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The primates of the Udzungwa Mountains: diversity, ecology and conservation

Francesco Rovero [1,2], Andrew R. Marshall [3], Trevor Jones [2,4] & Andrew Perkin [5]

1) Sezione di Biodiversità Tropicale, Museo Tridentino di Scienze Naturali, Via Calepina 14, 38100 Trento, Italy
e-mail francesco.rovero@mtsn.tn.it

2) Udzungwa Ecological Monitoring Centre, c/o Udzungwa Mountains National Park, P.O. Box 99, Mang'ula, Tanzania

3) Environment Department, University of York, Heslington, York YO10 5DD, United Kingdom and Flamingo Land Ltd., Kirby Misperton, Malton, North Yorkshire YO17 6UX, United Kingdom

4) Environmental Sciences Research Centre, Department of Life Sciences, Anglia Ruskin University, Cambridge CB1 1PT, United Kingdom

5) Nocturnal Primate Research Group, Department of Social Science and Law, Oxford Brookes University, Oxford OX3 0BP, United Kingdom

Summary - *The Udzungwa Mountains are one of the most important areas in Africa for primate diversity and conservation, with two endemic monkeys (Udzungwa red colobus* Procolobus gordonorum *and Sanje mangabey* Cercocebus [galeritus] sanjei*), and the near-endemic kipunji monkey* Rungwecebus kipunji*, a new genus and species discovered in 2004 and found in Udzungwa and Southern Highlands. With six species of galagos, or bushbabies, the area is also of exceptional importance for nocturnal primates. The form of Mountain galago* Galagoides orinus *occurring in the Udzungwa Mountains appears to be distinct on the base of vocalizations, and further work will be required to assess its taxonomic status. The primate community reflects the overall, exceptional biodiversity of these isolated and ancient mountains. The Udzungwa are part of the Eastern Arc mountain chain, a centre of global importance for biodiversity and endemism. Of all the Eastern Arc Mountain blocks, the Udzungwa have the largest forested area, widest altitudinal gradient and greatest habitat diversity. We review current knowledge on the diversity and distribution of the primate community of the Udzungwa Mountains, with an emphasis on ecology and conservation.*

Keywords - Cercocebus, Cercopithecus, Chlorocebus, Colobus, Otolemur, Papio, Procolobus, Rungwecebus, *Udzungwa.*

Introduction

Research on non-human primates of the Udzungwa Mountains of south-central Tanzania has increased steadily over the last 10-20 years and a considerable amount of knowledge has accumulated. Besides faunal inventories and distributional surveys in the area, primates are among the very few groups on which ecological studies have also been conducted, including a monitoring programme in operation for almost 10 years. These efforts have contributed to detailed information on threats, and for scientifically-based conservation management recommendations. This is

therefore an appropriate time for a review on Udzungwa primates, and here we aim to do so by (i) giving an overview of the primate community for this outstanding biodiversity area, (ii) providing a detailed account for each species, (iii) summarizing species richness, abundance and ecological work, and (iv) describing the main threats and conservation issues. We conclude by listing the relevant research, monitoring and conservation initiatives in the area.

The Udzungwa Mountains

The Udzungwa Mountains (7°40' S to 8°40' S and 35°10' E to 36°50' E; see figure 1) is a massif occupying an area of about 10,000 km^2 and representing the southernmost "island" of an "archipelago" of mountain blocks running from southern Kenya (Taita Hills) through eastern and south-central Tanzania, known as the Eastern Arc Mountains (Lovett & Wasser, 1993). This chain, in turn, is biogeographically inscribed in the eastern African "montane circle" (Fieldså *et al.*, 2005), that includes Mount Elgon and the Kenya highlands (north), the Albertine Rift (west), and the Tanzanian Southern Highlands (south). Moreover, it is also part of the broader "Eastern Afromontane" biodiversity hotspot (Mittermeier *et al.*, 2005). The Eastern Arc is made of very ancient mountains, that are up to 30 million years old, and are partially covered in rainforest especially on the eastern slopes that are under the moist and cooling influence of the Indian Ocean. Over such long time, both altitudinal and climatic influences have maintained the forest cover, resulting in both the persistence of ancient taxa and the diversification of more recent ones (Lovett & Wasser, 1993). Therefore, endemic taxa have accumulated in the Eastern Arc Mountains over millions of years (Fieldså & Lovett, 1997) as indicated by the high density of endemic vertebrates recorded (Myers *et al.*, 2000; Burgess *et al.*, 2007). The area is vulnerable to human exploitation due to the relatively small size of the remaining forests, severe fragmentation (Brooks *et al.*, 2002) and lack of effective conservation management (Museo Tridentino di Scienze Naturali, 2007).

Within the Eastern Arc Mountains, the Udzungwa Mountain stands-out for containing the largest forest blocks, with the largest altitudinal gradient of continuous forest cover. Most forests of the Eastern Arc do not exceed 50 to 100 km^2 and occur only on the highest slopes (generally between 1500 and 2000 m of altitude). Instead, the eastern-facing escarpment slopes of the Udzungwa Mountains have maintained continuous forest cover from the Kilombero valley at 250 m a.s.l. to the highest ridges above 2000 m. This is probably due to the relative remoteness from the coast and the poor farming suitability of its landslide-prone slopes that delayed human colonization and prevented the area from deforestation, in comparison with other blocks such as the Usambara and Uluguru Mountains (J. Kingdon, personal communication). It is only during the 1950s, with the construction of the railway to Zambia that runs all along the eastern escarpment, that logging in the lower zones of the eastern forests was initiated. This opened the way to the development of villages and small towns such as Ifakara. Moreover, between 1929 and 1958, most of these forests were legally gazetted as Forest Reserves (e.g. Mwanihana, Nyanganje, Iyondo and Uzungwa Scarp), thus ensuring long-lasting protection.

The unique forest size and habitat diversity in the Udzungwa Mountains have probably facilitated speciation of relatively large forest mammals, including two endemic monkeys (Udzungwa red colobus *Procolobus gordonorum* and Sanje mangabey *Cercocebus sanjei*). Therefore, the importance of the Udzungwa Mountains (including 18 endemic and 42 Eastern Arc endemic vertebrates; updated from Burgess *et al.*, 2007) is very well reflected in the mammalian fauna (Kingdon & Howell, 1993; Rovero & De Luca, 2007). There are five Udzungwa-endemic mammals and 14 mammals which are endemic to the Eastern Arc Mountains, Southern Highlands and Mount Kilimanjaro (updated from Burgess *et al.*, 2007). Among the strictly endemic mammals, in addition to the two monkeys (see below), is the recently described giant elephant-

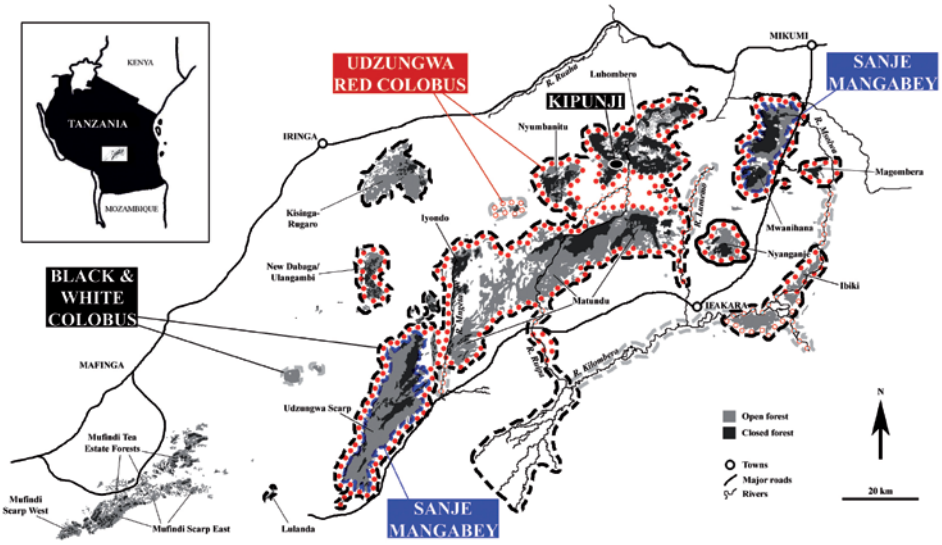

Fig. 1 - Map of the Udzungwa Mountains of Tanzania with distribution of the rarest diurnal primates. Black dashes and red dots show known distribution, while faded dashes and open red dots show suspected but unconfirmed distribution. Map produced by A.R.M. from data and maps in Marshall (2007), Marshall et al. (submitted b), Rovero & Perkin (2008).
The colour version of this figure is available at the JASs website.

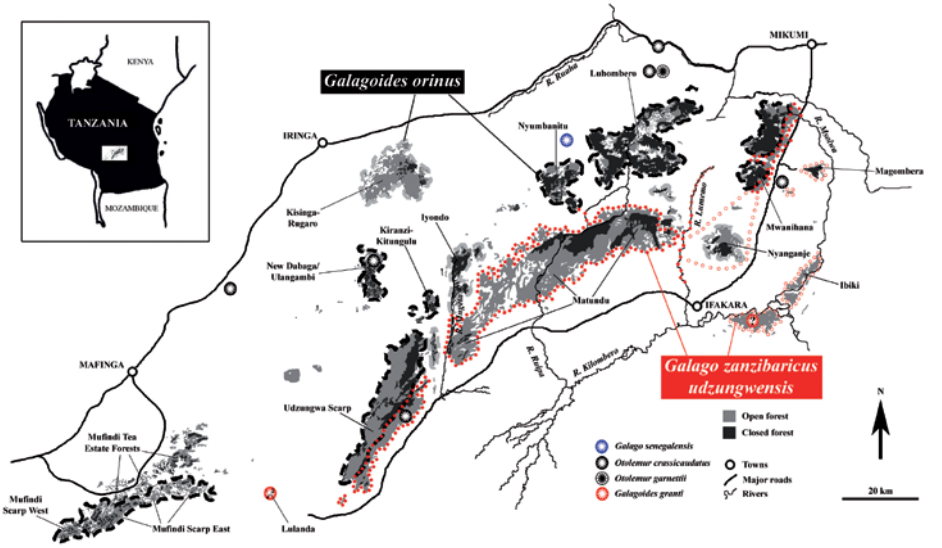

Fig. 2 - Map of the Udzungwa Mountains of Tanzania with distribution of nocturnal primates. Black dashes and red dots show known distribution, while faded dashes and open red dots show suspected but unconfirmed distribution. Map produced by A.R.M. from Marshall (2007) and A.P. (unpublished data).
The colour version of this figure is available at the JASs website.

shrew *Rhynchocyon udzungwensis* (Rovero *et al.*, 2008) and two shrews of the genera *Congosorex* and *Miosorex* (Stanley & Hutterer, 2000; Stanley *et al.*, 2005).

