Assessing and Restoring Biodiversity in Tanzania's Forests: The Case of Magombera

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Abstract

As in much of the tropics, most of the forest in Tanzania is heavily degraded. Forest degradation and loss has implications for species loss, climate change, hydrology, nutrient cycling and natural resources. Magombera forest is a threatened area of tropical lowland forest, long recognised for its biodiversity value. The aim of this paper is to synthesise results of ecological surveys presented in a recent report for the WWF Tanzania Programme Office, to provide impetus for the improved management of Magombera forest. An integrative conservation and monitoring strategy is also introduced that may be applicable across Tanzania for improving conservation management. From the literature and surveys presented, the biodiversity value of Magombera forest is highlighted. The large trees include 17 IUCN Red-List or potential Red-List species and 10 species limited to the forests of East Africa. An astounding 41.2 % of stems ≥ 20 cm diameter are within these two categories. The results also found the highest encounter rate of Udzungwa red colobus anywhere. The forest is also an important dry season refuge for elephants and is one of only two known localities of the chameleon *Kinyongia* sp. nov. (soon to be named after Magombera forest). Despite its conservation importance, our survey found a number of threats. The structure is typical of a forest that has undergone understorey disturbance and pole-cutting has affected the rare species composition. The mammal community has been notably impacted by hunting and there are very few medium-sized terrestrial mammals. The Udzungwa red colobus is the most vulnerable monkey to structural damage. From our surveys we suggest that the threats to Magombera forest should be prioritised as follows: 1) Pole cutting; 2) Bushfire; 3) Firewood collection; 4) Timber felling, 5) Hunting. In summary, Magombera provides an excellent opportunity for Tanzania to demonstrate its ability to manage an area of high conservation value. There are many recommendations for improving village livelihoods, protection of the forest and monitoring. Following presentation of these findings at the TAWIRI conference, project recommendations were presented to local villages. All villages made signed agreements to the proposals, including annexation into the Selous Game Reserve.

Introduction

Tropical Forests

Habitat degradation and loss are the greatest threats to terrestrial species (Baillie et al. 2004). Estimates of annual loss of tropical forest range from 8.7 to 12.5 M ha (Chapman & Peres 2001; Mayaux et al. 2005). An area between half and equal size to this is degraded by selective logging each year (Achard et al. 2002; Asner et al. 2005). Loss and degradation of tropical forests are a global concern as more than half of the world's species are found in tropical forests, despite covering only 7 % of the world's surface (WRI 1992). Subsequently, the number of species threatened with extinction in tropical forests is predicted to increase (Whitmore & Sayer 1992). Tropical forest loss and degradation also have implications for climate change, hydrology, nutrient cycling, and natural resource availability (Whitmore 1998). Restoring degraded forests may therefore be one of greatest challenges for ecologists this century (Duncan & Chapman 2003). In Tanzania, most forests have been heavily degraded by human activity and there has been no active management to restore forest health. For example an estimated 63 % the Udzungwa mountains of southern Tanzania has been heavily degraded (Marshall 2007; Marshall et al. in preparation). This statistic particularly striking given that this mountain range is of the least degraded in Tanzania.

Magombera

Magombera forest lies around 270 m above sea level, near to the villages of Katurukila, Magombera, Kanyenja and Msolwa Stesheni in Kilombero district (Morogoro region; Figures 1 and 4). This special forest is sandwiched between two of Tanzania's most impressive protected areas; the Udzungwa Mountains National Park to the west is one of the world's most important areas for the conservation of biodiversity and the Selous Game Reserve to the east is Africa's largest protected area. Lowland tropical forest such as that found in Magombera, is among the world's most threatened habitats (Collins 1990; Vieira & Scariot 2006). The habitat of Magombera has affinities to the lowland and montane forests of the nearby Udzungwa Mountains and the coastal forests of Tanzania and Kenya. This may in part be due to the mixed soil which includes both alluvial deposits from the Udzungwa Mountains and Karoo sandstone from the Msolwa floodplain (Rodgers et al. 1979). The habitat is unique from other areas of coastal and riverine forest found in the adjacent Selous Game Reserve (Vollesen 1980). Annual rainfall is estimated at 1514 mm and parts of the forest are seasonally flooded (Rodgers et al. 1979).

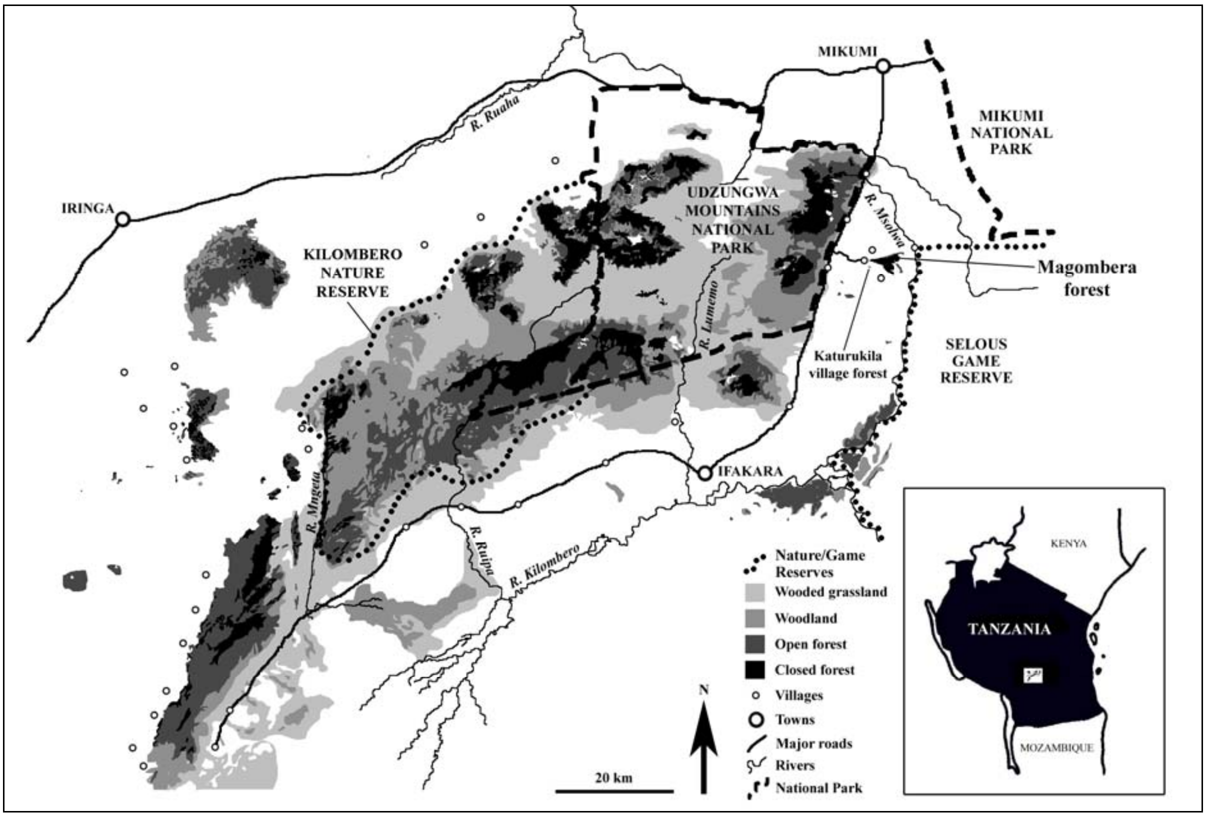

Figure 1. Habitat map of the Udzungwa Mountains showing location of Magombera forest and Katurukila village forest (adapted from Marshall 2007).

The conservation value of Magombera forest was first highlighted through the presence of the endangered Udzungwa red colobus monkey (*Procolobus gordonorum*; Rees 1964; IUCN 1977 in Rodgers et al. 1979). Ecological and behavioural observations made in 1977 then led to recommendations for a revised taxonomy of the species (Struhsaker & Leland 1980). In fact Magombera was then considered the largest and only viable population of this species (Rodgers et al. 1979; Rodgers & Homewood 1981). Later surveys in the Udzungwa Mountains revealed that the overall range and population of this rare species is greater than first thought (Rodgers & Homewood 1982; Decker 1994 and 1996; Dinesen et al. 2001; Struhsaker et al. 2004; Marshall 2007; Marshall et al. submitted; Marshall et al. in preparation). However Magombera forest continues to be an important stronghold for this rare monkey, which is restricted to the area around the Udzungwa Mountains. The species remains Vulnerable the IUCN Red List (Baillie et al. 2004), CITES Appendix 2 and Class A in the Africa Convention. It is also "Presidential Game" in Tanzania, meaning that it is illegal to hunt.

Magombera forest is also of enormous value for rare trees, biodiversity and water catchment, as we outline in this report. Three collecting trips in the 1970s led to a check-list of vascular plants for Magombera forest and the Selous Game Reserve, including several new species (Vollesen 1980). From this, Magombera forest was thought to contain close to 500 plant species including three potentially endemic trees. Decker (1994) also highlights the presence of montane birds at unusually low elevation and Rodgers et al. (1979) list a potentially endemic frog *Hyperolius* sp. nov. (from respective personal communications with Schiotz and Stuart). Other than the short vegetation survey already mentioned (Rodgers et al. 1979), prior to this report there had been no systematic survey in Magombera forest of any taxa besides monkeys. Furthermore, previous studies were mainly biased towards the easily accessible area near the TAZARA railroad.

A timeline of the conservation history of Magombera can be found in full in the ecological report for WWF Tanzania Programme Office (Marshall 2008; Marshall & Mtoka 2008). The forest was gazetted as a Forest Reserve in 1955, when the forest area was 15.05 km^2 (Rodgers et sl. 1979). The first major threat to the forest came in the 1960s, when the TAZARA railroad was built through the middle, including clearance of over 50 ha of forest and extraction of all marketable timber (Rodgers et al. 1979). In 1979 a ten day ecological survey and report summarised the importance of the forest and showed that the forest habitat was continuous with the Udzungwa Mountains (Rodgers et al. 1979; Figure 2a). Forest area at Magombera was approximately 10-11 km^2.

