that fires were less severe in these areas than at Migeregere.[28]

While the *Tanzanian Mpingo 98* expedition found adult mpingo in plots with a greater frequency than juveniles, this expedition found a healthier situation with juveniles occurring more frequently than adults. The lack of correlation between presence of mpingo adults and juveniles could suggest that sexual reproduction plays an important part in the spread of mpingo. However such explanations must be qualified by the many observations of mpingo clearly regenerating from old root stock with no adult mpingo apparent in the proximity (Ball *pers. obs.*).

The absence of juvenile mpingo in burned plots with low canopy cover (see Figure 11) may be a result of more complete fire penetration where the canopy is almost open, while some areas with higher canopy cover may escape burning when a fire passes through due to the denser, less-combustible green vegetation and reduced air supply. However one must remember that the while the above-ground part of a seedling may have been burnt away, healthy root stock may remain underground, and so these conclusions relate only to the above-ground shoots.

The absence of juvenile mpingo from closed canopy ground-water forest is consistent with the study site delimitation adopted by the *Tanzanian Mpingo 98* expedition (Gregory *et al.* 1999), while smaller ephemeral water courses provide an improved habitat for regeneration (c.f. Rodgers 1982 & Nshubemuki 1993) owing to the increased availability of water or soil erosion disturbing existing root stock and leading to reproduction by sucker. The significance of canopy height as a determinant factor in juvenile presence is cannot be explained by suggesting canopy height as a proxy factor for climax forest as Table 3 indicates no such relationship exists. Instead it is probably related to the aversion for large size dominant trees (especially *Brachystegia spp.* and *Julbernardia globiflora*) noted by Gregory *et al.* (1999). That is to say that mpingo seedlings are relatively shade intolerant, or have higher water requirements, compared to seedlings of other species in the areas surveyed, and cannot regenerate close to a large competing tree. The lack of agreement with Ball's finding (2004) that mpingo juveniles were more prevalent when local canopy cover in a 5m radius was 40% or less reinforces the qualification that Gregory *et al.* (1999) voiced about that result, and suggests that might have been an artefact of the *Tanzanian Mpingo 98* data, or alternatively another case of the difference between ideal and marginal habitat. Further investigation is clearly required to decide this issue.

Harvestable Timber

The most significant and obvious difference between the data collected by this expedition and that of 1998 is the relative paucity of mpingo encountered[29], and the even greater lack of harvestable mpingo. An overall density of $0.0075 m^3 ha^{-1}$ of harvestable timber means that for all intents and purposes all six of the study sites surveyed by this expedition can be considered to have negligible commercial stocks. That is to say no logger is likely to attempt to harvest any of the sites as they need a relatively high density to justify expenditure on fixed overheads.

Gregory *et al.* (1999) attempted to evaluate the sustainability of harvesting in Nachingwea district based on their findings at Migeregere. Two important factors requiring estimation were the total forest cover for the district, and the extent to which the data at Migeregere could be considered un-representative due to the deliberate selection of the mpingo-rich area surveyed there. Gregory *et al.* estimated the combined effect of these two factors to range from 6% to 20%, i.e. they should multiply

[28] Although a word of caution should be voiced about this conclusion, as the *Tanzanian Mpingo 98* expedition deliberately stratified their sampling to obtain equal numbers of plot types. In reality some data was subsequently lost, thus increasing the actual proportion of burnt plots.
[29] Although it is still 10 times the 14 trees per km² reported by Hawkins *et al.* (1996) in Mikumi National Park.

their estimates for mpingo abundance at Migeregere by an amount somewhere between these two ratios when determining the likely sustainability of harvesting in Nachingwea district.

If we consider that the site at Migeregere, together with the 6 randomly selected sites surveyed by this expedition, and an additional putative study site at Nachingwea town (the methodology for this expedition deliberately excluded build up areas), then we could conclude that at most only one site in 8 has harvestable mpingo at the levels similar to those recorded by the *Tanzanian Mpingo 98* expedition, and thus the most appropriate combined factor should thus be no more than 12.5%. If we plug this into the original calculation advanced by Gregory *et al.* (1999) we can refine their estimate to somewhere between at most 20 and 110 years stocks remaining. Thus the other factors such as prevalence of brown mpingo, the effect of fire and heart-rot on harvestability and the proportion of trees which are growing in unharvestable locations are all crucial to determining the sustainability of the harvest along with the important ratio of legal to illegal felling. More research is needed to elucidate these varying factors.