About one fifth of the Udzungwa Mountains is protected by the Udzungwa Mountains National Park (UMNP, 1990 km^2) gazetted in 1992. An additional similar area is protected either as Forest Reserve or Nature Reserve. Among these protected areas, Kilombero Nature Reserve was established in 2007 to include former Forest Reserves (Ndundulu, Nyumbanitu, Matundu and Iyondo comprizing an area of 1396 km^2; Marshall *et al.*, 2007) and Uzungwa Scarp Forest Reserve (USFR, 207 km^2) was established in 1929. The overall altitude range in the Udzungwa Mountains extends up to 2600 m a.s.l. at Mount Luhomero in the UMNP. As mentioned, the Udzungwa Mountains are extremely heterogeneous and contain several different habitat types, with closed-canopy forests interspersed with areas of dry woodland and grassland. Rainfall varies from 2000–3000 mm per year on the eastern sides of moist forest blocks to 500 mm per year on drier slopes (UMNP unpublished data), and it is concentrated in two periods: December-January and March–May.

Diversity of Udzungwa primates

Thirteen primate species (9 genera) are found in the Udzungwa Mountains (Tab. 1), including the two endemic monkey, the near-endemic *Rungwecebus kipunji* (Jones *et al.*, 2005; Davenport *et al.*, 2006), the Eastern Arc-endemic *Galagoides orinus* and the Tanzanian Eastern Arc and Coastal Forest-endemic subspecies *Galagoides zanzibaricus udzungwensis* (Butynski *et al.*, 2006).

Although a biogeographical analysis of the Udzungwa primate community is beyond the scope of this review, we here point out few important observations. Primate richness in some forest sites in central and western Africa is higher than in the Udzungwa Mountains, holding up to 13-17 species of primates (e.g. Ituri in the Democratic Republic of Congo, Makokou in Gabon, [Chapman *et al.*, 2001] and Nyungwe in Rwanda [Plumptre *et al.*, 2002]). However, it is the level of endemism among the Udzungwa primates that places these mountains among the most important sites in Africa for primate conservation. This is especially notable when considering that there are generally fewer species of mammals in east African forests than in the Guineo-Congolian forest in central and west Africa (Kingdon & Howell, 1993). Among the mammal species that are "missing" in the Eastern Arc and adjacent area compared to forests in central and western Africa are the larger forest specialists, including the apes, which may be partly related to the small extension of forests in the area (Kingdon, 1990). Moreover, many mammals from the Guineo-Congolian block tend to be sympatric specialists of generic radiations while the eastern congeners tend to be single, locally adapted allopatric isolates (Kingdon & Howell, 1993). This is especially clear with the *Cercopithecus* monkeys, as only the Sykes's monkey *Cercopithecus mitis* occurs throughout the Eastern Arc Mountains whereas up to six occur in other sites (Chapman *et al.*, 2001).

Diurnal primates: species accounts

A far greater amount of survey effort and fieldwork has been conducted on diurnal primates than on the nocturnal ones, and whilst virtually all forest patches in the range have been surveyed for diurnal primates, many gaps still occur in the presence of nocturnal species (see below). Despite this, surprisingly the kipunji monkey was discovered in 2004 in the Ndundulu forest. The fine distribution of most species still awaits further work and there are large forest patches such as Uzungwa Scarp and Iyondo where portions of the forest have yet to be surveyed. However, given the amount of work already conducted, we consider major changes on the distribution to be unlikely.

A distribution map for diurnal primates is presented in Fig. 1 and photographs in Fig. 3. The kipunji shows the narrowest and most localized occurrence, covering an area of approximately 9

Tab. 1 - Primates of the Udzungwa Mountains (adapted from Rovero & De Luca, 2007). Taxonomy follows Grubb* et al. *(2003) unless otherwise stated.

Scientific name	Common name	Habitat	Abundance	Altitude range	IUCN status	Distribution
Cercopithecidae						
Rungwecebus kipunji	Kipunji	SF,MF	R	1300-1750	CR	Ndundulu
Cercocebus (galeritus) sanjei	Sanje mangabey	LF,SF,MF	U	300-1800	EN	Mwanihana and Uzungwa Scarp
Cercopithecus mitis cf monoides/moloneyi	Sykes' monkey	LF,SF,MF	C	250-2500	LC	Throughout
Chlorocebus pygerythrus[1]	Vervet monkey	W,LF	U	250-1900	LC	Edge and cultivation throughout
Papio cynocephalus	Yellow baboon	W,LF	C	250-1900	LC	Throughout
Colobidae						
Procolobus gordonorum	Udzungwa red colobus	LF,SF,MF	C	250-2200	VU	Throughout
Colobus angolensis palliatus	Angolan colobus	LF,SF,MF	C	250-2200	LC	Throughout
Galagonidae						
Galagoides zanzibaricus udzungwensis	Udzungwa galago	W,LF,SF	C	300-1100	Not listed	Throughout
Galagoides orinus	Mountain galago	SF,MF	U	1100-2400	DD	Throughout
Galagoides granti	Grant's galago	MF	U	1200	DD	Lulanda (southern Udzungwa)
Galago senegalensis	Senegal galago	W	U	300-1000?	LC	Woodland west of UMNP[2].
Otolemur crassicaudatus	Greater galago	W,LF	R	250-2000	LC	Woodland (north and east of UMNP); New Dabaga-Ulungambi
Otolemur garnettii	Small-eared galago	W	R	1100	LC	Woodland (northern UMNP)

[1] The name *Chlorocebus pygerythrus* replaced *Cercopithecus aetiops pygerythrus* as proposed by Groves (2001) and maintained by Kingdon et al. (2008).
Habitat: W= woodland; LF= lowland forest; SF= sub-montane forest; MF= montane forest; see Tab. 2 for description of these categories. Abundance: R= rare, U= uncommon, C=common.

[2] UMNP= Udzungwa Mountains National Park.

km^2 in the Ndundulu forest (Jones *et al.*, submitted; Davenport *et al.*, 2008), followed by the Sanje mangabey that occurs in solely two forests covering approximately 400 km^2.

(1) Kipunji *(Rungwecebus kipunji)*

Taxonomy – In the short period since its discovery in both the Udzungwa Mountains and Tanzania's Southern Highlands (Davenport

Fig. 3 - Forest monkeys occurring in the Udzungwa Mountains of Tanzania: Sanje mangabey (top left, photo F. Rovero), kipunji (top right, photo F. Rovero), Udzungwa red colobus (mid left, photo T. Struhsaker), Angolan colobus (bottom right, photo A. Marshall), Sykes's monkey (bottom left, photo T. Struhsaker). The savannah monkey species, Yellow baboon and Vervet monkey, also occur in the area. The colour version of this figure is available at the JASs website.

& Jones, 2005), the kipunji has already undergone a controversial taxonomic history. Because it was clear that both known populations were very small, a decision was taken in 2005 to not capture a live animal, and in accordance with the guidelines of the International Commission for Zoological Nomenclature (Wakeham-Dawson *et al.*, 2002), the holotype and paratype specimens in the first species description were designated as individuals in photographs (Jones *et al.*, 2005) - a protocol which was not universally accepted (Timm *et al.*, 2005). On the basis of detailed observations of morphology, preliminary observations of ecology and behaviour, biogeography, and a comparative inter-taxa analysis of sonograms of vocalisations, kipunji was placed in the *Lophocebus* genus of mangabeys. However a year later, a sub-adult male kipunji caught in a trap in the Southern Highlands allowed for both skeletal morphology and molecular analysis, and the new species was placed into a new genus, *Rungwecebus*, named after its type locality Mount Rungwe in the Southern Highlands (Davenport *et al.*, 2006). The specific and common name (kipunji) is used by the Nyakyusa people around Mt. Rungwe, who were familiar with these monkeys long before any scientists.

Although the new genus was questioned by several scientists (e.g. Ehardt & Butynski, 2006), recent molecular results have clearly confirmed that *Rungwecebus* is more closely related to the baboons (genus *Papio*) than to the mangabeys (*Lophocebus*; Olson *et al.*, 2008). Nevertheless, the precise evolutionary relationship between *Rungwecebus* and *Papio* remains enigmatic.

Distribution – In the Udzungwa Mountains, the kipunji is currently thought to be limited to approximately 9 km^2 in southern Ndundulu forest (Jones *et al.*, submitted), within the newly gazetted Kilombero Nature Reserve (Marshall *et al.*, 2007).

Abundance – Currently estimated at 93 individuals in Ndundulu forest (Jones *et al.*, submitted), the species is classified as Critically Endangered by IUCN criteria (Davenport *et al.*, 2008), making it one of the world's most threatened primates.

Socioecology – Due to their recent discovery and the great difficulty in observing these very shy animals (as they flee through the 40 m-tall canopy of the forest), very little is currently known (Jones, 2006). Opportunistic observations suggest the kipunji in Ndundulu have a varied diet, with a bias towards fruits. Predators include African crowned eagle *Stephanoaetus coronatus* and leopard *Panthera pardus*; kipunji form polyspecific associations (following Struhsaker, 1981) with the other monkeys present in their range, most frequently with Sykes's monkey (Jones *et al.*, submitted).

(2) Sanje mangabey *(Cercocebus [galeritus] sanjei)*

Taxonomy - This endemic and IUCN-Endangered monkey was discovered in 1979 by Homewood & Rodgers (1981). It was classified as a subspecies of *Cercocebus galeritus* (*C. g. sanjei*) (Mittermeier, 1986; Groves, 1996); this classification was retained by Grubb *et al.,* (2003), whilst others have proposed that specific status is warranted (Kingdon, 1997; Groves, 2001; Ehardt *et al.*, 2005). Resolution of this taxonomic controversy awaits comparative morphological, sonographic and molecular studies between the Sanje mangabey and its sister taxon the Tana River mangabey (*C. g. galeritus*) of Kenya. Despite the taxon having an infra-specific authority (IUCN, 2008), a type specimen has yet to be deposited, as the juvenile that was found in the village of Sanje by the discoverers was not preserved.

Distribution – The Sanje mangabey occurs in only two forests, Mwanihana and Uzungwa Scarp. A third population was thought to occur in Ndundulu forest (Dinesen *et al.*, 2001) but this was a misidentification of kipunji (Jones *et al.,* 2005). Rumours also surfaced in 2006 that Sanje mangabeys might occur in Iyondo forest, but over four weeks of subsequent ground surveys have failed to confirm this, and we conclude that a third population is unlikely (T.J. & F.R., unpublished data). Three visits to the northern, higher elevation part of Iyondo forest were also conducted in 2001 but did not reveal any evidence for this species (Marshall *et al.*, submittted b).

Tab. 2- Features of the main habitat types in the Udzungwa Mountains of Tanzania (from Rovero & De Luca 2007). Details of vegetation zones are from Lovett (1993), however a fine gradient of changing vegetation types with altitude is more realistic (Lovett et al., 2006).

Habitat type	Altitude range	Dominant tree species	Description
Grassland and wooded grassland (WG)	300-1500	*Acacia spp., Brachystegia spp*	Bracken and grassland with scattered trees.
Woodland (W)	300-2000	Low elevation: *Commiphora spp., Adansonia digitata*. Low-to-mid elevation: *Brachystegia spp., Pterocarpus angolensis*. Mid-to-high elevation: *Acacia spp., Uapaka kirkiana*	Deciduous woodland with low canopy (to 20 m) variable from very dense to open.
Lowland forest (LF)	300-800	*Funtumia africana*, *Erythrophleum suaveolens, Treculia africana, Lettowianthus stellatus, Anthocleista grandiflora, Sorindeia madagascariensis, Parkia filicoidea, Pteleopsis myrtifolia*.	Forest with deciduous and semi-deciduous trees, canopy 15-25 m with emergents to 50 m.
Sub-montane forest (SF)	800-1400	*Parinari excelsa, Felicium decipiens, Harungana madagascariense, Allanblackia stuhlmannii, Trilepsium madagascariense, Isoberlinia scheffleri.*	Moist forest with mainly evergreen species, canopy 25-40 m with emergents to 50 m.
Montane forest (MF)*	1400-2600	*Parinari excelsa, Ocotea usambarensis, Hagenia abyssinica, Syzygium sp., Macaranga kilimandscharica, Caloncoba welwitschii*.	Evergreen moist forest, with canopy height progressively lower with altitude.