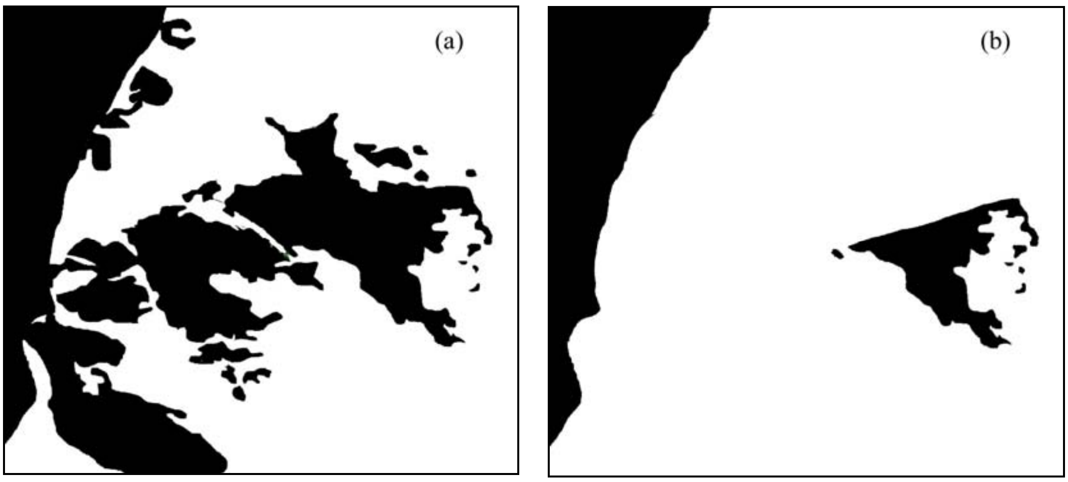

Figure 2. Forest cover (black) and open habitat (white) in the Magombera area in (a) 1979 (Rodgers et al. 1979) and (b) 2004 (Marshall 2005). The large area of forest on the left of both figures is the beginning of the Udzungwa Mountains. Open habitats are mostly sugar plantation and settlements.

In 1979 the Fourth East Africa Wildlife Symposium recommended immediate upgrading of conservation status (Rodgers & Homewood 1979). Subsequently all management authorities agreed that the southern area of Magombera forest should be annexed into the Selous Game Reserve (Baldus 1992; Hoffman 1995). However the result was that local villagers began clear-felling a 5 km^2 area of Magombera forest north of the TAZARA railroad, eventually forming the village of Magombera. In 1981, the Forest Reserve status was revoked (Holmes 1995) to enable annexation into the Selous Game Reserve. However in 1992, it was realised that annexation to the Selous Game Reserve was never fomalised and that the Kilombero Sugar Company (KSC) had purchased some of the area for wood cutting and small holder production (Baldus 1992; Decker 1994). The sugar company soon agreed to set aside the area for conservation, however later threats to relocate squatters into the forest (Jones and Rovero personal communication 2002) again highlighted the vulnerability of the forest. Once again this resulted in a highly publicised campaign to protect the forest, including an agreement from the

Honourable Minister for Natural Resources and Tourism agreed that "… Magombera forest will remain as a Nature Reserve…" (Meghji 2002). Following this, extensive survey of monkeys and large trees in Magombera revealed that the forest was still threatened, particularly by pole-cutting and fire (Marshall 2005 & 2007; this report).

Finally a proposal by WWF-TPO and Andy Marshall for funds to initiate baseline monitoring and facilitate annexation to the Selous Game Reserve was accepted by the Critical Ecosystem Partnership Fund. At the time of writing, from Landsat imagery, the remaining forest area is 10.34 km^2 and completely isolated from the nearest forest fragment in the Udzungwa Mountains (Figures 2b and 3; Landsat ETM+; Global Land Cover Facility/U.S. Geological Survey; Oct 25th and Nov 1st 1999; Paths 167-8; Rows 65-6). This forest size south of the rail has likely been relatively stable since clearance of the northern area began in 1980. However the status of the remaining forest was unknown until the current survey. Furthermore, land survey by WWF-TPO found that the Illovo Sugar (formerly KSC) own 61.5 % of the land proposed for annexation. They have agreed to lease the land for conservation management, however compensation for the loss of land is required (Dave Coates pers. comm.).

Importance of Monitoring

Monitoring of the state of forest health over time allows managers to determine how successful their forests are being conserved, and therefore to guide future planning and develop local education. Monitoring is vital to ensure successful conservation of habitats (Sutherland 2000). However, only a very low proportion of protected areas in Africa have long-term monitoring programmes (Struhsaker et al 2005). Fully quantifying the effects of management practices on a forest ecosystem would require painstaking work, due to the massive number of species involved. However basic criteria for assessing ecosystem health and habitat composition/structure are rarely determined (Balmford et al. 2003). Selection of key species as "indicators", "guilds", or "functional types", can assist in making more rapid assessments (Skorupa 1986 & 1988; Landres et al. 1988; Gondard et al. 2003). Monitoring rare species is also of importance to determine habitat requirements for management.

Aim and Objectives

With increasing research in the past ten years, we now have far more reliable information on the ecology of Magombera forest in relation to other forests in Tanzania. The aim of this paper is to provide impetus for the improved management and ecological monitoring of Magombera forest. The content is a synthesis of a recent report for the WWF Tanzania Programme Office (Marshall 2008; Marshall & Mtoka 2008). There are seven main objectives that we address using both new and published data:

1) To introduce methods and results of two ecological surveys;
2) To determine the ecological importance of Magombera forest;
3) To prioritise threats;
4) To assess forest health;
5) To assess the status of selected rare and indicator species;
6) To test methods for forest restoration;
7) To make recommendations for future management, village livelihoods and monitoring.

Methods

The methods have been designed to allow a broad overview of the ecological importance of Magombera forest. A complete inventory of all flora and fauna would have been impractical and unnecessary at this stage. Instead the survey covered the four major issues of (i) threats, (ii) structure, (iii) key species, and (iv) restoration. Assessing the level and types of human threat to the forest is of obvious importance for determining management activities, both in the forest and surrounding villages. Not least because unauthorised activities that damage forests are illegal under Tanzanian law, regardless of protected status. Assessment of forest structure is important for determining forest health.

Key animal and plant species were selected for special attention for various reasons. In particular, trees were selected as they are the physical structure of the forest, including the bulk of the biomass, and the major target for illegal activities. Monkeys were chosen as they can be indicators of disturbance and key dispersers of seeds. They are also of special interest in Magombera forest due to their high density, particularly the rare Udzungwa red colobus. They are also relatively easy to observe and important flagship species for conservation. Duikers were chosen as an indicator of hunting pressure. Finally given the huge need for restoring forests throughout the tropics, the methods also include experimental plots to determine the effect of removing restricting climbers for encouraging tree growth.

Surveys were carried out primarily along two 4 km transects (Mtalawanda and Ngulumilo; Figure 3), during two sampling periods. Transects consisted of narrow paths marked with numbered tags at 50 m intervals. The 4 km length was chosen for consistency with ongoing research in the adjacent Udzungwa Mountains. Transect routes were decided from government topographic maps to best fit inside the forest habitat and were spaced 570 m apart to reduce the chance of monkey groups passing between the two areas. Care was taken to negotiate paths around trees rather than cutting them. To further minimise impact on the forest, elephant / human paths were followed whenever these co-incided approximately with the pre-determined routes. Andy Marshall established the two transects, surveyed large trees, monkey density, colobus monkey group size and duiker abundance between 2003 and 2005. In 2007, Marshall again co-ordinated surveys of trees, monkeys and duikers, as well as threats and forest restoration. The 2007 data were collected primarily by villagers Hamidu Mlendendo and Exaud Kivambe (March 2007 to December 2007) and local co-ordinators John Msirikale (March to June 2007) and Samuel Mtoka (November to December 2007). All data collectors were trained by Andy Marshall. Published sources are also used to supplement the data collected.

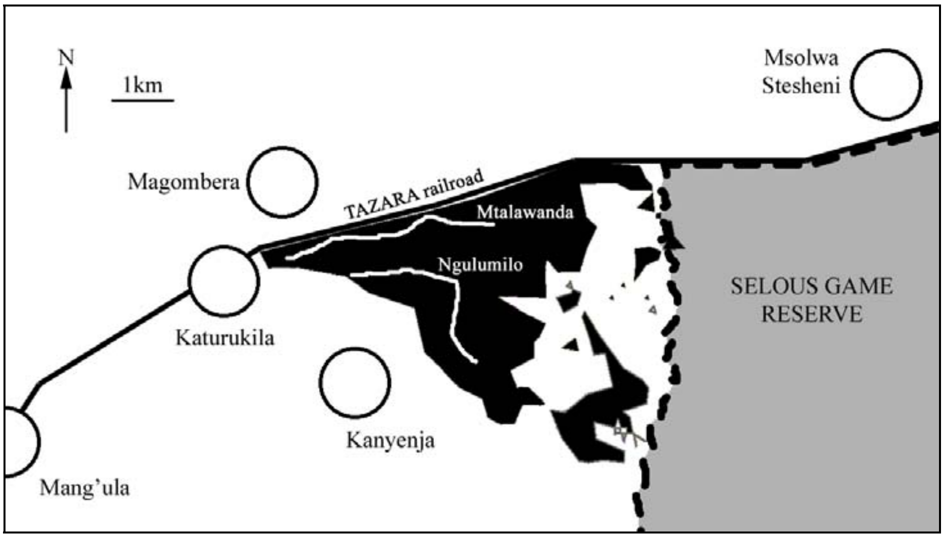

Figure 3. Position of monitoring transects (white lines) in Magombera forest (black blocks), including adjacent villages (circles) and TAZARA railroad (black line).

Threats

Human threats to Magombera forest were surveyed using two methods. The principle method was using 100 m by 20 m plots, within which all signs of human impact were enumerated on standardised datasheets. Forty such plots were placed, spaced 100 m apart along the two transects (20 on each transect beginning at the 0 m tag) between March and May 2007. An additional 40 plots were also placed 100 m away from alternate 100 m tags on each transect (beginning at the 100 m tag) between August and September 2007. These were to determine whether the illegal activities are occurring away-from or close-to transects. To help relocation of these plots, they were all placed on a simple bearing from each marker (Mtalawanda: south; Ngulumilo 0-1900: north; Ngulumilo 2100-3900: east).