In the meantime we are left with the experts' consensus which partly drove the formation of this expedition in the first place: that mpingo harvesting is probably not sustainable at present, and almost certainly will not be sustainable now the new bridge over the River Rufiji is completed, and the region is opened to large-scale logging (MCP 2000).

Appendix I : The Teams

Expedition Director

Steve Ball

Team A

Al Greer (leader), Canisius Kayombo (co-leader, lead taxonomist), Dan Lashley, Abdon Mapunda, Frank Mawi, Jeremy Pickles, Phil Whitby

Team B

Ben Please (leader), Wendy Foden (co-leader, lead taxonomist), Riziki Shemdoe (co-leader), Hassan Chinole, Daniel Minja, Keri Page, Anthony Sangeda, Raechel Slattery, Ewan Wallis

Team C

Jon Goh (leader), Iddi Mwanyoka (co-leader), Moira Herring, Jess Hrivnak, Musa Mpandula, John Ndonde, Fortunate Senya, Kinyemi Sepeku, Maria Sheridan

Drivers

Paskal Ngonyani, Ibrahim Durban, Hasani Saidi

Game Scouts

Patrick Matthew, Abdullah Mandale, Hassani, Mtila, Simba, Habibu, Mewile, Said Ngabyela, Chande Ligeni, Abdalah Njambe, Mussa Omari

Taxonomic Compilation

Canisius Kayombo & Wendy Foden

Data Entry and Cross-checking

Darren Norris

Proof-reading and Constructive Criticisms

Anne-Marie Gregory

Local Foresters

The final goal is, of course, a regional management plan for mpingo and this will require a complete inventory of mpingo in any area covered by the plan. To prepare for this *Mpingo Survey 2000* helped build institutional capacity by including in each team at least one local forester, either from the Regional or District office. Specifically it was hoped this would achieve the following:

- Increase enthusiasm for mpingo amongst demoralised local foresters.
- Effect a skills transfer so that they can train others and continue the work after the end of the expedition.
- Generally foster better contacts and co-operation at the District level.

Appendix II : Accounts

Income

We would like to thank all our sponsors listed below for their generous support of the expedition.

Received	£
Mpingo Conservation Project Reserves	5,770.54
Personal Contributions	8,258.60
Panton Trust	4,000.00
Royal Geographical Society	1,750.00
Cambridge Commonwealth Travel Bursaries	6,000.00
Mary Euphrasia Mosely Trust	800.00
Kleinwort Benson Charitable Trust	500.00
Bartle Frere Trust	350.00
Trinity Hall College	250.00
Magdalene College	250.00
Gibbs Charitable Trust	200.00
Ferguson Charitable Trust	200.00
Fauna & Flora International	200.00
Girton College	150.00
A.S. Butler Charitable Trust	100.00
Bude Lions Club	100.00
Other	204.50
TOTAL	**29,083.64**

We must also thank BP Tanzania for their donation of free fuel to the expedition.

Outgoings

Due to loss of records in the field some of the figures below are estimates. Figures in pounds sterling calculated at a standard exchange rate of GBP £1 = TSh 1,200/- which was roughly prevailing at the time. Where this exchange rate was not achieved the difference is recorded as an exchange rate loss.

Pre-expedition Expenditure	£
Flights	6,315.00
Insurance	918.40
Medical	2,331.95
Visas	490.00
Research Permits	2,903.53
Tents	960.00
Field Equipment	70.45
Photography	200.00
Brochures	81.00
Administration	351.53
Financial	180.00
TOTAL	**14,801.86**

Field Expenditure	**£**
Equipment	299.96
Maps	110.00
Accommodation	1,026.76
Provisions	1,588.44
Public Transport	445.42
Vehicle Hire	2,031.68
Diesel/Petrol & Oil	1,721.57
Counterpart Wages	3,032.13
Driver & Game Guard Wages	1,872.24
Local Labour	1,242.45
Other	97.30
Currency Exchange Losses	486.93
TOTAL	**13,954.88**

Post-Expedition Expenses	**326.90**

GRAND TOTAL EXPENDITURE	**29,083.64**

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