* MF includes upper montane forest (sensu Lovett, 1993), which is above 1800 m and often contains bamboo towards the peaks of the mountains.

Abundance - Homewood & Rodgers (1981) estimated the total population at 3000 individuals. More recent estimates based on surveys re-scaled the population to be fewer than 1300 (Ehardt, 2001). Further refinement of these estimates led to a figure of 1500 individuals with 600 to 900 occurring in Mwanihana forest, and the rest in Uzungwa Scarp Forest Reserve (Ehardt *et al.*, 2005).

Recent habituation of two groups suggests that these figures may have been biased by an underestimation of mean group size. Primarily, the former estimate of 13.6 individuals per group (Ehardt *et al.*, 2005) is well below the 35-60 individuals now known from other habituated groups (T.J. unpublished data). Moreover, extensive census work in USFR found that Sanje mangabey encounter rates were more than double those in Mwanihana (0.07 groups per km in Mwanihana vs 0.15 in USFR). Whilst the terrestrial and elusive habits of this monkey species prevent them from being effectively censused using the line-transect counts, the results suggest a comparable (or even greater) density of mangabeys in USFR than in Mwanihana. However, we believe that a greater proportion of higher forest in Mwanihana contains mangabeys. Thus, based on previous and our own surveys, we estimate 50-60 groups in Mwanihana, while in Uzungwa Scarp we estimate 30-40 groups. Using the conservative figure of 35 individuals per group it results between 1750-2100 individuals in Mwanihana and between 1050-1400 in Uzungwa Scarp, giving a total population estimate of 2800-3500 animals. These figures should be treated with caution however, as focal

group follows of overlapping habituated groups, increased knowledge of group sizes, and fine-scale habitat suitability analysis will undoubtedly lend more precision.

Socio-Ecology - The following summary information are drawn from extensive study of two habituated groups in Mwanihana forest between 2004 and 2007 (T.J. & R. Laizzer unpublished data). Sanje mangabeys live in multi-male/multi-female groups of approximately 40 to 60 individuals, with up to 5 adult males. Group home range size is approximately 4-6 km^2, and it may overlap with the home range of up to three neighbouring groups. In the highly heterogeneous Mwanihana forest, Sanje mangabey home range can encompass habitats including primary and secondary forest, which are all exploited over the course of an annual cycle. Ranging appears to be primarily determined by the seasonal availability of favoured fruits, which form the greatest component of their diet. The diet also includes flowers, fungi, invertebrates and small vertebrates; over 90 species of food plants have so far been recorded. All strata of the forest are exploited, and travelling and foraging are most often on the forest floor. The extraordinary "whoop-gobble" ritualised loud-call is used by adult males to advertise whereabouts of the group and contributes to preventing inter-group conflicts, which overall are rare. Sanje mangabeys form polyspecific associations in Mwanihana with Sykes's monkey and the two colobines. Their main predators are African crowned eagles, though considerable time spent on the ground also exposes them to leopards and spotted hyenas *Crocuta crocuta*, and defensive bites from cryptic snakes such as Gaboon viper *Bitis gabonica* are also a hazard. Sanje mangabeys can be aggressive towards their predators, especially towards eagles – which on one occasion led to the death of the predator (Jones *et al.*, 2006).

(3) Udzungwa red colobus *(Procolobus gordonorum)*

Taxonomy – Together with the Sanje mangabey, this IUCN-Vulnerable monkey is the other Udzungwa-endemic. Grubb *et al.,* (2003) noted that "the red colobus monkeys have long been one of the thorniest taxonomic problems among the African primates", with various and contrasting classifications being proposed (see Groves 2007 for an account of colobine diversity). However, the same authors recognized the Udzungwa red colobus as one of the few species easily recognizable, together with the Zanzibar red colobus *P. kirkii*, the Tana river red colobus *P. rufomitratus*, and the Western red colobus *P. badius*. Analysis of skull morphology and metrics indicate a clear phenotypic affinity of *P. gordonorum* to *P. badius* in size (Bruner *et al.*, 2006) and to *P. kirkii* in shape (Nowak *et al.*, 2008). Recent molecular phylogeny analyses have shown that congruence between the mitochondrial relationships and those based on pelage and vocalization data are most evident, among other taxa, in the grouping of *gordonorum* with *kirkii* (Ting, 2008).

Distribution – The distribution and vulnerability of the Udzungwa red colobus to extinction have recently been reassessed (Marshall, 2007; Marshall *et al.,* submitted a-b). It occurs throughout the Udzungwa mountains range, as well as few forest patches in the Kilombero valley, notably the Magombera forest that contains approximately 1000 individuals in about 10 km^2 of ground-water forest (Marshall, 2008). Its presence in small forest fragments in the Kilombero valley has decreased drastically in recent years because of habitat destruction for farming and settlements. It also occurred in montane forests in the Vidunda Mountains, immediately north of the Udzungwa across the Ruaha river, where it has been recently extirpated (WWF-TPO, 2006). Within the Udzungwa mountains range, it occurs in nearly all forest blocks, excluding the forests in the south-west (Mufindi) portion, where both earlier (Lovett & Pócs, 1993; Dinesen *et al.*, 2001) and recent surveys (Rovero & Perkin, 2008) failed to detect this species.

Abundance – Accurate abundance estimates are available only for the few forest patches where line-transect censuses have been conducted. Because of large variations in the encounter rate recorded across forests (e.g. USFR: 0.14 groups

encountered per km walked; and Magombera forest: 1.28 groups/km), an overall estimate based on extrapolation is intrinsically difficult. This is further complicated as red colobus encounter rate is also reduced at high elevations (Marshall *et al.*, 2005). The possible reasons for the decrease in red colobus abundance include energy limitations and/or reduced food density and dietary quality of vegetation at high elevations (Marshall *et al.*, 2005). It may also be due to the low availability of young leaves versus the more deciduous lowland forests (Marshall, 2007). Comparative evidence in the literature for such a trend remains scant. Using current data the overall population probably ranges between 25,000 and 35,000 individuals (Struhsaker *et al.*, 2004; Rovero *et al.*, 2006; Marshall *et al.*, submitted a; authors' unpublished data).

Socio-Ecology – The Udzungwa red colobus lives in multi-male/multi-female groups (Struhsaker & Leland 1980), ranging in size from 3 to 83 individuals (n = 134; mean = 27.2; Marshall *et al.*, in press). Extensive work by T. Struhsaker and others has shown that group size is affected by several habitat parameters - including tree density, degree of deciduousness and forest size - interplaying with demographic parameters, such as the size of adult male coalitions and the numbers of adult females and juveniles per group (Struhsaker *et al.*, 2004). Thus, groups are bigger in size in the large blocks of mature, moist, mixed evergreen and semideciduous forest (such as Mwanihana) but not correlated with altitude. Conversely, groups are smaller in small, deciduous and degraded (i.e. low habitat quality) forest (Struhsaker *et al.*, 2004; Marshall *et al.*, 2005; Marshall *et al.*, submitted a).

Like other colobine monkeys, the species is arboreal and is rarely seen on the ground. Activity pattern consists of long feeding bouts alternating with complementary, long resting periods (Rovero, 2003). Observations on feeding behaviour indicate that Udzungwa red colobus include a large variety of plant items in their diet (Wasser, 1993; Decker, 1996; Rovero, 2003; Marshall *et al.*, in press; Marshall *et al.*, submitted a), with large ingestion of leaves and especially young leaves (leaves might account for up to 70% of the diet), together with petioles and other plant parts such as buds and fruits (Rovero, 2003; Pucci & Rovero, 2004). Whilst as few as 5 or 6 plant species might provide the majority of food items to a group at a given time (Decker, 1996; Rovero, 2003; Marshall, 2007; Marshall *et al.*, submitted a), the richness of food plant species in the forest is an important variable correlating overall with the abundance of red colobus (Rovero & Struhsaker, 2007). This might suggest that food variety, as indicated by the number of tree species included in the diet, is an important habitat quality factor year-round. From our observations, the plants that are frequently eaten include: *Albizia gummifera, Antiaris toxicaria, Celtis gomphophylla*, *Entada rheedii* (climber), *Eryhrophloeum suaveolens, Funtumia Africana, Parinari excelsa*, *Parkia filicoidea, Saba comorensis* (climber). Red colobus in the Udzungwas associate with all sympatric diurnal monkeys with the exception of yellow baboons and are most frequently observed in association with Angolan colobus. Predators include African crowned eagle and leopard.

(4) Angolan colobus *(Colobus angolensis palliatus)*

Taxonomy – The form occurring in the Udzungwa Mountains is *C. a. palliatus*, ranging throughout the Eastern Arc Mountains, except North Pare (Rovero & Perkin, 2008), and in coastal Kenya and Tanzania (Kingdon, 1997). The classification of *C. angolensis* is reviewed by Grubb *et al.* (2003). The authors consider the form *C. a. sharpei,* occurring in the Southern Highlands and earlier proposed as a valid subspecies on pelage features, as synonym of *C. a. palliatus*. Preliminary analysis of mitochondrial relationships between populations in Udzungwa, Southern Highlands and Kenya indicates that a greater difference is found between the Kenya and Udzungwa populations (both considered *C. a. palliatus*) than between the Udzungwa and Southern Highlands populations, reflecting geographical distance (M. McDonald unpublished data). Similar patterns of phylogenetic similarities, especially between southern Udzungwa forests and the Southern Highlands, have also been

found for some groups of amphibians and reptiles (M. Menegon personal communication).

Distribution – This species occurs throughout the Udzungwa mountains range as well as in few forest patches in the Kilombero valley (Marshall *et al.*, submitted b). In the southernmost area (Mufindi), it was only recorded in two tiny forest patches at Lulanda and not in the larger forests of this area (Rovero & Perkin, 2008). As observed for the red colobus, the presence of this colobus in the Kilombero valley has probably decreased in recent years, because of habitat destruction. Within the Udzungwa range, its distribution is very similar to that of the red colobus; however, the Angolan colobus seems relatively more common at higher altitudes (e.g. in the upper-montane forest zone; Marshall *et al.*, 2005). Like the red colobus, it is negatively affected by forest degradation, but to a lesser degree (Marshall *et al.*, 2005; Rovero & Struhsaker, 2007; Marshall, 2008; Marshall *et al.*, submitted a-b).

Abundance – Total population abundance is unknown except for a few forests like Magombera (650 individuals; Marshall, 2008 and in press) and Matundu (at least 2,338 individuals; Marshall *et al.*, submitted a), for which there are enough data to provide an estimate. We consider it confusing to attempt an overall estimate, unlike for the red colobus for which more data on group count and density estimation are available, and in view of the endemic and threatened status of that species. There are likely to be at least 10,000 in the Udzungwas as a whole (Marshall *et al.*, submitted a). A comparison of relative abundance data (social group encounter rates) among several forests is given below.