In each plot, we recorded the number of pole-sized trees ("poles"; stems above 5 cm but below 15 cm diameter at breast height [dbh; 1.30 m]), divided into three categories: Live; Cut <1 yr (cut less than 1 year before survey); Cut >1 yr (cut more than 1 year before survey). We also recorded the number of timber-sized trees ("timber"; stems 15 cm dbh or greater), divided into the same three categories as poles. Signs of human disturbance were also counted including sawing tressles or pits, sounds of cutting, signs of firewood collection, snares. The presence/absence of bushfire, human tracks and human/elephant paths was also noted.

In addition to these plots, casual walks were also made throughout the area towards the end of 2007, primarily along paths not related to our transects. These were carried out as it was clear that people in the area often use these paths when accessing the forest. Thus there was an increased chance that damaging activities would be detected. GPS co-ordinates were taken during all of these casual walks.

Forest Structure

Forest structure was assessed along the entire length of the two transects between February 2004 and April 2005. Within 2.5 m either side of the transects, all trees 10 cm dbh or greater were measured for dbh (cm; using a girthing tape), height (m; using a laser range-finder), distance from the centre of the transect (m; using a tape measure) and distance along the transect (m; estimated by pacing). Stems were then re-measured in 2007, noting whether they were still alive, or whether they had died or had been cut or damaged since the first survey.

Key Species

i. Trees

Survey of trees was based on the same stems as the forest structure plots. To allow for better analysis of larger trees, stems of dbh 20 cm or more were also identified and measured within 5 m either side of each transect. All trees were identified in the field where possible during fieldwork in 2004/5. Where this was not possible, specimens were collected and dried for later identification at the Royal Botanic Gardens, Kew, with the assistance of Kaj Vollesen. To investigate the conservation importance of Magombera forest, we were particularly interested in those species that are rare globally, or of restricted range. "Rare species" were therefore classed as those included or proposed for inclusion on the IUCN Red-List, or known only from the Eastern Arc and Coastal Forests of Tanzania, Kenya and Mozambique (Gereau & Luke 2003; Baillie et al. 2004; Lovett et al. 2006; Roy Gereau personal communication).

ii. Monkeys

Three monkey species are permanent residents of Magombera forest (Udzungwa red colobus, Angolan black and white colobus *Colobus angolensis palliatus* and Sykes monkey *Cercopithecus mitis*), with vervet monkeys (*Cercopithecus aethiops*) also occasionally found at forest edge. Monkeys were surveyed along both transects between February 2004 and March 2005, and again between March and September 2007. Beginning between 0700 h and 0730 h, an observer walked at 1 km per hour, recording all signs of monkeys. When monkey groups were encountered, the observer spent a maximum of 10 min noting several details on a standardised form. Firstly the observer recorded the time, distance along the transect and the horizontal distance and compass bearing to the first individual seen of each species per group (using a laser range-finder to measure distances). Where the horizontal distance could not be measured directly, the direct distance from the observer to the animal was recorded, along with the slope upwards using a clinometer. Basic trigonometry was then used to calculate horizontal distance. Where possible, the perpendicular distance to the first individual was measured. Where this was not possible, it was calculated using the horizontal distance, bearing and transect GPS location.

Other data recorded for each observation included the species of monkey present in each group, or in adjacent trees to each group. The mode of detection of each species was also noted, and also whether the species was physically seen, or just heard moving or vocalising. Once the observer had recorded all details and was certain that no other species were present, the finish time was noted and the walk continued.

From transect counts made in the 2004/5 surveys, monkey density was estimated using a strip transect method (Whitesides et al. 1988; Marshall et al. 2007). Histograms of distance versus number of visual observations were plotted using a range of bar widths. Visual inspection of the histograms was then made to determine a cut-off distance at which the observations made a sharp and sustained decline (red colobus 27 m, black and white colobus 22 m and Sykes monkeys 41 m). Transect width was then calculated as the sum of the cut-off distance and estimated mean group spread of the three monkey species, multiplied by two as observations were made on both sides of the transect (Whitesides et al. 1988). Use of group spread to adjust cut-off distances is contentious, and therefore estimates of group spread were deliberately high to avoid over-estimation of density and population size. Red colobus mean group spread was estimated as 30 m, black and white colobus 20 m and Sykes monkeys 50 m.

Density per km^2 was then calculated separately for heavily degraded (i.e. no continuous canopy) and less degraded sections of the transects, using transect length (km) × width (km) × mean number of groups per transect walk within the cut-off distance. Density was calculated separately for heavily degraded areas to ensure that the final estimate allows for the proportion of habitat. Counts of group size in the same areas in 2004/5, mostly made independently of transect counts, were then used to calculate a mean group size. This was used to convert the group density figure to individual density for each transect walk in both heavily degraded and less degraded areas. This figure was then extrapolated to the total estimated area of Magombera forest to give an estimate of population. In making this extrapolation it was estimated that 40 % of Magombera forest is heavily degraded. Again this estimate is on the high side, to avoid overestimation. Density and population were not calculated for the 2007 survey because we had no information on group size and spread. Collecting data on these measurements is very time consuming. Instead we use the encounter rate (groups seen per kilometre transect walked) to compare relative abundance between the two sampling periods.

Methods for estimating density of group-living animals such as monkeys are contentious (Marshall et al. 2007). Wherever possible during the 2007 survey, the locations of all individuals in each group seen before reacting to observer presence were recorded, as for the first individual. This was to allow for later experimentation with methods for density estimation using the centre of individuals seen (Plumptre & Cox 2006; Marshall 2007; Marshall et al. 2007). However, observers new to using the technical equipment found this difficult and so was not deemed a feasible method at the current time.

iii. Duikers

Red duiker (*Cephalophus natalensis harveyi*), suni (*Neotragus moschatus*) and bushbuck (*Tragelaphus scriptus*) are all known to be present in Magombera forest. During primate transect counts, all observations of small antelope were also recorded in the same way as primates. Because of low sample size, we did not calculate density or population of duikers. Therefore as for primates, we use the basic encounter rate as our figure of comparison.

iv. Other Taxa

While conducting all surveys we also recorded signs of other animals whenever encountered. However no systematic surveys were carried out beyond the trees, monkeys and duikers.

Forest Restoration

Plots for investigating forest restoration were placed near to the Ngulumilo transect. This site was chosen over Mtalawanda to avoid the area nearest the villages, and therefore reduce the chance of theft/damage. A total of 29 plots were placed 100 m from the transect on a known compass bearing. Plots were 5 × 5 m, with trenches 15 cm deep dug at each corner to assist re-locating plots. Small marks of paint were also made on trees around each plot to assist relocation. Eleven of the plots were placed in areas with a dense cover of restricting climbers, which were subsequently cleared using secateurs (hand-held plant pruners) and machetes (pangas). Protective clothing was worn over hands and arms to avoid skin irritation from plant hairs. Eight of the plots were placed in areas with a dense cover of restricting climbers, which were not cleared. As a control, a further ten plots were placed in areas where restricting climbers were not present (or in very low density) to begin with.

Plots were established between July and September 2007. Within each plot, all tree stems 1 cm dbh or greater were identified and measured at 1.3 m from the ground. Fluorescent tape was tied to each stem, each with a unique number written on the tag in permanent ink. Saplings below 1 cm dbh were also identified and counted, but were not measured. Plots were then re-measured in November 2007, with the intention that re-measurement will then continue into the future at three month intervals. Plots will also be visited periodically to ensure that restricting climbers have not re-grown in plots that were cleared. During the dry season, regeneration was minimal, however during the wet season we expect that two visits will be required to cut-back climbers. Thus we expect that only two or three visits per year will be enough prevent restricting climbers from regenerating.

Wherever possible, data are presented as mean plus or minus (±) a 95 % confidence limit. This is a standard measure of mathematical error calculated as (1.96 × standard deviation) / √(number of samples). Where the 95 % confidence limits of two samples do not overlap, the difference between the two samples can be considered statistically significant.

Results and Discussion

Threats

The biggest threat to Magombera forest is the cutting of poles (trees 5-15 cm dbh) for tool handles and building. There is no clear species or site bias for pole-cutting, however the rate is alarming, with a visible effect on the understorey. Cutting is occurring both on and away from research transects. There are more live stems available away from transects than close to transects, however a similar proportion of stems is removed each year (Figure 4a). Most cutting occurs at weekends, presumably when villagers expect rangers to be absent from the area. Similarly there were reports from villagers that some people enter the forest at night, or when researchers are not present.

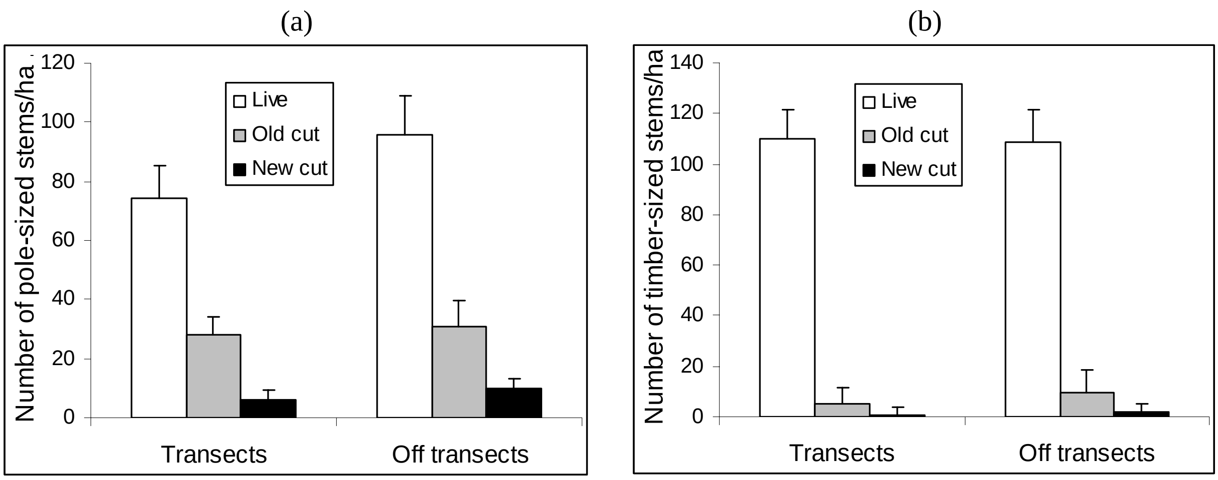

Figure 4. Number of live, old cut (over 1 year) and new cut (within one year) pole-sized (a; 5 to 15 cm diameter) and timber-sized (b; above 15 cm) trees per hectare in eighty 100 m × 10 m plots. Data are presented separately for plots on and away from transects.