Socio-Ecology – This colobus species lives in one (occasionally 2/3)-male/multi-female groups ranging in size from 2 to at least 14 individuals (Marshall *et al.,* submitted a). Similarly to the pattern observed for the red colobus, group size decreases in degraded forests (Marshall *et al.*, 2005, Marshall submitted a). Typically an arboreal monkey, this colobus spend large amounts of time resting, and feeds predominantly on mature leaves (D. Dahl Lisbjerg, T. Struhsaker, A.R.M. & F.R. unpublished data). A preliminary list of food plants in Matundu forest is reported by Marshall *et al.* (submitted a), with two trees (*Celtis gomphophylla* and *Erythrophleum suaveolens*) accounting for a consistent proportion of feeding observations. Angolan colobus associate with all sympatric diurnal monkeys with the exception of yellow baboons, and are most frequently observed in association with Udzungwa red colobus. This species exhibits notable aggressive defence against its main predator, the African crowned eagle, with adult males often approaching within a few metres of an eagle perched in a tree, vigorously displaying.

(5) Sykes's monkey *(Cercopithecus mitis)*

Taxonomy – This monkey is part of the large and highly polytypic *Cercopithecus mitis/albogularis* subgroup of guenons (reviewed in Grubb *et al.*, 2003). The subspecific status in the Udzungwa Mountains is uncertain, as it cannot be unequivocally attributed to either *monoides* ("Tanzania Sykes's monkey" by Grubb *et al.*, 2003) or *moloneyi* ("Moloney's white-collared monkey"). T. Butynski (personal communication) suggests the form occurring in the Udzungwa is likely part of a long cline of *C. mitis* forms which runs from at least southeast coastal Kenya and northeast coast of Tanzania (*C. m. kibonotensis*), up the Rufiji river (*C. m. monoides*), to at least the Southern Highlands in southwestern Tanzania (*C. m. moloneyi*). Similar phenotypic clines for *C. mitis* occur in central Kenya and in the Albertine (Western) Rift Valley.

Distribution – It occurs throughout the Udzungwa Mountains range as well as in forest patches in the Kilombero valley. In Mwanihana forest, this species prefers secondary, regenerating and semideciduous zones of the forests (Rovero *et al.*, 2006), however, it is also common in higher elevation forests (e.g. Marshall *et al.*, 2005). In other areas (e.g. Matundu) the preference for secondary, regenerating and semi-deciduous forest has not been confirmed (Marshall *et al.*, 2005; Marshall, 2008; Marshall *et al.*, submitted a-b), although the species is not so clearly negatively influenced by habitat degradation as the two colobines.

Abundance – Total population abundance is unknown. By being more elusive than the two colobus, it is more difficult to spot from line-transects and, most critically, reliable group counts are difficult to obtain. A comparison of relative abundance data among forests is given below.

Socio-Ecology – This monkey lives in mono-male/multi-female groups ranging in size from 2 to at least 22 individuals (Rovero *et al.*, 2006; A.R.M. unpublished data). It is an opportunistic species that uses all vertical forest strata and feeds predominantly on fruits. A preliminary list of food plants for Matundu forest is reported in Marshall (2007) and Marshall *et al.* (submitted a), which includes several, unidentified climbers, and the tree species of *Antiaris toxicaria, Erythrophleum suaveolens*, *Ficus sycomorus*, *Khaya anthotheca* and *Parkia filicoidea*. Sykes's monkeys are found in polyspecific association with Sanje mangabeys, Angolan colobus and Udzungwa red colobus.

(6 - 7) Yellow baboon *(Papio cynocephalus) and* vervet monkeys *(Chlorocebus pygerythrus)*

We do not provide a detailed introductory account for these two species as they are widespread, savannah monkeys and most research in the Udzungwa mountains has focussed on forest primates. Their known occurrence among several forest fragments in the Udzungwa Mountains is presented in Marshall *et al.* (submitted b), but they are likely to be widespread in the intervening human-dominated landscape. Yellow baboon ranges from Somalia to the Zambezi valley and across south-central Africa to Angola, whilst vervet monkey ranges throughout eastern and southeastern Africa (Kingdon *et al.*, 2008). In the Udzungwa Mountains, yellow baboons are mostly found in the dry woodland and wooded grassland areas inside the Udzungwa Mountains National Park, but their detailed distribution and abundance is unknown. In Iyondo and Matundu, they occur in the interior of the low-land transitional forest. They are also found in the Kilombero valley and in the lower, deciduous zone of the large forest blocks such as Mwanihana and Uzungwa Scarp. In these two forests, monitoring data on baboons have been collected over the years (see below). Baboon crop-raid regularly when in proximity of villages and farms, causing increasing conflicts with the local people especially on the east side of the Udzungwa Mountains National Park. On the contrary, vervet monkeys are rarely seen in the Udzungwa Mountains, only occurring at forest edges such as Magombera and Dabaga (Marshall, 2008; Marshall *et al.,* submitted b).

Nocturnal primates: species accounts

With six species, the Udzungwa Mountains has a large assemblage of galagos, or bushbabies (Tab. 1; photographs in Fig. 4). The area has received relatively wide survey coverage for galagos but gaps still remain and many observations remain unpublished. In comparison, Mozambique has only three galagos species and Kenya six. In the Udzungwa, surveys have been conducted in Matundu (where *G. zanzibaricus udzungwensis* was described from; Honess, 1996), in several forest patches in the UMNP, Ndundulu, Nymbanitu, Uzungwa Scarp and southern, Mufindi forests (Butynski *et al.*, 1998; Perkin, 2001; Butynski & A.P., unpublished data). Various other biologists have provided opportunistic records, mainly from forest areas, whilst comprehensive surveys are still lacking in the dry woodland areas.

Almost all the galago species are allopatrically distributed throughout the mountain range (map in Fig. 2). At most two species are found sympatrically, these being *G. zanzibaricus udzungwensis* and *G. orinus*, whose ranges narrowly overlap at around 1000 m a.s.l. at sites such as Mwanihana and Uzungwa Scarp, and *Otolemur crassicaudatus* (a woodland dwelling galago) and *O. garnettii* (a forest dwelling galago), whose ranges narrowly overlap in the northern part of UMNP. Conversely, in other sites in the Eastern Arc and coastal forests two or three species are fully sympatric. There are also some apparent distributional "anomalies": *O. garnettii* is a widespread species throughout the Eastern Arc and coastal forests but in the Udzungwa Mountains was only recorded at one site along a riverine forest strip at Mbatwa (northern UMNP). Similarly, an isolated

Fig. 4 - The six species of galagos, or bushbabies, occurring in the Udzungwa Mountains of Tanzania. The top ones and the one on the mid left belong to the genus Galagoides, and weigth 88-165 g for 137-160 cm in total body length: Mountain galago (top left, Ndundulu forest, western Udzungwa, photo M. Menegon), Udzungwa galago (top right, Pande Game Reserve, eastern Tanzania, photo N. Doggart), Grant's galago (mid left, from Rondo, southeastern Tanzania, photo S. Bearder). The Senegal galago belongs to the genus Galago and weigths 112-300 g for 132-210 cm in total body length (mid right, western Udzungwa, photo M. Poulsen). The bottom ones are "greater galagos" of the genus Otolemur and weigth 550-1800 g for 230-400 cm in total body length: Greater galago (bottom left, from South Africa, photo S. Bearder) and Small-eared galago (bottom right, Pemba island, photo B. Hayes). The colour version of this figure is available at the JASs website.

record of *G. granti* was reported for Lulanda forests (Mufindi); in Tanzania this species has only been recorded south of the Kilombero and Rufiji rivers. These distributional records are likely to be a combination of the variety of habitat types within the Udzungwa Mountains and biogeographical factors.

Being the galagos nocturnal, small (100-2000 g) and arboreal, studying them in the wild is challenging. They are primarily identified in the field from their vocal repertoire which may contain more than 20 different call types. The species-specific advertising call is primarily used to identify species, in addition to visual records and live-trapping. Only two species occurring in the Udzungwa have been studied using radio-tracking, whilst most of what is known is based on miscellaneous observations collated from different observers. Unless otherwise quoted, the information reported here are from A.P. (unpublished data).

(1) Large-eared Greater galago
(Otolemur crassicaudatus)

Taxonomy - The genus *Otolemur* was included in *Galago* in recent years, but sepatarated by Olson (1979). He differentiated the two species *O. crassicaudatus* and *O. garnettii* and various subspecies, which had broadly been recognized in earlier reviews. All of these reviews were museum based studies. Despite Olson's (1979) thorough review, the taxonomy of *O. crassicaudatus* is still debated as some authors recognise more species within this taxon due to the several sub-species and geographic variation. Moreover, vocalization data (Zimmermann, 1990; Bearder *et al.*, 1995; A.P. unpublished data) suggest that there is very little intra-specific variation in the loud call of *O. crassicaudatus* throughout its range. Here, we follow Olson (1979), Jenkins' (1987), Zimmermann (1990) and Grubb *et al.* (2003) in recognising only *O. crassicaudatus* (plus *O. garnettii*) within genus *Otolemur*. The currently recognised subspecies are *O. c. crassicaudatus, O. c. monteiri* and *O. c. argentatus.* The subspecies occurring in the Udzungwa Mountains is *O. c. monteiri*.

Distribution - *O. crassicaudatus* is distributed in woodland habitats from southern Kenya and Uganda south to South Africa and west to Angola. In the Udzungwa Mountains this species has a patchy distribution from the Mbatwa area in northern UMNP west to the Udekwa village woodlands and south to Mufindi in various woodlands (including mixed farmland and *Eucalyptus* plantations). There is one record of *O. crassicaudatus* from village land at Mang'ula in the eastern foothill of UMNP and in the Ruaha river gorge, and one at Mbatwa (northern UMNP; A.P. unpublished data; D. De Luca personal communication) otherwise we have very few records from the lowland parts of the eastern UMNP and no records from the woodlands of the central valley in the UMNP. In the southeastern Udzungwa Mountains there are scattered records of *O. crassicaudatus* near Chita and Ifakara indicating that it occurs throughout the low elevation woodland in this area (M. Menegon & T. Jones personal communication).

Abundance - No studies have been carried out but densities appear to be low based on individual sightings collected from several intensive nocturnal surveys that mainly occurred in forest habitat (Honess, 1996; Butynski *et al.*, 1998; Perkin, 2001; Perkin, unpublished data). This species is hard to overlook due to its large size and characteristic loud calls. However, further surveys in the woodland areas of the Udzungwa Mountains may reveal additional records.

Socio-ecology - *O. crassicaudatus* in nocturnal, arboreal and lives in dispersed groups. It is the most gregarious of all the galagos, probably due to its large body size and diet. In areas where fruit is abundant, the young stay with the mother during the long period of immaturity (15 months) and they frequently move with her as a cohesive group (Clark, 1985; Bearder, 1987). Grouping also occurs at sleeping sites during the day when a mother and three offspring may be joined by an adult male. Communication involves a wide range of auditory, visual, tactile and olfactory signals including 18 structurally distinct calls (Bearder, 1974; Clark, 1978; Bearder, 2007). Sleeping sites are made in a dense tangle of creepers and branches

at a height ranging from 5 to 12 m above ground. Adult females make nests when they have infants: leafy platforms that are inaccessible, depressed in the middle and with foliage above to provide shelter (Bearder & Doyle, 1974). *O. crassicaudatus* is omnivorous, eating insects, fruit and gum in varying proportions (Bearder & Doyle, 1974). Trees that produce abundant gum from established wounds (usually *Acacia karoo*) are visited regularly (Harcourt, 1986). Flowers, seeds, nectar, millipedes, and insects also consumed (Clark, 1985; Harcourt, 1986).

(2) Small-eared galago *(Otolemur garnettii)*

Taxonomy - Originally called *Otolicnus garnettii* by Olgiby, with no provenance given to the type specimen, the type locality was designated to be Zanzibar Island (now called Unguja I). Since then, numerous synonyms for both the generic and specific name have been used (for details see Olson, 1979). Until recently, this taxon was considered a subspecies of *Otolemur* (also called *Galago*) *crassicaudatus* (e.g. Hill, 1953; Petter & Petter-Rousseaux, 1979). It is now generally accepted to be a full species (Olson, 1979; Harcourt, 1984; Jenkins, 1987; Masters, 1988; Nash *et al.*, 1989; Groves, 2001; Grubb *et al.*, 2003). Following Groves (2001), four subspecies are recognised.

Distribution - Endemic to eastern Africa, Somalia-Maasai Bushland and Coastal Forest Mosaic biotic zones. It occurs in coastal and riverine forests from Juba River, Somalia, south to Ruvuma River, Tanzania. Also on Zanzibar, Pemba and Mafia Islands. Inland in the forests of the Kenya Highlands, Mount Kilimanjaro and most of the Eastern Arc Mountains. Olson (1979) indicates that *O. garnettii* also occurs just south of the Ruvuma River in Mozambique, and that it may occur farther south. There is one confirmed record from Milo Forest, Southern Highlands (Honess, 1996; A.P. & T. Davenport personal observations). Although the map in Nash *et al.* (1989) shows *O. garnettii* in the Udzungwas Mountains, there is no evidence of this (Honess, 1996; Butynski *et al.*, 1998; Perkin, 2001) except for one record from a small riverine forest at Mbatwa, northern UMNP (Perkin, unpublished data). The species has also been recorded in the adjacent Uvidunda Mountains (Iyunji forest; T. J., personal communication).

Abundance – The single geographic record currently collected is unusual given the large areas of potentially suitable forest habitat in the Udzungwa Mountains. Only three to four individuals were seen or heard along a 500 m stretch of riverine forest during a four day survey in 2004 (Perkin, unpublished data).

Socio-ecology – This galago is nocturnal and arboreal and lives in dispersed groups, although it is solitary when foraging. Adults spend most of the night alone and, usually, sleep alone as well, though grooming and play between individuals does occur. That it is apparently less social than *O. crassicaudatus* may be due to fewer infants being born or to differences in diet between the two species (Nash & Harcourt, 1986). *O. garnettii* has an extensive vocal repertoire with 12 spectrographically different call types used by adults of both sexes (Zimmerman, 1990; Bearder *et al.*, 1995). Vocalizations are given to announce their presence to other individuals, whilst most other calls are associated with alarm situations (Harcourt, 1984; Bearder *et al.*, 1995). This galago spends the day in sleeping sites of tangled vegetation in tall bushes or trees, whilst the use of tree holes is unknown. *O. garnettii* is omnivorous and forages mostly in trees, spending approximately half of the time above 5 m from ground (Harcourt & Nash, 1986). Diet at Diani in coastal Kenya is made of about 50% animal matter and 50% fruit. Invertebrates make up the majority of the animal matter, mostly beetles, orthopterans and centipedes (Harcourt & Nash 1986). *O. garnettii* also forages in farmland, taking bananas, breadfruit, mangos, paw paw and other fruit crops, including coconut tree sap, which is tapped by local people for producing "palm wine".

(3) Senegal galago *(Galago senegalensis)*

Taxonomy – This taxon is a polytypic species. Originally, only the species *Galago senegalensis* was recognized (Schwartz, 1931). Seven species have since been split from this taxon: Southern Lesser

Galago *Galago moholi*, Somali Lesser Galago *Galago gallarum*, Spectacled Lesser Galago *Galago matschiei,* Zanzibar Galago *Galagoides zanzibaricus*, Mozambique Galago *Galagoides granti*, Malawi Galago *Galagoides nyasae*, and Kenya Coast Galago *Galagoides cocos*, based on differences in vocalizations, genetics, and in the morphology of the body, cranium, penis and hand pads (Nash *et al.*, 1989; Zimmermann, 1990; Anderson 1999; Bearder, 1999; Anderson *et al.*, 2000; Del Pero *et al.*, 2000; Masters & Bragg, 2000; Anderson, 2001; Groves, 2001; Grubb *et al.*, 2003). All species can be distinguished by their species-specific advertisement call. It may well be that additional cryptic species will be recognized within *G. senegalensis* as this remains a widespread taxon with considerable variation (Masters & Bragg, 2000). The sub-species recognised are *G. s. senegalensis, G. s. braccatus, G. s. dunni* and *G. s. sotikae*. In the Udzungwa Mountains, it is unclear which subspecies occurs as the exact ranges of the subspecies are not known, but it is most likely *G. s. braccatus.*

Distribution – The most most widely distributed galago occuring in woodland habitats of sub-Saharan Africa, from Senegal (ca. 16° N) to the Gulf of Aden (ca. 15° N) in the area between the Sahara and coastal forest in the west, and the forests of the Congo Basin on the south. Over most of its range, *G. senegalensis* is the only small galago in savannah, thorn scrub and woodland, whilst it is sympatric with *O. crassicaudatus* in several parts of East Africa (Nash *et al.*, 1989). The range of *G. senegalensis* in Tanzania is poorly understood, but it occurs in dry *Acacia* and *Brachystegia* woodland approximately from Lake Rukwa to the northern parts of the Udzungwa Mountains. Further to the south, *G. senegalensis* species is predicted to meet with the southern lesser or Mohol galago *G. moholi* in southeast Tanzania within suitable woodland habitats. In the Udzungwa Mountains *G. senegalensis* is only known from a single record from the woodland west of Ndundulu/Luhomero forest; M. Poulsen, personal communication), confirming its presumed occurrence as previously suspected (Rovero & De Luca, 2007).

Abundance – The single record currently available despite the considerable survey effort deployed indicates that *G. senegalensis* occurs at low densities in the Udzungwa Mountains.

Socio-ecology - No major studies have been conducted on *G. senegalensis* in the wild. This species is nocturnal, arboreal and occurs in small dispersed groups of 1 to 6 animals (Haddow & Ellice, 1964). Animals usually forage alone and occasionally in groups of up to 3 individuals. *G. senegalensis* has an extensive vocal repertoire with 18 spectrographically different call types used by adults of both sexes. Loud calls used in contact and alarm situations are the most prominent calls of the species' repertoire (Zimmermann, 1985; Anderson *et al.*, 2000). This galago nests in tree holes, old bird nests and beehives, with leaves being brought in the mouth to line the nests (Haddow & Ellice, 1964). Few studies suggest that its diet is similar to that of *G. moholi* (Bearder & Doyle, 1974; Bearder & Martin, 1980). Studies of stomach contents revealed that the diet is predominantly made of animal matter: Coleoptera and Lepidoptera (caterpillars) as well as spiders, scorpions and winged termites (*Alates*).

(4) Udzungwa galago *(Galagoides zanzibaricus udzungwensis)*

Taxonomy - The taxonomy of *Galagoides zanzibaricus* is not fully resolved. Previously regarded as a subspecies of *Galago senegalensis* (Schwartz, 1931), the specific name was revived by Kingdon (1971). It was moved from genus *Galago* to genus *Galagoides* by Olson (1979) and subsequently split off in three species: Mozambique (Grant's) Galago *Galagoides granti,* Zanzibar galago *Galagoides zanzibaricus*, and Kenya Coast Galago *Galagoides cocos* (Honess, 1996; Groves, 2001; Grubb *et al.*, 2003), based on differences in vocalisations, and in body, penile and hand morphology (Bearder *et al.*, 1995; Honess, 1996; Anderson, 2000; Groves, 2001; Butynski *et al.*, 2006; Perkin, 2007). There are two sub-species: Zanzibar Galago *G. z. zanzibaricus* and the Matundu Galago *G. z. udzungwensis* (Honess, 1996; Honess & Bearder, 1996; Butynski *et al.*, 2006). The latter subspecies was

originally described as a full species (*G. udzungwensis*) by Honess and Bearder (1996), with Matundu forest being the type locality. The taxon was then considered conspecific and a synonym of *G. zanzibaricus* (Groves, 2001; Grubb *et al.*, 2003) following data by A. P. and then recognised as a subspecies of *G. zanzibaricus* by Butynski *et al.* (2006), that maintained the name of the type population from Unguja I., Zanzibar as *G. z. zanzibaricus*. The name *G. z. udzungwensis* was maintained to avoid new names being introduced even though it is not endemic to the Udzungwa Mountains.

Distribution - Endemic to lowland forests of Tanzania. *G. z. zanzibaricus* is endemic to Zanzibar and probably Mafia islands (subspecies pending identification) but absent from Pemba (Butynski *et al.*, 2006; A.P., unpublished data). *G. z. udzungwensis* is endemic to the Eastern Arc Mountains and coastal forests of mainland Tanzania. Its distribution on mainland ranges from the East Usambara and South Pare Mountains south to the Rufiji River and west to the Udzungwa Mountains (where the southern Kihanzi gorge is the known southwestern limit of this species). It is replaced at Kihanzi – southernmost tip of Uzungwa Scarp - and south of the Rufji River by *G. granti* (Butynski *et al.*, 2006). In the Udzungwa Mountains it is widespread in lowland forests generally below 600 m, locally to 1000 m (e.g. at Kihanzi). The species locally overlaps with *G. orinus*.

Abundance - *G. z. zanzibaricus* is widespread in eastern and southern parts of Unguja Island (Zanzibar) where suitable habitat remains. Recent surveys led to density estimatations of over 200 individuals/km^2 (Butynski *et al.*, 2006), however densities of *G. z. udzungwensis* are highly variable. It is common in the lowland Udzungwa Mountains where 10.0 animals per hour were encountered (survey effort of 290 hours; Butynski *et al.*,1998; A.P., unpublished data). In contrast, 3.7 animals per hour were encountered (effort of 10 hours) in the small (405 ha) Kimboza Forest Reserve in the lowland Uluguru Mountains, and only 0.3 and 0.4 animals per hour in lowland forest at two sites at Kihanzi, southern Uzungwa Scarp (survey effort of 5 and 12 hours, respectively; Honess, 1996 and A.P. unpublished data). In Matundu forest, during the 'dusk chorus', up to 20 individuals per hectare were recorded calling (equivalent to over 500 individuals/km^2), as compared to less than 100 individuals/km^2 reported for at other sites in the range of this species (Butynski *et al.*, 1998; Butynski *et al.*, 2006).