If the current rate of pole-cutting continues without increasing (9.4 % of standing stock per year), the forest understorey will be gone within 11 years (Figure 5). In 2007, 4.4 % of villagers in the area were dependent on Magombera forest for poles (Harrison & Laizer 2007). However resources outside of Magombera forest have now been depleted to critical levels (personal observation; Harrison & Laizer 2007). Given this depletion, the 7.0 % of villagers that were dependent on these resources (Harrison & Laizer 2007) will be forced to use Magombera forest and the rate of removal will increase by 2.6 times. This more likely scenario would mean that pole-sized stems will be completely removed within four years (Figure 5). More importantly, even now, the absence of regenerating stems in most of Magombera means that the regenerating stock is too sparse to replace canopy trees when they die.

Two of the most common canopy tree species remaining in Magombera are used as timber elsewhere in the region (*Isoberlinia scheffleri* and *Erythrophleum suaveolens*). Therefore despite removal of the timber species of high market value (e.g. *Milicia excelsa* and *Khaya anthotheca*), the forest is not devoid of timber. Despite this, timber-felling was rare both on transects and away from transects (mean 1.1 per hectare per year; Figure 4b), with no particular species bias. However in October 2007, local assistants encountered a large group of people felling several trees about 1 km east of the Mtalawanda trail. These people were reportedly from Msolwa Stesheni village. Immediately upon encountering these people, rangers from the nearby Udzungwa Mountains National Park organised a joint patrol of Magombera forest with rangers from the Selous Game Reserve. Two people were arrested as a result and since that time illegal timber-felling in Magombera forest has ceased.

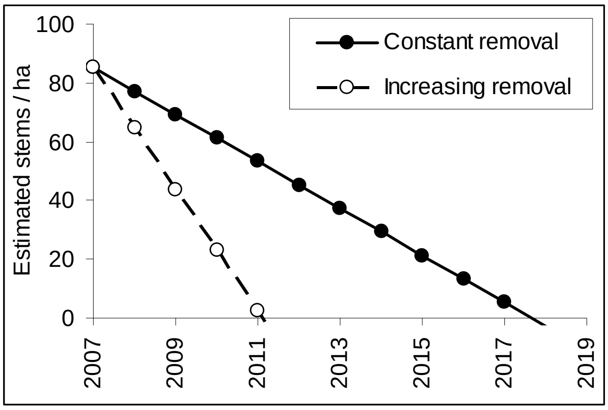

Figure 5. Estimated availability of pole-sized trees in Magombera with time. Extrapolations are shown using the current level of extraction (constant removal), and the more likely scenario of increasing removal, due to decreasing alternatives (see text).

Annual bushfires that spread from adjacent fields into the forest are also seriously threatening understorey regeneration. Together with pole-cutting, fire encourages the rapid colonisation of scrambling and herbaceous vegetation that is restricting the growth of regenerating trees. Out of the 80 forest threat assessment plots, 44 had signs of bushfire (55 %). The fires are hot and on rare occasions can even burn canopy trees.

Firewood collection was also widespread across the forest, and was seen in 49 out of 80 forest threat assessment plots (61.25 % of plots). Thirty of these plots were located away from transects, and only 19 on the transects, so the presence of transects has not encouraged increased access for firewood. The effect of firewood collection is to remove detritus (and therefore potential soil nutrients) from the forest floor. This has obvious importance for understorey plant growth, fungi and for soil and understorey detritivores such as millipedes and other invertebrates. It may also impact the small mammal community as seen in the adjacent Udzungwa Mountains (Kiondo unpublished data). These direct impacts on smaller animals have knock-on effects further up the food chain.

There was very little evidence of hunting during both the 2004/5 and 2007 surveys. Three snares set for duikers were found in the southern end of the forest during 2004/5. An entire skeleton (besides tusks) of one elephant was found along the Mtalawanda trail, however it is uncertain how this died. A group of fishermen was also once apprehended during the 2004/5 fieldwork. However no snares were seen in any of the forest threat assessment plots during 2007. Fishing continues in the seasonal streams and the nearby Msolwa river and there were occasional reports of poachers killing hippopotamus and elephants. A large animal snare was also found along the Mtalawanda trail during 2007 and colleagues found the remains of a snared buffalo along the same trail in 2005 (Tom Struhsaker personal communication). Overall hunting is not considered a major problem in Magombera forest. However the low level of hunting may in part be because most ground-living medium-sized mammals have already been over-hunted (see duiker survey results below). Importantly for the rare Udzungwa red colobus, the people of the area do not appear to hunt or eat monkeys. This is reflected in the behaviour of both colobus species, as most do not tend to flee far at the sight of humans, especially in the areas near to Katurukila village.

Other more minor activities also occur in the forest (e.g. cutting of grass for mats and herbal medicine collection), however these are considered of low priority for management planning. After completing the surveys, a more serious observation was the occurrence of charcoal collection, which can be extremely degrading. This however remains rare in Magombera forest.

Forest Structure

The forest structure in Magombera is typical of a forest that has undergone understorey disturbance. The impact is best seen when compared to less disturbed forest, so here we present a structural comparison with Isaula, Itula, Bwawani and Machumbo areas of Matundu forest (from similar elevation in lowland Udzungwa; Marshall unpublished data). The overall effect is that the mean size of stems in Magombera is significantly higher than in Matundu (Figure 6). A small increase is also seen from the Magombera survey made in 2004/5 to the Magombera survey in 2007.

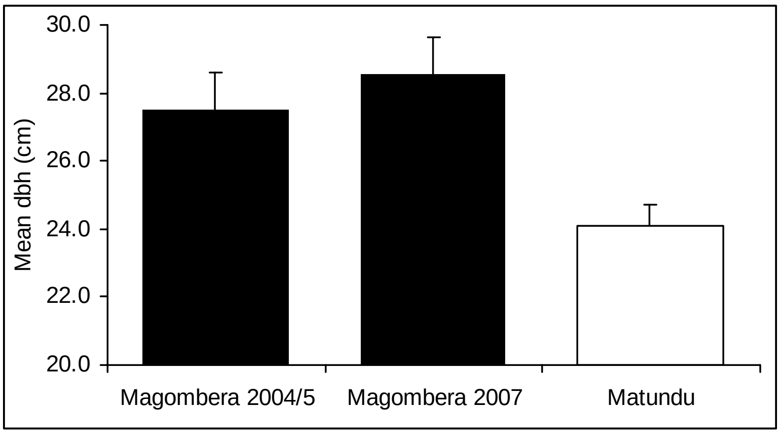

Figure 6. Increased mean dbh of trees 10 cm dbh or greater in Magombera forest (this study) versus Matundu (Marshall unpublished data) and in Magombera 2007 versus 2004/5 forest. The differences shown are due to removal of understorey trees for poles (see Figure 7).

Examining the structural composition further by dividing the stems into 5 cm classes reveals that the observed difference is due to removal of stems in the smallest size class (Figure 7). In the 2004/5 survey of Magombera there were 1,203 stems, of which 1,112 were remaining in the 2007 re-survey (300.8 and 278.0 per hectare respectively). This compares with 365.1 per hectare in the less disturbed transects of Matundu.

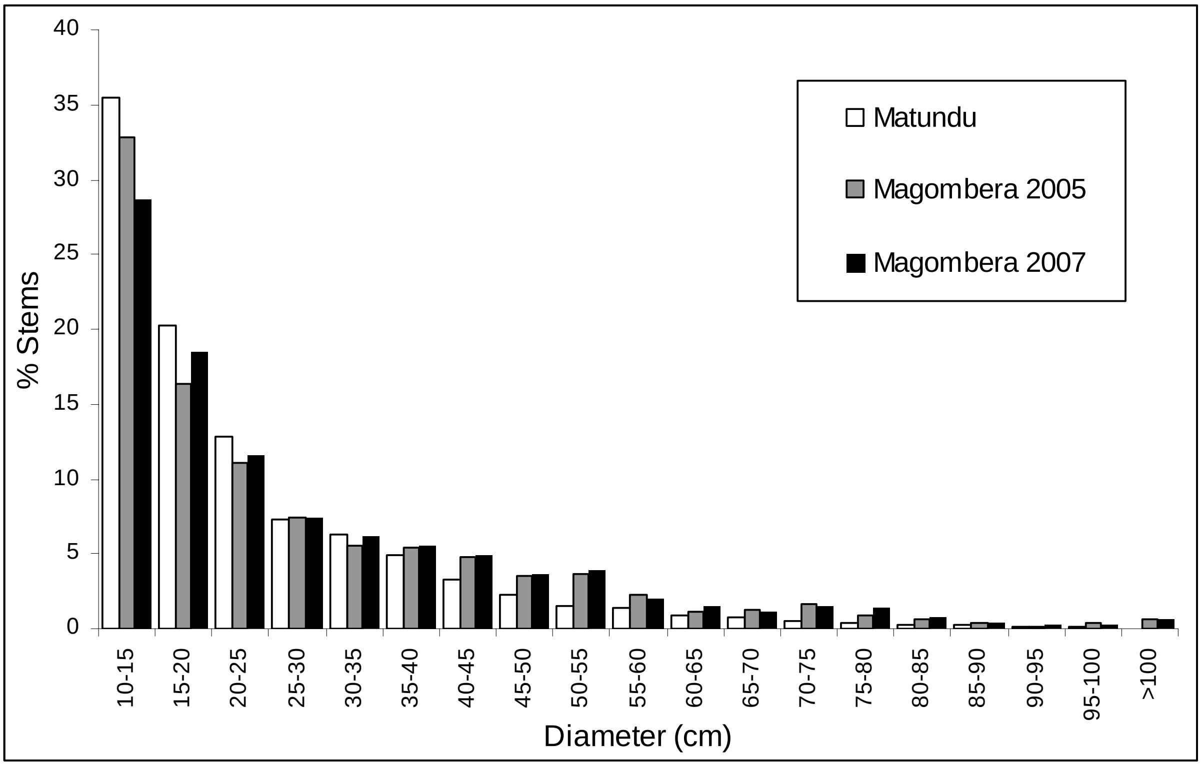

Figure 7. Size-class distribution of trees 10 cm or greater in Magombera forest (this study) versus Matundu forest (Marshall unpublished data). Note the decreasing proportion of stems in the lowest size class from Matundu to Magombera 2004/5 to Magombera 2007. This is due to removal of poles.