Socio-ecology - *G. z. udzungwensis* is nocturnal, arboreal, occurs in dispersed groups but is a solitary forager. Relatively little is known about this taxon. Observations suggest the social system is similar to that of *G. cocos*, i.e. dispersed monogamy with one adult male in close association with one or two adult females (Harcourt & Nash, 1986; Bearder, 1987; Harcourt & Bearder, 1989; Honess, 1996). Groups of 2-4 individuals emerge at dusk and counter call with the advertisement call is a 'Single Unit Rolling Call' which often used as a 'gathering call' (Honess, 1996, Bearder *et al.*, 2003). This species-specific call is composed of trilled units which increase then decrease in intensity and is given more frequently than other calls, up to 90% of calls recorded (Honess, 1996; Butynski *et. al.*, 2006). The nests are made in tree holes and in tangles of dense vegetation and are lined by freshly-cut leaves brought in the mouth. It usually forages within 10 m of the ground and on branches that are 0.5-5 cm in diameter (Honess, 1996). The little information on diet and feeding ecology indicates preference for fruits and invertebrates. Unusually, this species has not been observed to eat gum in the wild.

(5) Mountain galago *(Galagoides orinus)*

Taxonomy – The mountain galago was originally described as *Galago demidovii orinus* (Lawrence & Washburn, 1936) from one specimen taken from the Uluguru Mountains (Allen & Loveridge, 1927) and recognised as a full species based on differences in vocalizations and morphology (Honess & Bearder, 1996). The specific status was accepted by Kingdon (1997), Groves (2001) and Grubb *et al.* (2003). Penile morphology of *G. orinus* indicates that this taxon is highly distinct, although this is based on data

from only two individuals from the Udzungwa population, and not the type population (Perkin, 2007). Moreover, there is considerable variation in the vocal repertoire among the populations of *G. orinus* in the Eastern Arc Mountains (Perkin *et al.,* 2002). Comparative analysis in particular of the advertising calls has shown spectrographically different vocal repertoires (see details in socio-ecology paragraph) from the populations of: (1) Taita hills (Perkin, 2002), (2) Usambara, Nguru, Rubeho, and Uluguru Mountains, and (3) Udzungwa Mountains (A. P. unpublished data). Given that vocal repertoires have been found to be species-specific and are used to recognise galago species in the wild, this preliminary finding may imply that the Udzungwa population of *G. orinus* is a new cryptic species. Further comparative studies based on phylogenetic and morphology (pelage, face masks and penile morphology) will be required to to assess the degree of distinctiveness. Current research based on integrating vocalizations, reproductive anatomy and genetics generally indicates a greater diversity of galago species than previously realised (Masters, 1988, Bearder *et al.*, 1995; Honess & Bearder, 1996; Groves, 2001; Perkin *et al.,* 2007).

Distribution – It is an Eastern Arc-endemic species, known from the Udzungwa, Uluguru, Rubeho, Nguru, Ukaguru, South Pare, East and West Usambara Mountains (Perkin, 2000; Perkin, 2001; Perkin *et al.*, 2002; Doggart *et al.*, 2006; A.P., unpublished data). It occurs in the sub-montane and montane moist forest with altitudinal range of 600-2600 m a.s.l. (Butynski *et al.*, 1998; Perkin, 2000, 2001; Doggart *et al.*, 2006).

Abundance – The abundance is highly variable but accurate data are difficult to obtain since *G. orinus* spends much time in the canopy, making detection difficult. In undisturbed forest habitat, Perkin (2001) from the Uluguru Mountains and Honess (1996) from the East Usambara Mountains report encounter rates of 2.7 animals per hour (survey effort of 30 hours) and 1.2 animals per hour (34 hours), respectively. In disturbed sites within the same forests, encounter rates were higher, i.e. 5.4 (74 hours) and 4.7 (14 hours) respectively. In the Udzungwa Mountains, relatively low encounter rates were recorded in the less disturbed sub-montane and montane forests at Udzungwa Scarp, Ndundulu and Luhomero (Butynski *et al.*, 1998; Perkin, 2001). In Kigogo and Mufindi Scarp East, two of the largest forests in the southern Udzungwa range, encounter rates were relatively high (3.2 animals per hour). Overall, it is concluded that *G. orinus* occurs at a low density (possibly less than 100 individuals/km^2) throughout most of its range (Butynski *et al.*, 1998).

Socio-ecology - No studies have been carried out on the behaviour and socio-ecology of *G. orinus.* Observations indicate that *G. orinus* is nocturnal, arboreal, lives in dispersed groups but is a solitary forager whilst maintaining contact with conspecifics through high-pitched contact calls. The advertising call of the type population (Uluguru Mountains) is the "croak", or double unit repetitive call which comprises of two low frequency croak units repeated at low then higher amplitudes. The Udzungwa population has a distinctively different advertising call, the "squeak" and the single unit repetitive call which comprises of a high frequency squeak unit of two-to-six subunits followed by low frequency repeated series of single "churr" units (A.P., unpublished data). This galago uses nests in tree holes for daytime sleeping, holding up to seven individuals (F.R., personal communication). At night time it uses all forest strata, is fast moving and capable of jumps longer than 5 m. It uses a combination of hearing, sight and olfactory senses to locate prey, communicate with conspecifics, and detect predators. It has been observed mobbing predators such as palm civets *Nandinia binotata* with intense bouts of alarm calls. The limited data available suggest that *G. orinus* is omnivorous, and feeds on moths, cockroaches, gum from the liana *Toddalia asiatica* and takes baits of banana and peanut butter. Insects probably form a predominant portion of the diet, and are taken in the trees and occasionally from the leaf litter.

(6) Grant's galago *(Galagoides granti)*

Taxonomy - Originally described by Thomas & Wroughton (1907) as a full species (*Galago*

granti), it was named after the collector, C.H.B. Grant (Elliot, 1913). Subsequently, Grant's galago was classified as *Galago senegalensis granti* (Schwarz, 1931) and following subdivision of *G. senegalensis*, and recognition of the Zanzibar galago (*G. zanzibaricus*) by Kingdon (1971), it was classified as a southern subspecies of the Zanzibar galago, *Galago zanzibaricus granti* (Jenkins, 1987) or *Galagoides zanzibaricus granti* (Olson, 1979; Nash *et al.*, 1989; Skinner & Smithers, 1990). It was finally placed in its current genus - and confirmed at full species status - by Honess (1996) based on species-specific advertisement calls, penile and hair morphology (Anderson, 2001; Butynski *et al.*, 2006; Perkin, 2007).

Distribution – This galago is endemic to southeastern Africa (Zambezian Woodland and Coastal Forest Mosaic Biotic Zones). *G. granti* ranges between the Rufiji river in the north to the proximity of Limpopo river in the south. Inland it ranges into the mountains of eastern Zimbabwe and around the shores of Lake Malawi (Jenkins, 1987; Honess, 1996; Kingdon, 1997; Perkin, 2000). It is a habitat generalist, typically preferring lowland forest, coastal forest and thicket as well as forest woodland mosaics, thus differing from the dry woodland-specialists such as *Galago moholi*. It is occasionally found in submontane forest (e.g. in the Mahenge Mountains, southwest of the Udzungwa Mountains) where is appears to replace *G. orinus*. The altiudinal range is 0-1800 m a.s.l. In the Udzungwa Mountains, this species is rare, being only recorded in a small forest fragment in the Mufindi area (Lulanda). This is the only confirmed record of this taxon northwest of the Rufiji River.

Abundance – Surveys conducted in coastal forest sites, southeastern Tanzania, yielded encounter rates of 3.8 animals per hour at Rondo forest (900 m a.s.l.), 4.5 at Mtopwa (40 m a.s.l.; Honess, 1996), 4.3 at Noto (450 m a.s.l.), and 4.9 at Namatimbili (300 m a.s.l.). At Lulanda forest, Udzungwa Mountains, the relatively low encounter rate recorded (1.2) indicates a low population density.

Socio-ecology - *G. granti* is nocturnal and arboreal but very little is known about the socio-ecology of this species. It occurs in dispersed groups of up to six individuals, but most observations are of solitary animals (Honess, 1996). Observations suggest that the social system is similar to that of *G. cocos,* i.e. dispersed monogamy with one adult male in close association with one or two adult females. Advertising call are often answered by conspecifics and mostly given in the first two hours after sunset and last two hours before sunrise, corresponding with emergence from, and gathering for, sleeping. This galago uses tree holes as nest sites (Thomas & Wroughton, 1907; Honess, 1996; Bearder *et al.*, 2003). The diet includes insects, fruits and gum (Honess, 1996; Perkin, unpublished data). Stomach contents of specimens collected at Newala, southwestern Tanzania, had fruits, flowers and insect remains (Lumsden & Masters, 2001).

Patterns in species richness and relative abundance of diurnal primates

Species richness

Marshall (2007) and Marshall *et al.* (submitted b) have investigated the relationship between species richness and fragment size among the seven monkey species, thus updating the knowledge of the distribution of these species across the Udzungwa Mountains. Using data from 22 forest fragments, the authors deployed multivariate techniques to determine the species-area relationship and assess the influence on species richness of four co-variables relating to human pressure and habitat.

Species richness is shown to have a log-linear, significant relationship with forest area, with the logarithm of forest size explaining nearly 51% of the variance of species richness in a Generalized Linear Model analysis. Correlation between forest area and elevation range suggests that larger forests have a broad elevation range and therefore high diversity of habitats. The species-area relationship must therefore be influenced by habitat diversity. In some of the northeastern forests, human population pressure has also influenced species richness, largely through hunting and

isolation. Notably, the seven small forests (<11 km^2) that are both isolated by farmland and affected by hunting have fewer species than the six other small forests (Marshall *et al.*, submitted a). The species most affected by this condition is the red colobus, thus supporting earlier sources highlighting the vulnerability of this and other red colobus species (Struhsaker, 1999; Mitani *et al.*, 2000). Hunters report that red colobus monkeys are easily shot, whereas mangabeys are extremely difficult to shoot (Jones, unpublished data); this is also supported by our behavioural observations. The major conclusion of this analysis is that large forests support more species, with forests above 150 km^2 being the most important for conservation, and that annual bush-fires are restricting the diversity of Udzungwa primates by preventing connectivity and expansion of most forests.

Relative abundance

The species-area relationship analysis allowed development of important hypotheses on broad distributional patterns and drivers of community impoverishment (e.g. Lomolino, 2000) using a large spectrum of Udzungwa forests. For a much more limited set of forests, population abundance data are also available, allowing assessment and monitoring of populations, and also detailed investigations into the drivers of population change.

The line-transect method is very well established and routinely deployed for forest monkeys (e.g. Struhsaker, 1997; Mitani *et al.*, 2000) and allows determination of both relative abundance data (encounter rates, i.e. the number of social groups per km of transect walked) and density estimations through various analytical techniques based on distance sampling (Marshall *et al.*, 2008). Despite unknown variations in visibility, that certainly require future assessment, encounter rates are the simplest approach for comparing different forests in the Udzungwa Mountains.

Data summarized here have been collected in six forests over the last 10 years using line-transect census. Transects were 3 to 4 km in length and repeated usually twice a month (see methodological details in Rovero *et al.*, 2006). The number of transects set at each site varied from 2 to 3. The number of repetitions varied from 10 to 85 depending on the study purpose (population assessment or monitoring project). In particular, long-term data are being collected in Mwanihana, Magombera and Uzungwa Scarp as part of ecological monitoring programmes.

The analyses indicate that there are dramatic variations in relative abundance of any species across sites (Fig. 5). Mwanihana and Uzungwa Scarp (USFR) are comparable forests, as they both represent east-facing escarpment slopes of similar size and altitudinal/vegetation gradient. The transect lines sampled the lower to sub-montane forest at both sites. However, whilst the former has been relatively well protected, the latter has been poorly managed and the forest is affected by hunting and canopy degradation from tree cutting (Museo Tridentino di Scienze Naturali, 2007). These differences may explain the clear lower abundance of both colobine monkeys in USFR than Mwanihana (DeFries *et al.*, 2009). The Sanje mangabey was relatively more abundant along transects in USFR, suggesting a combination of greater habitat suitability and/or lower vulnerability to hunting (Rovero & Struhsaker, 2007; Marshall *et al.*, submitted a). These results make USFR a top-priority site for the conservation of this flagship species.

The two sites sampled in Matundu forest include fairly intact forest in the east, and heavily disturbed semi-deciduous and regenerating forest in the west near the Ruipa river. As further discussed in the next chapter, habitat features may affect the abundance of the canopy-dependent red colobus. Moreover, lower abundance in degraded forest appears also to be associated with decreased group size and altered natality and age/sex composition (Struhsaker *et al.*, 2004; Marshall *et al.*, submitted a). A similar relationship has been found in Ndundulu/Luhomero and New Dabaga/Ulangambi forests (both in the north-west) for both colobines and Sykes's monkey (Marshall *et al.*, 2005). On the contrary, Magombera forest, a remnant patch of ground-water forest in the Kilombero valley, is special as it yields the highest

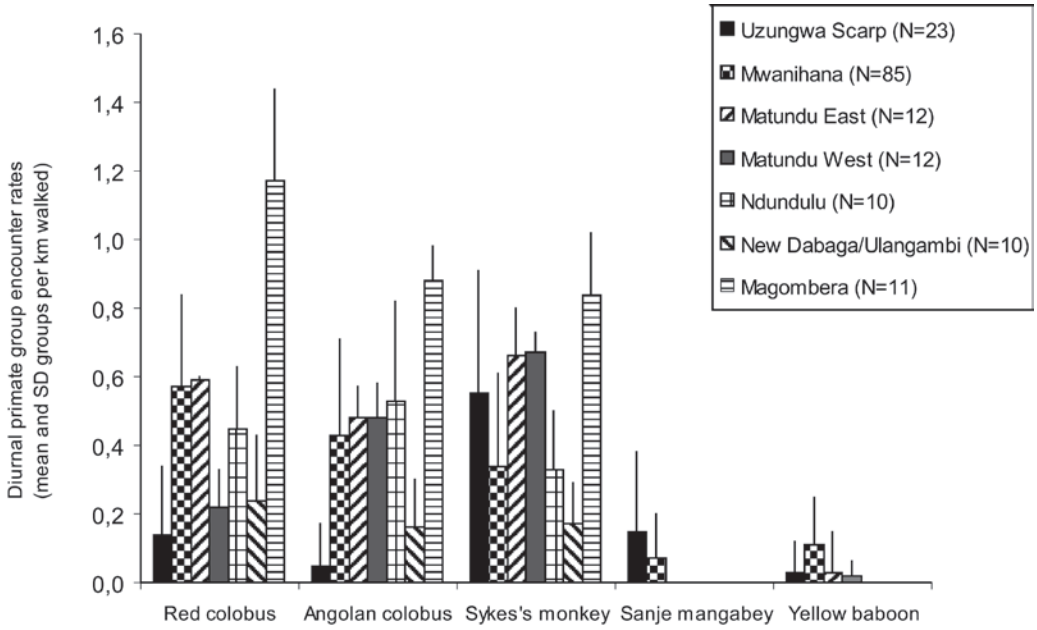

Fig. 5 - Summary of diurnal primate encounter rates (number of social groups recorded per km walked) across 7 sites in six forests in the Udzungwa Mountains. Data source: F.R./UEMC unpublished data (Uzungwa Scarp); Rovero et al., 2006/UEMC unpublished data (Mwanihana); Marshall et al., submitted a (Matundu); Marshall et al., 2005 (Ndundulu and New Dabaga/Ulangambi); Marshall in press (Magombera). UEMC = Udzungwa Ecological Monitoring Centre.

encounter rates than anywhere for both colobus and Sykes's monkey. Marshall (2008) argues that a compression effect, as a result of drastic forest reduction and isolation, might have influenced the unusual high abundance of primates in Magombera.

Effects of Vegetation and Human Disturbance on Abundance

Mwanihana forest

The work summarized above has helped refine research questions towards understanding the underlying determinants of primate abundance and group size, prompting more detailed analyses of the important features of vegetation and human disturbance. Relations between primate occurrence along the transect lines and gross vegetation type have been analysed for the diurnal primates censused in Mwanihana (Rovero *et al.*, 2006). This work indicated that both colobus prefer evergreen and semi-evergreen forest, Sykes's monkeys prefer semideciduous forest, while yellow baboon prefer the lower deciduous forest. Subsequently, Rovero & Struhsaker (2007) used multivariate regression analysis to investigate the relationship between primate occurrence and a set of vegetative variables. These variables were derived from measuring trees above 10 cm of diameter at breast height (DBH) along a 5 m-wide strip centred on the transect line. The authors used portions of 200 m to build a regression analysis to account for the fine-scale variations in primate abundance (presumably related to high vegetation heterogeneity). For the red colobus only, data on food plants from focal group observations were also available.

A summary of the vegetative and human predictors of monkey abundance is reported in Table 3. In Mwanihana forest, red colobus abundance was positively related to mean basal area of trees above 20 cm DBH and to the species richness of their food plants. Angolan colobus abundance was positively related to the total basal area of large trees and to the proportion of trees with lianas. Sykes' monkey abundance was positively related to tree species diversity and the proportion of trees with lianas. That red colobus were positively associated with mean basal area of large trees confirms selectivity for areas with large, mature trees, as seen elsewhere for other red colobus species (Skorupa, 1986; Medley, 1993). Tree species diversity and proportion of trees with lianas were the two vegetative variables with greatest predictive value in terms of the relative abundance of Sykes's monkeys. Tree diversity was highest in semi-deciduous portions of transects than in deciduous and semi-evergreen. Although liana cover was high in semi-evergreen habitats, especially in areas with gaps and regenerating vegetation, it was even higher in semi-deciduous habitats and in the large open area found along one of the transects. The regression model derived for the yellow baboon is of clear interpretation since it indicates avoidance of the semi-evergreen forest, as indeed this species is confined to the lowland, deciduous parts of the transects. The results point out the importance of data on food habits and range use from focal group studies, since the strongest, positive predictors of abundance were derived for the Udzungwa red colobus. The model stresses the importance of both mature habitat structure and variety of food plant trees.

Uzungwa Scarp Forest Reserve

The same study design was recently repeated in USFR, which may help to decipher the effect of hunting versus other types of disturbance, as the Mwanihana forest experiences very low levels of hunting. The effect of disturbance was firstly assessed through Spearman's correlation tests between primate counts and disturbance indicators measured along the transect lines, namely: (1) distance from forest edge, (2) number of disturbance signs (i.e. trees and poles cut, trails, pitsawing sites), and (3) percentage of gaps in the canopy. The results show that abundance of both colobus species was significantly, negatively correlated to gaps in the canopy and positively correlated to the distance from forest edge. Red colobus were also negatively correlated to the number of disturbance signs. Sykes's monkey showed an opposite trend, being positively related to gaps and negatively related to distance from forest edge (DeFries *et al.*, 2009; F.R., unpublished data). Preliminary results of finer-scale analysis using GLM, as in Rovero and Struhsaker (2007), are interesting because for each species the final models retained at least one of the disturbance variables mentioned above (Tab. 3; F.R., unpublished data). Moreover, the model predictive powers were much higher than those for Mwanihana for both colobus and Sykes's monkeys, implying a higher effect of human disturbance (and probably hunting), in determining the spatial occurrence and abundance of the diurnal primates in this heavily disturbed forest.

Matundu forest

Marshall (2007) worked in Matundu forest and adopted the same design as Rovero & Struhsaker (2007) to further analyse the effect of disturbance on forest monkeys. The study found similar results to the above studies in Mwanihana and Uzungwa Scarp for both abundance and group size, while also incorporating a measure of community composition from correspondence analysis, other than habitat topography variables such as slope, and the presence of swamps, rivers, streams, ridge tops and valley floors (Tab. 3). Results emphasise the importance of broad habitat type for these species, that, in turn, highlight the usefulness of forest monkeys as habitat indicators (Marshall *et al.*, submitted a). As habitat specialists, red colobus monkeys emerge as one of the best indicators of forest habitat structure in the Udzungwa range, whereas Angolan colobus are more adaptive forest specialists and Sykes's monkeys are forest generalists.

Tab. 3 - Summary of vegetative, habitat and human disturbance predictors of the relative abundance of four primate species censused along line-transects in three forests in the Udzungwa Mountains. The variables indicated (in parenthesis, positive or negative effect on the number of primate groups) are those significantly retained by stepwise, multivariate Generalized Liner Modelling. The regressions are built on line transect segments of 200 m in length (see text for details).

Forest	Red colobus	Angolan colobus	Sykes's monkey	Yellow baboon
Mwanihana[1] (N = 58)	MBA[4] large trees (+) Food plant richness (+)	TBA[5] large trees (+) Liana coverage (+)	Tree diversity (+) Liana coverage (+)	MBA large trees (-) Liana coverage (-)
Uzungwa Scarp[2] (N = 50)	MBA large trees (+) Distance to road (+) Liana coverage (-)	MBA large trees (+) Distance to road (+)	Disturbance signs (-) Distance to road (-)	No significant model
Matundu[3] (N = 120)	Vegetation gradient[6] (+) Streams p/a[7] (+) Slope (-) Valley p/a (+) Swamp p/a (-)	Volume of top 2 diet species (+) Stem density (+)	Slope (+) Climber cover (-) Vegetation gradient (-) Log10 mean tree volume (-)	No significant model

[1] Source: Rovero & Struhsaker (2007); [2] F.R. unpublished data. [3] Marshall (2007) and Marshall *et al.,* (submitted a). [4] Mean Basal Area; [5] Total Basal Area; [6] Main gradient in tree community composition, from heavily disturbed lowland and deciduous forest to less disturbed lowland/submontane semi-evergreen forest (as measured by Detrended Correspondence Analysis axis 1 score). [7] p/a= presence/absence.

Major threats and conservation

Colobines

For the endangered and endemic Udzungwa red colobus, hunting and habitat degradation are currently the main threats (Tab. 4). Forest reduction and isolation are also severe threats to the survival of this monkey. With the foreseen increasing effort in protection (expected because of the upgrading of legal protection of some Forest Reserves), hunting might be currently decreasing and only persisting in the western and north-western Udzungwa forests such as Uzungwa Scarp, New Dabaga/Ulangambi and Iyondo. In these forests, the density of red colobus might already be below the threshold for hunting to be a convenient practice (e.g. Nielsen, 2006). Survival of the Angolan colobus also depends upon protection of semi-evergreen forest blocks, and its attractive fur is highly valued.