Key Species

i. Trees

Eighty-two species of tree greater than or equal to 10 cm dbh were found in the plots, with a further three species seen outside of plots (Appendix 1). The species list is likely to be a near-complete inventory of tree species that reach 10 cm dbh, however there may be a few additional species missed by the plots. Little attempt was made to search for additional species. The relative composition of the most abundant species (Table 1) was very similar to previously reported by Rodgers et al. (1979) and Vollesen (1980; Table 2). Notably, there are no records of any full-sized *Khaya anthotheca* or *Milicia excelsa* trees remaining in Magombera forest, although there is some sparse regeneration. Vollesen's (1980) list of common species (Table 2) also includes the shrub layer, for which there are no new data.

Despite the general concordance between the species list presented here and those of previous studies, a notable difference is the now high abundance of *Lettowianthus stellatus*. Both Rodgers et al. (1979) and Vollesen (1980) list the species as present but not abundant. This gives an interesting insight into the ecology of this species as it must have regenerated very rapidly to become the second most common tree, in just 25 years. *L. stellatus* has little value for timber or poles and this may have allowed it to flourish.

Rodgers et al. (1979) suggested that *Erythrophleum suaveolens*, *Xylopia parviflora* (now *X. longipetala*), *Isoberlinia scheffleri* forest was the dominant habitat, with scrubby clearings. They also identified *Syzygium guineense* swamp forest (probably *Syzygium guineense* (Willd.) DC. subsp. *guineense*; Roy Gereau personal communication). The community types from our more recent surveys seem largely similar to these, with a continuum of habitat types largely described by the relative dominance of *Erythrophleum suaveolens* and *Isoberlinia scheffleri* (Marshall unpublished data; not included here as not relevant to the aims of the report).

Table 1. The ten most abundant tree species from plots in Magombera forest. Two size classes are given; "larger trees" (20 cm dbh or greater) and "understorey/midstrata trees" (10 to 19.9 cm dbh). Data presented include frequency per plot, percentage out of the total sampled (1,253 larger trees and 562 understorey/midstrata), and the number of plots in which each species was found.

Larger trees				Understorey/Midstrata			
	Freq	**%**	**Plots**		**Freq**	**%**	**Plots**
Isoberlinia scheffleri	230	18.4	38	*Ochna holstii*	79	13.3	18
Lettowianthus stellatus	198	15.8	57	*Calycosiphonia spathicalyx*	74	12.5	26
Erythrophleum suaveolens	162	12.9	62	*Isoberlinia scheffleri*	47	7.9	25
Xylopia longipetala	87	6.9	50	*Diospyros abyssinica*	41	6.9	15
Tapura fischeri	76	6.1	33	*Tabernaemontana pachysiphon*	37	6.3	18
Ochna holstii	66	5.3	20	*Craterispermum schweinfurthii*	37	6.3	11
Pseudobersama mossambicensis	37	3.0	8	*Diospyros zombensis*	22	3.7	14
Sorindeia madagascariensis	32	2.6	16	*Tapura fischeri*	20	3.4	16
Diospyros mespiliformis	29	2.3	22	*Dracaena mannii*	18	3.0	16
Vitex doniana	28	2.2	19	*Aoranthe penduliflora*	17	2.9	11

Table 2. Dominant vascular plants in Magombera forest in 1978 (Vollesen 1980). The three structural classes are those used by Vollesen. Heights are approximate and names are ordered alphabetically.

Upper storey (35 m)	Second/lower storeys (10 - 25 m)	Shrub layer
Anthocleista grandiflora	*Coffea spathicalyx**	*Allophylus pervillei*
Dialium holtzii	*Craterispermum schweinfurthii*	*Didymosalpinx norae*
Erythrophleum suaveolens	*Ochna holstii*	*Diospyros zombensis*
Isoberlinia scheffleri	*Pachystela brevipes**	*Gardenia posoquerioides*
Parkia filicoidea	*Polyalthia verdcourtii*	*Leptactina platyphylla*
Tetrapleura tetraptera	*Pseudobersama mossambicensis*	*Oxyanthus pyriformis*
Treculia africana	*Sorindeia madagascariensis*	*Porterandia penduliflora**
*Xylopia parviflora**	*Vitex doniana*	*Psychotria schliebenii*
		Rawsonia lucida
		Rinorea ferruginea
		*Tabernaemontana usambarensis**
		Tarenna pavettoides

* Names now revised to *Calycosiphonia spathicalyx, Xylopia longipetala*, *Synsepalum brevipes, Aoranthe penduliflora* and *Tabernaemontana pachysiphon.*

Rodgers et al. (1979) also estimated that the forest contains close to 500 plant species, including five species of conservation importance ("provisional endemics": *Polyalthia* sp. [later named *P. verdcourtii*], *Ixora* sp. and *Memecylon magnifoliatum*; "Eastern Arc mountain endemics": *Isolona heinsenii* and *Isoberlinia scheffleri*). While there is no more information on the total number of species, there is certainly now better information on the species of conservation concern, which are far more numerous than first expected. In total 18 "rare" species were found in plots for trees 10 cm dbh or greater (Table 3). These include 10 Eastern Arc and Coastal Forest endemic species and 17 either on the IUCN Red-List or recommended for inclusion on the Red-List (Table 3). Despite the early speculation, there are probably no trees that are endemic to Magombera forest alone. However of note is the presence of *Polyalthia verdcourtii*, which is only known from Magombera and Matundu forests (Gereau personal communication). *Memecylon magnifoliatum* is also probably known only from

Magombera and one other collection in the Selous (personal communication from Doug (R.D.) Stone to Quentin Luke), although we did not record this species.

Table 3. Rare tree species in Magombera forest plots, including the number of stems and plots in which they were found. Two size-classes are given; "larger trees" (20 cm dbh or greater) and "understorey/midstrata trees" (10 to 19.9 cm dbh). IUCN Red-List criteria are from Baillie et al. (2004), Gereau & Luke (2003) and Gereau pers. comm. (EN = Endangered, VU = Vulnerable, PT = Potentially threatened, LC = Least concern). Range information is from Lovett et al. (2006) (EACF = Eastern Arc Mountains and Coastal Forests of Tanzania, Kenya and Mozambique, SSA = Sub-Saharan Africa, T = One location in Tanzania outside EACF, M = Mozambique not CF, Z = Zanzibar).

			Larger trees		Under/Mid	
Species	IUCN	Known range	Stems	Plots	Stems	Plots
Isoberlinia scheffleri	VU	EACF	230	37	47	25
Lettowianthus stellatus	LC *	EACF	198	56	6	6
Pseudobersama mossambicensis	PT	EACF/S.Africa	37	7	7	5
Aoranthe penduliflora	VU	EACF	13	9	17	11
Dialium holtzii	LC *	EACF/M	9	5	0	0
Polyalthia verdcourtii	EN *	EACF	7	5	8	6
Pterocarpus mildebraedii	EN +	EACF	7	5	3	2
Eugenia capensis	PT +	EACF/M	6	2	5	4
Cordia peteri	EN	EACF	4	4	4	3
Vitex mossambicensis	LC *	EACF/Z	1	1	1	1
Vepris amaniensis	PT	EACF	1	1	12	7
Guibourtia schliebenii	VU	CF/M	1	1	0	0
Burttdavya nyasica	PT	EACF/Z/SE.Africa	1	1	0	0
Haplocoelopsis africana	PT	Tropical Africa	1	1	1	1
Kraussia speciosa	VU	EACF	0	0	2	2
Oxyanthus pyriformis subsp. *tanganyikensis*	PT	EACF	0	0	2	2
Rothmannia macrosiphon	VU	EACF	0	0	2	2
Khaya anthotheca	VU	Tropical Africa	0	0	1	1

* Proposed status   + Require verification due to uncertain sub-species (Roy Gereau personal communication)

The proportion of trees that are "rare" is remarkable. An astounding 41.2 % of stems 20 cm dbh or greater are either IUCN Red-Listed or endemic to the Eastern Arc Mountains and Coastal Forests (21.9 % of species; 129 stems per hectare; 3.5 species per hectare). Even the two most abundant large trees in Magombera forest fall into this category (*Isoberlinia scheffleri* and *Lettowianthus stellatus*; Tables 1 and 3). A lower proportion of stems 10 to 19.9 cm dbh are "rare" (19.9 % of stems; 23.1 % of species; 29.5 stems per hectare; 3.75 species per hectare). This reduction in rare stems and species among smaller trees, suggests that the high level of pole-cutting is having a serious effect. These figures can again be put in context by comparison with equivalent figures from nearby Matundu forest (Udzungwa Mountains; Marshall unpublished data), where 17.5 % of stems 20 cm dbh or greater are either IUCN Red-Listed or endemic to the Eastern Arc Mountains and Coastal Forests (9.2 % of species; 24.4. stems per hectare; 0.4 species per hectare). For stems 10 to 19.9 cm dbh in Matundu, 12.4 % are within this category (15.0 % of species; 22.4 stems per hectare; 1.4 species per hectare).

The comparison of rare species between the two forests is equally as clear when both size-classes are combined (Magombera: 32.2 % of stems, 23.08 % of species, 94.0 stems per hectare, 4.5 species per hectare; Matundu: 12.8 % of stems, 13.7 % of species, 41.3 stems per hectare, 1.5 species per hectare). From this, Magombera clearly has major importance for the conservation of rare trees. However it's protected status is significantly lower than Matundu, which mostly lies within the Udzungwa Mountains National Park.

ii. Monkeys

Our 2004/5 transect counts produced an overall population estimate of 1,022 ± 359 Udzungwa red colobus monkeys. This far exceeds the previous estimates of 450 (Rodgers et al. 1979; before clearance of area north of rail) and 472 (Decker 1994; after clearance of the area north of the rail), which were based on far less survey effort. The observed encounter rate is higher than anywhere else (Figure 8; Mtalawanda mean 1.28 ± 0.33 groups per kilometre walked, Ngulumilo 1.06 ± 0.21). The population density is therefore also likely to be the highest anywhere, as predicted by Rodgers et al. (1979). This however assumes that visibility does not differ greatly from studies elsewhere in the Udzungwa Mountains. Direct comparison of density is not currently possible due to methodological differences between studies (e.g. Rovero et al. 2006; Marshall 2007).