Kipunji

The area of Ndundulu where this species still occurs is pristine mature primary forest, and during the time we have been working there (since 2004), we have not observed any signs of human activity in the area. The greatest current threats to the Ndundulu kipunji population are therefore not anthropogenic, but relate to the extremely small size of the population (Tab. 4). The reasons for their severe decline are unclear but there may now be a complex suite of factors preventing the population from increasing, such as resource competition or predation (Jones, 2006). These effects may be exacerbated by ecological and behavioural changes caused by the decline of the population to such a drastically low number of individuals. The shyness of the population appears extreme compared to other forest monkeys, and our observations suggest that the social group may not be very cohesive (Jones *et al*., submitted). Another indication of a possible ecological collapse may be group size, which is significantly smaller than in the larger and more widely distributed population in the Southern Highlands (mean group size estimate of 18.8 in Ndundulu compared with 30.7 in the Southern Highlands; Davenport *et al.*, 2008). Thus, it may well be that the Udzungwa population totalling about 100 monkeys is not viable in

Tab. 4 - Summary of main and secondary factors currently threatening the three globally threatened monkeys in the Udzungwa Mountains.

Species	Main current threats	Secondary threats
Red colobus	- Hunting (mainly shotguns) - Habitat degradation (mainly from tree cutting)	- Forest reduction - Forest isolation
Sanje mangabey	- Habitat degradation (tree and pole cutting, firewood collection) - Population isolation (increased high risk of diseases and inbreeding depression)	- Hunting (mainly snares) - Disturbance from people/tourists (for habituated or semi-habituated groups)
Kipunji	- Small population size (high risk of diseases and inbreeding depression)	- Habitat degradation (bushfires at forest edge)

the long term (Harcourt, 2002), thus facing high extinction risk and vulnerability to diseases.

Sanje mangabey

The Sanje mangabey faces different threats in the two forests where it occurs. In the Uzungwa Scarp, the greatest threat to the population is habitat loss or modification through uncontrolled cutting of trees and poles, as a result of low levels of law enforcement within this Forest Reserve. These activities can reduce the overall extent of mangabey habitat and lead to a reduction in availability of food plants. A secondary threat in this forest is hunting with snares which are primarily set for duikers and bushpigs, but which can also capture these semi-terrestrial monkeys. In Mwanihana forest, cutting and hunting are minimal. With increasing tourism and research efforts, however, a potential threat in this forest is posed by the interaction of the habituated groups with researchers and tourists: if the National Park observational regulations (Jones, 2007) are not adhered to, this exposes the monkeys to diseases potentially transmitted by humans. Stress can also alter behaviour (e.g. reduced foraging time) and exacerbate individuals' vulnerability to diseases. A threat to both populations is the increased potential for contraction of diseases and inbreeding depression which can occur naturally in small, isolated populations.

Management and conservation

An assessment of the conservation status of several forests on the eastern side of the mountain range has confirmed that whilst the National Park has been relatively well protected, Forest Reserves have not and are still being encroached at alarming rates (Museo Tridentino di Scienze Naturali, 2007). The establishment of the Kilombero Nature Reserve, that groups some of these Forest Reserves, will hopefully result in increased protection. It is unfortunate, and admittedly an oversight, that the Kilombero Nature Reserve did not include Uzungwa Scarp, as this was already known as one of the most important forests for biodiversity conservation across the Eastern Arc (Marshall *et al.*, 2007). However, recent plans by the Tanzanian Government aim to upgrade Uzungwa Scarp to Nature Reserve status (Burgess, personal communication).

Since Uzungwa Scarp is completely isolated from the northern, united network of protected areas, a potential wildlife corridor that covers this gap has also been assessed (Museo Tridentino di Scienze Naturali, 2007) and it is currently being considered by the government for attribution of legal protection (Burgess, personal communication). The importance of establishing habitat corridors between forest patches has been raised as an effective measure for the conservation of primates (e.g. Struhsaker *et al.*, 2004), as it increases the effective forest size and ensures gene

flow between forests. We have collected evidence that even monkeys depending upon large forest blocks, such as the red colobus, use riverine gallery forests and small forest patches that can potentially link larger blocks. Forest restoration will in turn depend largely on fire prevention, since anthropogenic fires appear the major deterrents to forest regeneration (Marshall *et al.*, 2001; Dinesen *et al.*, 2001; Struhsaker *et al.*, 2004).

Besides effective forest protection and corridor restoration, community involvement is undoubtedly a key strategy to decrease potential conflicts between people and wildlife, thus ensuring positive public support and attitudes towards protected areas. A great deal of work has been conducted by the WWF-Tanzania Programme, the Tanzania Forest Conservation Group and, more recently, the various research and monitoring projects listed below. On the eastern side of the National Park, where human density and potential conflicts are greatest, continued efforts are required to develop alternatives to firewood collection, a practice allowed on regular basis as an exception to National Park regulations. Firewood collection might negatively impact the predominantly terrestrial Sanje mangabey, and is often associated with illegal hunting.

Main current research and monitoring activities

Udzungwa Ecological Monitoring Centre and primate monitoring programme

The primate monitoring programme was established in 1998 in Mwanihana forest as part of a broader, and the first comprehensive project on primate survey and research in the Udzungwa Mountains (Ehardt *et al.*, 1999). It was conducted discontinuously in collaboration with the National Park until 2006 (Rovero *et al.*, 2006, Rovero & Mtui, 2006). With the establishment of the Udzungwa Ecological Monitoring Centre (UEMC), since 2007 the programme became a routine activity by this Centre, with monitoring being conducted on a monthly basis. UEMC is a facility of the National Park to facilitate and implement ecological monitoring and research across the Udzungwa Mountains; it was established and is currently administered by Italy's Museo Tridentino di Scienze Naturali. UEMC extended the programme to the Uzungwa Scarp and resumed monitoring of a fourth transect in northern Mwanihana.

Since the inception of the monitoring programme, emphasis was placed on training local biologists and assistants to collect data, as a cost-effective and sustainable strategy. With various data collectors being involved over the years, however, much attention was devoted to ensure inter-observer consistency in data collection, achieved through inter-observer reliability trials and careful data comparison (details in Rovero *et al.*, 2006). The results have so far shown that abundance has been relatively stable for the five monkeys censused in Mwanihana. Variations between data sets by multiple observers have not revealed any temporal trend and thus they were attributed to observer bias (Rovero & Mtui, 2006). The primate monitoring data collected by UEMC and individual researchers represent a baseline data set that is being also used for some of the population analysis presented earlier (e.g. Rovero & Struhsaker, 2007). The long-term research aim is defining the interaction of habitat and human disturbance factors and potential causes of variation of genetic structure and population size across forest blocks.

Udzungwa Forest Project

Largely sparked by high numbers of Udzungwa red colobus, a monitoring programme in Magombera forest was initiated in 2007 by The Worldwide Fund for Nature (WWF; Marshall 2008a). Following completion of the WWF project, the new Udzungwa Forest Project (under Flamingo Land Ltd. and the University of York, UK) has established a long-term system for monitoring primates, forest habitat and other animals and improvement of local livelihoods (Marshall 2008b). This kind of holistic approach to conservation of primates allows integration of research, management and development. The project is working with the local villages, schools, management authorities, NGOs and land-

owners to help manage the area in several ways. The project is also carrying out various monitoring and research activities within the Udzungwa Mountains, including primate population estimation and colobus dietary partitioning.

Sanje mangabey projects

Since 2002 two Sanje mangabey groups in Mwanihana forest have been fully habituated for ecological monitoring, research and educational tourism purposes. The "Mizimu group", in the Sonjo Valley, were the focus in 2003-4 of the first ever intensive ecological study of the species (Jones, unpublished data), and research on this group is ongoing under coordination by C. Ehardt and collaborators. The "Njokamone Group", close to the National Park headquarters in Mang'ula, was habituated more recently to provide an educational tourism experience for both local communities and national and international visitors to the UMNP (Jones, 2007). The National Park and T.J. continue to collaborate on group monitoring to assess and avoid any possible negative effects of mangabey viewing. An additional monitoring project began in mid-2008 to assess demographic trends over the long term based on regular recording of group size and age/sex composition of a sample of groups in Mwanihana forest.

Red colobus projects

Research on this species was initiated by T. Strushsaker in the late 1970s (e.g. Struhsaker & Leland, 1980) and continued in collaboration with several biologists with the primary aim of understanding long-term, socio-ecological variations of group size and composition. In addition to extensive work on demographic variations (e.g. Struhsaker *et al.*, 2004), research is now moving towards habituation of selected groups to obtain more detailed information on activity pattern and ranging, social interactions, niche partitioning between the two colobus species and dietary requirements (Marshall 2008 b; Struhsaker, personal communication). Preliminary research on population genetics has also been conducted, and plans are to expand this work (Ting, personal communication).

Kipunji monitoring and research

Following their discovery in Ndundulu in 2004, an intensive census was carried out to determine distribution and abundance of the population (Jones, 2006; Davenport *et al.*, 2008). Since 2006, the following activities are being conducted in Ndundulu and adjacent villages: monitoring and habituation of a focal group; training of local village scouts and UMNP rangers in basic kipunji survey and monitoring techniques; environmental education and awareness-raising. In addition, ecological research has been initiated into potential factors constraining population size, including assessment of habitat suitability and use.

Research on galagos

Relatively little research on nocturnal primates has been conducted, and no monitoring programme has yet been established. This is mainly due to the difficulties in conducting nocturnal research, the limited expertise available, and the fact that many of the galago species are not locally threatened. However there are many gaps in our knowledge. The taxonomic status of the Udzungwa population of *G. orinus* and *G. senegalensis* subspecies is unclear. Likewise, the complex biogeography of galagos in the Udzungwa Mountains remains understudied, together with the basic ecology and behaviour. An accurate methodology for calculating galago densities has yet to be developed and therefore estimating population abundance remains very challenging. Conservation of nocturnal primates in the Udzungwa Mountains clearly depends on habitat protection as there appears to be no other factors such as hunting that currently threatens these species.

Conclusions and recommendations

Although there are still large gaps in the knowledge of the Udzungwa primates, we have a fairly clear picture (especially for the diurnal primates) about their occurrence, abundance, ecological determinants, and threats. This knowledge allows us to prioritise (1) forest protection, (2)

anti-poaching and (3) awareness-raising among local communities as the key measures to ensure long-term conservation of these species. In addition, site- and species-specific conservation strategies need to be considered, particularly the intrinsic threat that the Critically Endangered kipunji faces because of its small population size. Monitoring efforts should be strengthened and expanded as the only way to ultimately assess population changes and the effect of conservation measures. Of greatest relevance and urgency for increased protection are the largest forests that have received poor protection, primarily Uzungwa Scarp. Towards this end, the continued collaboration already well established between researchers, conservation agencies, local authorities and communities is critical. In this context, we believe that the work done by researchers in the area can contribute a great deal towards preserving the forests and their primates.

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Info on the web

http://www.udzungwacentre.org
Web-site of the Udzungwa Ecological Monitoring Centre, contains a summary of research projects and references for the Udzungwa Mountains, including general and logistic information.

http://www.york.ac.uk/res/celp/people/associates/marshall
Information on the Udzungwa Forest Project and various publications.

http://www.easternarc.or.tz
This web-site contains a comprehensive cover of the Eastern Arc Mountains with thematic reports on the whole range or selected blocks available for download.

http://www.primate-sg.org
The site of the Primate Specialist Group of the Species Survival Commission of the World Conservation Union (IUCN).

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