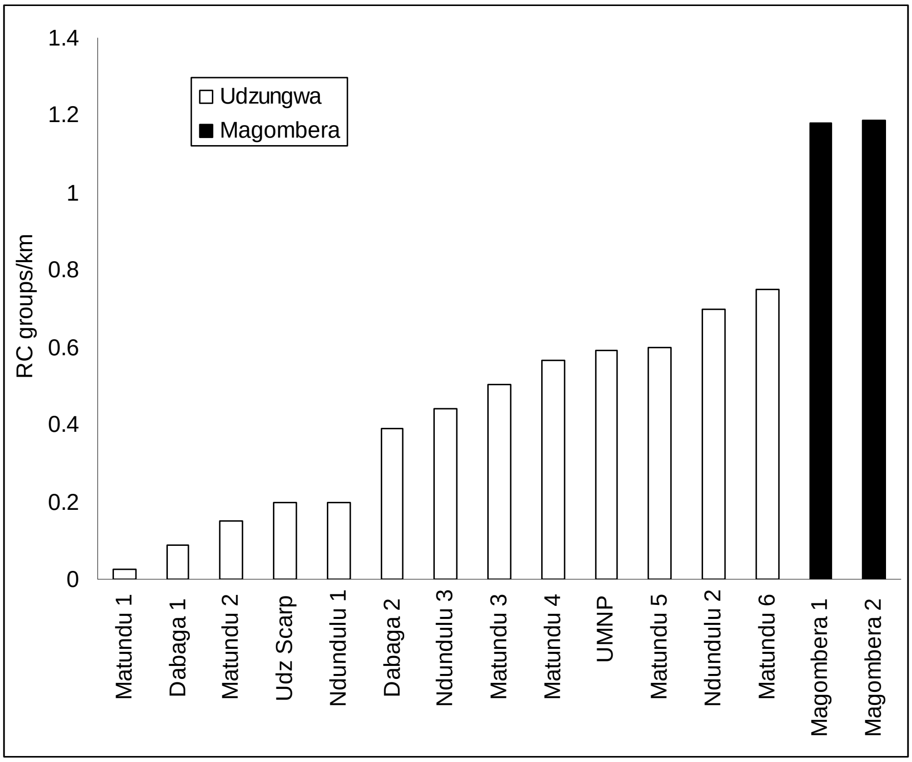

Figure 8. Red colobus groups seen per kilometre transect in the two Magombera transects in 2004/5, versus other localities in the Udzungwa Mountains (Pedersen & Topp-Jørgensen 2000; Marshall et al. 2005; Rovero et al. 2006; Marshall 2007).

The reason for the high encounter rate of the Udzungwa red colobus in Magombera is uncertain. The species is certainly more adapted to lowland semi-deciduous and semi-evergreen forests than the higher elevation evergreen forests, as seen from its reduced abundance at high elevation (Marshall et al. 2005; Marshall 2007). However the abundance in Magombera is uncharacteristically high and may therefore be a result of compression by rapid forest clearance from the surrounding area. If this is true, the population is likely to be unsustainable and we would expect a future decline. The mean and range of group size of Udzungwa red colobus in Magombera from counts in 2004/5 (22.6 ± 5.5) is towards the lower end of the known range for the species (compare 27.2 ± 15.5 from all published counts to date; Marshall et al. in press). It is also more comparable with degraded forest elsewhere (Kalunga mean 18.6) than with less degraded forest (Udzungwa mean 41.6; Struhsaker et al. 2004). While the habitat is far less degraded than the count made in Kalunga, it may suggest some instability as red colobus group size frequently reflects habitat status (Struhsaker et al. 2004; Marshall et al. 2005; Rovero et al. 2006; Marshall 2007). This requires further study.

From the 2004/5 survey, the two other monkey species resident in Magombera forest are also in high numbers, but within the range of expected relative densities from studies elsewhere (Pedersen & Topp-Jørgensen 2000; Marshall et al. 2005; Rovero et al. 2006). The black and white colobus mean encounter rate was 0.88 ± 0.10, with a mean group size of 11.7 ± 2.5, which is also high for the species. From this we estimate a total population of 626 ± 375. This is the first population estimate for black and white colobus in Magombera forest. Rodgers et al. (1979) estimated a density of 3.4 groups per km^2. This earlier study did not have reliable data on group size so no population estimate was made.

Sykes monkey density is relatively harder to estimate due to the risk of double-counting and because group-size are difficult to count (Marshall et al. 2007). Therefore we only present a simple encounter rate (mean per kilometre walked 0.84 ± 0.18). As for red colobus, these estimates for black and white colobus and Sykes monkeys were not based on long-term systematic survey, leading Rodgers et al. (1979) to emphasise the high potential for bias. Vervet monkeys were also seen occasionally just inside the forest edge, but observations were too infrequent to analyse (mean per kilometre 0.01 ± 0.02).

In support of the compression hypothesis, repeated surveys in 2007 found a decreased encounter rate of all monkey species (Figure 9). However interpretation of this decline requires some caution. Continued disturbance in Magombera forest may have affected the monkey populations. As well as the physical disturbance reported here, primates in areas of high human activity can be susceptible to human diseases, particularly in small forest fragments (Gillespie et al. 2005; Gillespie & Chapman 2006). It is also possible that the difference has arisen due to having different observers carrying out the 2004/5 and 2007 surveys. Interobserver differences in detection and measurement are a well-known problem for interpreting primate transect counts (Mitani et al. 2001; Rovero et al. 2006). Therefore firm conclusions should not be drawn from this observation and differences will be interpreted with continued monitoring.

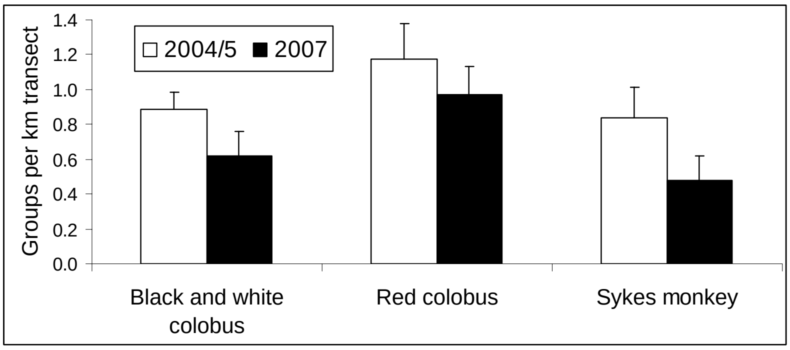

Figure 9. Comparison of primate encounter rate in 2004/5 and 2007.

A further impact of habitat degradation on the red colobus of Magombera forest is seen from statistical analysis of the 2004/5 encounter rate per 200 m section of transect versus vegetation characteristics of the two transects. From 11 habitat variables, the only clearly significant predictor of red colobus encounter rate was the total volume of trees (Table 4). This supports several previous studies that show the Udzungwa red colobus to be highly dependent on intact, closed-canopy forest (Struhsaker et al. 2004; Marshall et al. 2005; Rovero et al. 2006; Marshal 2007). Conversely, black and white colobus showed no clear relationship with habitat (Table 4). Sykes monkeys also did not show clear relationship with habitat, however they were significantly more abundant along the Mtalawanda transect than the Ngulumilo transect (Table 4). This may be due to the close proximity to agriculture where Sykes monkeys can supplement their diets by crop-raiding. Colobus monkeys are however not known to raid crops and neither species showed transect preference.

Table 4. Results of GLM analysis of primate group relative abundance versus forest structure, site and composition variables. Strong significant relationships are highlighted in bold type. No significant model was produced for black and white colobus (*p* > 0.05). %D is the percentage deviance i.e. the amount of variation explained and *p* is the statistical probability.

Species Models	Trend	*p*
B&W colobus (%D 15.00, *p*0.062)		
√ (Climber cover)	positive	0.022
Volume trees ≥ 20cm	positive	0.090
Red colobus (%D 18.94)		
Volume trees ≥ 20cm	**positive**	**0.023**
√ (Climber cover)	positive	0.048
Sykes monkey (%D 17.22)		
Transect	**Mtalawanda > Ngulumilo**	**<0.001**

iii. Duikers

Duikers are very rare in Magombera forest, despite the low density of snares found above. Both suni and red duiker are significantly fewer in Magombera forest than Matundu forest, where hunting has been largely absent for several years (Figure 10). In addition, bushbuck were observed opportunistically on two occasions and a suni was heard calling once. Bushbuck, red duiker and suni were at very low densities in 1979 (Rodgers et al. 1979) although no quantitative data are available for that time. The density has therefore been low for some time. However Rodgers et al. (1979) also noted that game traps were present throughout the forest, suggesting that hunting may simply have reduced in response to declining density caused by over-hunting. Together with this, the lack of connectivity to other forest areas lessens the chance of re-colonisation from elsewhere. Hence population recovery from past hunting is likely to be slow. Monitoring the recovery is complicated by decreased visibility caused by regeneration of a tangled understorey. As a result, no red duikers were seen during the 2007 transect counts. This may improve if the forest trees can be encouraged to regenerate.

iv. Other Taxa

Kamara (1979) lists elephant, waterbuck, buffalo, bush pig, warthog, aardvark, porcupine, cane rat, elephant shrews and tree squirrels as being present in Magombera forest. These mammals were all observed during the surveys with the exceptions of warthog and waterbuck. Signs of hippopotamus were also seen. Bushpig are now rare in Magombera, yet were "plentiful" in 1979 (Rodgers et al. 1979). This decline is presumably another effect of past hunting.

Elephants are present in Magombera forest mainly between July and December (Marshall 2008; Marshall & Mtoka 2008). This increase in elephant activity co-incides with the late dry season. During these months, the water supply in the adjacent Selous Game Reserve is at its lowest and bushfires are common. Magombera forest is therefore important as a dry season refuge for these animals, where water is accessible year-round. During survey work, elephants were observed eating sugar cane in nearby fields, raising concern that they pose a serious human-wildlife conflict. Elephants are certainly dangerous and have been known to injure people in their fields. In wetter months, the forest may act as a buffer between the Selous and the villages, thus reducing these dangerous encounters. In terms of crop-raiding, Kamara (1979) suggests that cane-rats and bushpigs are the major threat. Now that bushpigs are sparse, they are presumably less of a threat. Other threats include birds and vervet monkeys. Sykes monkeys may also pose a threat given their skewed distribution in the forest, being more abundant near to agricultural areas (Table 4). Colobus monkeys do not raid crops.

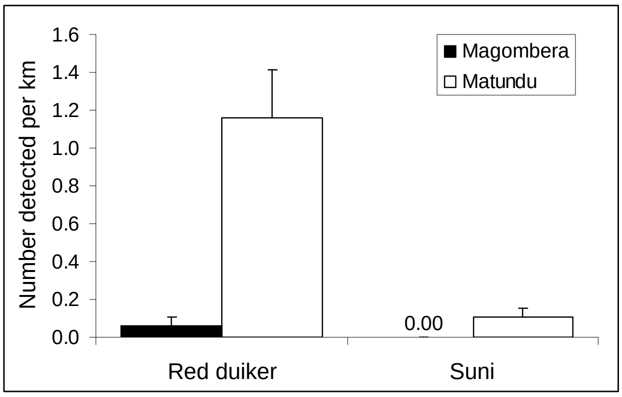

Figure 10. Duikers seen during transect counts in Magombera (high hunting pressure in the 1970s), compared to Matundu forest (low hunting pressure for several years; Marshall unpublished data).

Additional taxa that remain to be covered in detail include birds, small mammals, amphibians, reptiles and invertebrates. Although bird observations have been made in Magombera forest and there are montane species at unusually low elevation (Jensen & Brøgger-Jensen 1992; Stuart in Decker 1994; Baker personal communication), a list has not been published.

Of interest among the poorly known herpetofauna is the treefrog listed as *Hyperolius* sp. nov. in Rodgers et al. (1979). This has now been named *Hyperolius reesei* and is endemic to the Kilombero valley. Finally among the herpetofauna, an undescribed species of *Kinyongia* chameleon was discovered being eaten by a snake, whilst conducting 2004/5 fieldwork. The species has yet to be named formally, but it will soon be named after Magombera forest (Menegon personal communication). It is only known from Magombera forest and the Udzungwa Mountains.

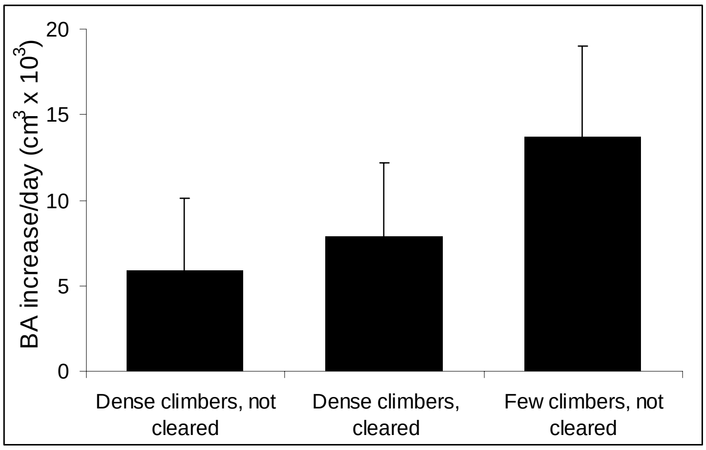

Figure 11. Regeneration of trees 1 cm dbh or greater in 5 m × 5 m plots.

Forest Restoration

Plots to determine the potential for restorative management by clearance of restricting climbers produced results loosely as expected (Figure 11). After three months the least growth of trees 1 cm dbh or more, was seen in plots where the extensive cover of climbers was not cleared. In plots where climbers had been removed, growth was slightly greater. Growth was greatest in the control plots where there were no climbers to begin with. These differences are not statistically significant. It should however be noted that the period of growth after plot establishment was dry and therefore the chance of seeing significant results this soon, was slim. Continued monitoring will be required to determine the full effect of removing climbers for encouraging regrowth, although these early indications are encouraging. Also encouraging is that 37.0 % of 261 saplings counted were from IUCN Red-Listed or Eastern Arc and Coastal Forest endemic species. This is higher than the 32.2 % of mature stems in this category, and suggests potential for improving the biodiversity value of the forest still further.

Recommendations

From the results it is clear that Magombera is a forest of huge importance for conservation of biodiversity. It also has value as water catchment for neighbouring villages and has potential for ecotourism such as bird- or monkey-watching. Furthermore, like all forests it has value as a carbon sink for mitigating the effects of climate change. Accordingly, if conserved in a way that maintains the forest structure and biomass, there is potential for Tanzania to generate financial income from developed nations in the form of carbon credits. However despite the many benefits for biodiversity, local human well-being, global climatic stability and income, the forest has not been protected and continues to be degraded. From our surveys we suggest that the threats to Magombera forest should be prioritised as follows:

1) Pole cutting (understorey trees predicted to disappear within 4 years)
2) Fire (annual fires are preventing regeneration and encouraging growth of restricting climbers)
3) Firewood collection (removal of forest floor woody detritus is likely to affect regeneration)
4) Timber felling (currently low, however recent threats suggest monitoring is needed)
5) Hunting (currently low, perhaps because most medium-sized ground mammals already removed)

In its current state, Magombera forest is a huge assest to Tanzania, famous for its chequered past both locally and internationally. Given its high profile and biodiversity value it therefore provides an excellent opportunity for Tanzania to show the world its capability to protect and manage an area of high importance for conservation. From the findings above there are several recommendations for management, policy-making, village activities and ecological monitoring. These are outlined below grouped into immediate, short-term and long-term priorities.

Immediate Priorities

It is imperative that the needs of local villagers are considered in making any management plans. Workshops were held in February 2007 in the four villages adjacent to the forest, at both administrative levels (village council and village general assembly). During workshops the ecological, socio-economic and land-use findings of this project were presented, including awareness-raising on the value of the forest, threats and policy (Marshall 2008; Marshall & Mtoka 2008; contact WWF-TPO for workshop reports). From these workshops, signed agreements to annex Magombera forest into the Selous Game Reserve have been made with all four villages. Other major project recommendations were also discussed.

All project documents will now be handed to Kilombero district officials for approval. Following this, it is imperative that the managing authorities with interests placed in Magombera forest are made aware of the project findings. This may best be achieved through a meeting between key members of the current project, WWF-TPO senior staff, Illovo Sugar and senior officials from both the Forestry and Beekeeping and Wildlife Divisions. From this the agreement made in 1980 by all managing authorities, to annex Magombera forest into the Selous Game Reserve should be re-confirmed so that the process can begin. Importantly, such a meeting would need to determine exactly what is required for annexation to be completed, including actions, facilities and personnel.

To ensure that the forest remains protected during the planning process, some activities are required in the vicinity of the forest. Most importantly for ensuring protection, the nature of current patrols needs to be improved. During nearly three years of survey, not a single ranger was encountered in

Magombera forest. Villagers and a former ranger of the Selous informed the project that patrols are usually made only along the TAZARA railway or forest edge and do not generally enter the forest. Many illegal activities must therefore be missed. Instead there are several well-established paths through the forest that could be used. Given that cutting often occurs at weekends, on public holidays, or at night, it is suggested that patrols are designed so that they are made at less conventional times. An emergency response system is also suggested to ensure that rangers are able to react quickly to major activities such as intensive cutting or bushfire inside the forest. A simple system could be to provide the co-ordinator and field assistants carrying out monitoring work in Magombera forest with the phone number of a member of the Selous Game Reserve Msolwa sector, who can authorise an immediate response. To assist with annexation, boundaries also require measuring, as intended under the current WWF-TPO project.

Continuation of monitoring activities using the methods outlined in this report is vital for assessing and reducing threats for feedback into management. Clear targets for monitoring need to be established including short- and long-term goals. A new project (the "Udzungwa Forest Project" [UFP]; Marshall 2007a) has been proposed to continue from the baseline monitoring initiated by this WWF-TPO project, involving local villagers and Tanzanian graduates. The proposed project aim is to safeguard the future of Magombera forest by providing a link between managers and villagers including scientific advice on ecology, management and resource planning on village lands. Importantly the proposed project intends to build capacity and education to encourage future self-sufficiency. It is recommended that the establishment of this project be included in discussions at the proposed management authority and village meetings. The project has already been endorsed by the Kilombero District Commissioner.

Short-Term Priorities

A major initial priority in nearby villages will be to develop a land-use plan, as currently being facilitated by the WWF-TPO project. Most importantly, the future of Magombera forest is dependant on complete cessation of cutting. In other areas of Tanzania, including the Dabaga highlands (Iringa region), all villagers have private woodlots from which they have an indefinite supply of poles for tool handles and building. A similar system could be adopted in the Magombera area for sustaining both pole and firewood needs. The major obstacles to overcome in developing such a plan are a shortage of land and a high rate of immigration (3.4 % per year; Harrison & Laizer 2007). Calculation is therefore required of the land required to sustain village needs, taking into account the amount of poles and firewood required each year, and the growth rate and space occupied by the selected tree species. If possible indigenous species should be used, for example from nurseries established by WWF-TPO along the edge of the Udzungwa Mountains National Park. In order to preserve land, villages also need to curb immigration. Without this it will be near impossible to make sustainable plan as the calculations would need constant updating and land would disappear.

Villages will also have to decide on priorities for livelihoods in relation to increased protection of the forest. These priorities should result from village discussions. For instance, alternative fuel sources may be important to help remove dependence on the forest for firewood. Income generating activities could also be considered that also benefit forest conservation or education. For example growing and selling tree saplings, or ecotourism. Strategies could also be developed for reducing the danger of elephants on farmland, e.g. hanging chilli-soaked rags around plots. Limited technical advice and/or financial assistance may be available for some small activities through UFP, however it is important that land-use plans are first in place to avoid increased immigration in response to this.

The major aim for management should be to complete the Selous annexation process. This should also include boundary demarcation. Following annexation, a management plan is needed, developed in conjunction with monitoring activities. This should include biological and village livelihood aims (for example using the structure suggested in Figure 12). The Selous managing authorities and UFP should encourage community-based tourism in Magombera forest to ensure that revenue from tourism reaches the local community. Commercial and subsistence hunting in Magombera forest should be forbidden as this would endanger the biodiversity and tourism value.

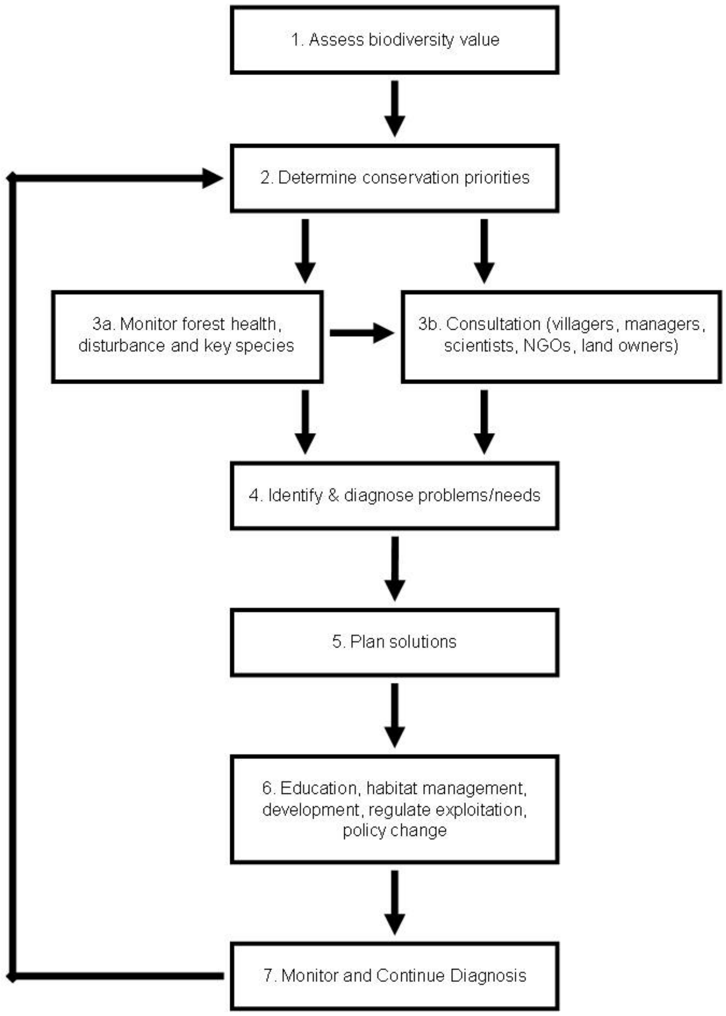

Figure 12. Proposed steps for integration of monitoring, education and conservation management in Magombera forest (from Marshall 2007a; adapted from Sutherland 2000).

Depending on observations made during monitoring, active restoration of the forest understorey through widespread clearance of restricting climbers could be considered. Any large-scale clearance should be careful to avoid damaging rare/globally threatened species of climber. The financial cost of this activity is not high (we estimate it should cost around $20 per hectare of forest per year to clear restricting climbers). By hiring local villagers to carry out this management activity, this would also improve income generation.

The success of some short-term goals can only be determined by setting monitoring targets, including cessation of pole-cutting, reduction in firewood collection and obtaining a statistically significant increase in the number of tree stems between 1 and 5 cm dbh.

Long-Term Priorities

A current problem for Selous Game Reserve rangers accessing Magombera forest, is that the Msolwa ranger post is not conveniently located for accessing Magombera forest. The road route is around 35 km, as vehicles must pass north along the Msolwa river all the way back to the main Mikumi-

Ifakara road (Figure 1). Establishing a ranger post near to Magombera forest would improve logistics and would also allow potential for improving relations with the villages including help with wildlife-related problems such as scaring away elephants.

Some more long-term monitoring goals could include: re-establishment of large tree species previously lost through logging (especially *Milicia excelsa* and *Khaya anthotheca*); stabilised density of the Udzungwa red colobus; recovery of duikers and understorey trees to densities comparable with lowland Udzungwa; and cessation of firewood collection.

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Appendices

Appendix 1. List of large trees (10 cm dbh or greater) in Magombera forest plots (x = present in plots; o = present outside of plots; . = not recorded). Note that this may not be a comprehensive list for the whole forest.

Species	Family	Transect	
		Mtal	Ngul
Lannea antiscorbutica (Hiern) Engl.	Anacardiaceae	.	x
Sorindeia madagascariensis Thouars ex DC.	Anacardiaceae	x	x
Lettowianthus stellatus Diels	Annonaceae	x	x
Polyalthia verdcourtii Vollesen	Annonaceae	x	x
Xylopia longipetala De Wild. & T. Durand	Annonaceae	x	x
Funtumia africana (Benth.) Stapf	Apocynaceae	.	o
Rauvolfia mombasiana Stapf	Apocynaceae	x	.
Tabernaemontana elegans Stapf	Apocynaceae	x	x
Tabernaemontana pachysiphon Stapf	Apocynaceae	x	x
Voacanga africana Stapf	Apocynaceae	x	x
Kigelia africana (Lam.) Benth.	Bignoniaceae	x	.
Markhamia lutea (Benth.) K. Schum.	Bignoniaceae	x	x
Bombax rhodognaphalon K. Schum.	Bombacaceae	x	.
Cordia peteri Verdc.	Boraginaceae	x	x
Ehretia cymosa Thonn.	Boraginaceae	x	x
?*Cassia* sp. 2	Caesalpiniaceae	x	x
Cordyla africana Lour.	Caesalpiniaceae	x	x
Dialium holtzii Harms	Caesalpiniaceae	x	x
Erythrophleum suaveolens (Guill. & Perr.) Brenan	Caesalpiniaceae	x	x
Guibourtia schliebenii (Harms) J. Léonard	Caesalpiniaceae	x	.
Isoberlinia scheffleri (Harms ex Engl.) Greenway	Caesalpiniaceae	x	x
Senna singueana (Delile) Lock	Caesalpiniaceae	x	.
Tetrapleura tetraptera (Schumach. & Thonn.) Taub.	Caesalpiniaceae	x	x
Pteleopsis myrtifolia (M.A. Lawson) Engl. & Diels	Combretaceae	x	x
Terminalia sambesiaca Engl. & Diels	Combretaceae	x	.
Tapura fischeri Engl.	Dichapetalaceae	x	x
Dracaena mannii Baker	Dracaenaceae	x	x
Diospyros abyssinica (Hiern) F. White	Ebenaceae	.	x
Diospyros ferrea (Willd.) Bakh.	Ebenaceae	x	x
Diospyros kabuyeana F. White	Ebenaceae	x	x
Diospyros mespiliformis Hochst. ex A. DC.	Ebenaceae	x	x
Diospyros natalensis (Harv.) Brenan	Ebenaceae	x	x
Diospyros squarrosa Klotzsch	Ebenaceae	x	.
Diospyros zombensis (B.L. Burtt) F. White	Ebenaceae	x	x
Antidesma vogelianum Müll. Arg.	Euphorbiaceae	x	x
Bridelia micrantha (Hochst.) Baill.	Euphorbiaceae	x	.
Croton ?*sylvaticus* Hochst. ex Krauss	Euphorbiaceae	x	.
Drypetes parvifolia (Müll. Arg.) Pax & K. Hoffm.	Euphorbiaceae	x	.
Mallotus oppositifolius (Geiseler) Müll. Arg.	Euphorbiaceae	x	x
Casearia gladiiformis Mast.	Flacourtiaceae	x	x
Flacourtia indica (Burm. f.) Merr.	Flacourtiaceae	x	.
Rawsonia lucida Harv. & Sond.	Flacourtiaceae	x	.
Garcinia livingstonei T. Anderson	Guttiferae (=Clusiaceae)	x	x
Anthocleista grandiflora Gilg	Loganiaceae	x	x
Strychnos mitis S. Moore	Loganiaceae	x	.
Memecylon sousae A. Fern. & R. Fern.	Melastomataceae	.	o
Ekebergia capensis Sparrm.	Meliaceae	.	x
Khaya anthotheca (Welw.) C. DC.	Meliaceae	x	o
Pseudobersama mossambicensis (Sim) Verdc.	Meliaceae	.	x
Turraea robusta Gürke	Meliaceae	.	x
Albizia gummifera (J.F. Gmel.) C.A. Sm.	Mimosaceae	x	.
Parkia filicoidea Welw. ex Oliv.	Mimosaceae	x	.
Antiaris toxicaria Lesch.	Moraceae	x	.
Ficus sycomorus L.	Moraceae	x	.

Milicia excelsa (Welw.) C.C. Berg	Moraceae	x	x
Treculia africana Decne.	Moraceae	x	x
Eugenia capensis (Eckl. & Zeyh.) Sond.	Myrtaceae	x	x
Syzygium guineense (Willd.) DC. subsp. *guineense*	Myrtaceae	x	.
Ochna holstii Engl.	Ochnaceae	x	x
Dalbergia fischeri Taub.	Papilionaceae	x	x
Pterocarpus mildbraedii Harms	Papilionaceae	x	x
Cassipourea gummiflua Tul.	Rhizophoraceae	x	x
Aoranthe penduliflora (K. Schum.) Somers	Rubiaceae	x	x
Burttdavya nyasica Hoyle	Rubiaceae	.	x
Calycosiphonia spathicalyx (K. Schum.) Robbr.	Rubiaceae	x	x
Catunaregam pentandra (Gürke) Bridson	Rubiaceae	.	x
Craterispermum schweinfurthii Hiern	Rubiaceae	x	.
Didymosalpinx norae (Swynn.) Keay	Rubiaceae	x	.
Kraussia speciosa Bullock	Rubiaceae	x	.
Leptactina platyphylla (Hiern) Wernham	Rubiaceae	x	x
Oxyanthus pyriformis (Hochst.) Skeels subsp. *tanganyikensis* Bridson	Rubiaceae	x	.
Rothmannia macrosiphon (Engl.) Bridson	Rubiaceae	.	x
Tarenna pavettoides (Harv.) Sim	Rubiaceae	x	x
Tricalysia pallens Hiern	Rubiaceae	x	x
Vangueria apiculata K. Schum.	Rubiaceae	.	x
Vepris amaniensis (Engl.) Mziray	Rutaceae	x	x
Blighia unijugata Baker	Sapindaceae	x	.
Haplocoelopsis africana F.G. Davies	Sapindaceae	x	.
Synsepalum brevipes (Baker) T.D. Penn.	Sapotaceae	x	x
Harrisonia abyssinica Oliv.	Simaroubaceae	x	.
Cola ?*microcarpa/discoglypremnophylla*	Sterculiaceae	.	x
Sterculia appendiculata K. Schum.	Sterculiaceae	.	o
Vitex doniana Sweet	Verbenaceae	x	x
Vitex mossambicensis Gurke	Verbenaceae	x	x
Rinorea arborea (Thouars) Baill.	Violaceae	.	x