The Uluguru Mountains of eastern Tanzania: the effect of forest loss on biodiversity

Neil Burgess, Nike Doggart and Jon C. Lovett

Abstract The Uluguru Mountains in eastern Tanzania contain at least 16 endemic vertebrate and 135 endemic plant taxa, with hundreds of more taxa shared only with forests in eastern Tanzania and Kenya. This degree of endemism is exceptional in tropical Africa, and the Uluguru Mountains are one of the 10 most important tropical forest sites for conservation on the continent. Surveys carried out during 1999–2001 updated information on the status of forests and biodiversity across the Uluguru Mountains. Forest area has declined from *c*. 300 km^2 in 1955 to 230 km^2 in 2001. Forest loss has been greatest over altitudes of 600–1,600 m, and concentrated in submontane forest. During the recent surveys most of the endemic and near-endemic vertebrate species known from the Uluguru Mountains were re-recorded, but three endemic snake species and two near-endemic bird species were not found. These species were previously known from the elevations where deforestation has been greatest. More than 50 plant species are also known only from the altitude range that has been heavily deforested. The primary cause of forest loss has been clearance for new farmland. The forest that does remain is largely confined to Catchment Forest Reserves managed for water by the Tanzanian Government. Without these reserves the loss of forest, and hence the loss of biodiversity, in the Uluguru Mountains would most likely have been much greater.

Keywords Biodiversity, East Africa, endemic species, extinction risk, forest loss, Tanzania, Uluguru Mountains.

Introduction

The Uluguru Mountains of eastern Tanzania form one of the component blocks of the Eastern Arc Mountains of Kenya and Tanzania (Fig. 1). This mountain range, composed of ancient Precambrian igneous and metamorphic rocks, stretches from the Taita Hills in southern Kenya to the Udzungwa Mountains in south-central Tanzania, and is under the climatic influence of the Indian Ocean (Lovett, 1988, 1990). The Eastern Arc has long been known as a centre of both floral (Polhill, 1968) and faunal (Allen & Loveridge, 1927; Loveridge, 1942; Moreau, 1966) diversity and endemism.

The unique nature of the Eastern Arc Mountains was recognized in the Tanzania Forest Action Plan (Bensted-Smith & Msangi, 1989), a planning process supported by the Tanzanian government. The Eastern Arc Mountains have also been recognized by BirdLife International (ICBP, 1992; Stattersfield *et al*., 1998), Conservation International (Mittermeier *et al*., 1998, 1999; Myers *et al*., 2000) and the World Wildlife Fund (Olson & Dinerstein, 1998) as an area of global importance for the conservation of biodiversity. Moreover, the importance of the Eastern Arc and adjacent lowland coastal forests were highlighted in the Country Study on Biodiversity (Government of Tanzania, 1998), and in the Tanzania Forest Programme (Government of Tanzania, 2001).

The Uluguru Mountains range from *c*. 150 m altitude on their south-eastern margin to over 2,630 m at their highest point. In total they cover *c*. 1,500 km^2 of highlands, mainly in a ridge running almost north-south, but with a few outlying hills. The mountains are steep, with extensive cliffs and rock outcrops, and formerly the natural vegetation, particularly of the eastern face, was moist forest. At lower altitudes and on the western slopes below *c*. 1,000 m this forest would formerly have graded into savannah woodland, but farmland now largely obscures these transitions. At high elevations in the southern Uluguru mountains the forest gives way to grassland in flatter areas, and to elfin forest on the wetter peaks above 2,000 m. The lowest altitude of the forest now varies along the range. Around Uluguru South Forest Reserve (Fig. 2) the lower border is $>$1,500 m on the eastern face, and at *c*. 2,000 m on the western face. It is only in Uluguru North Forest Reserve,

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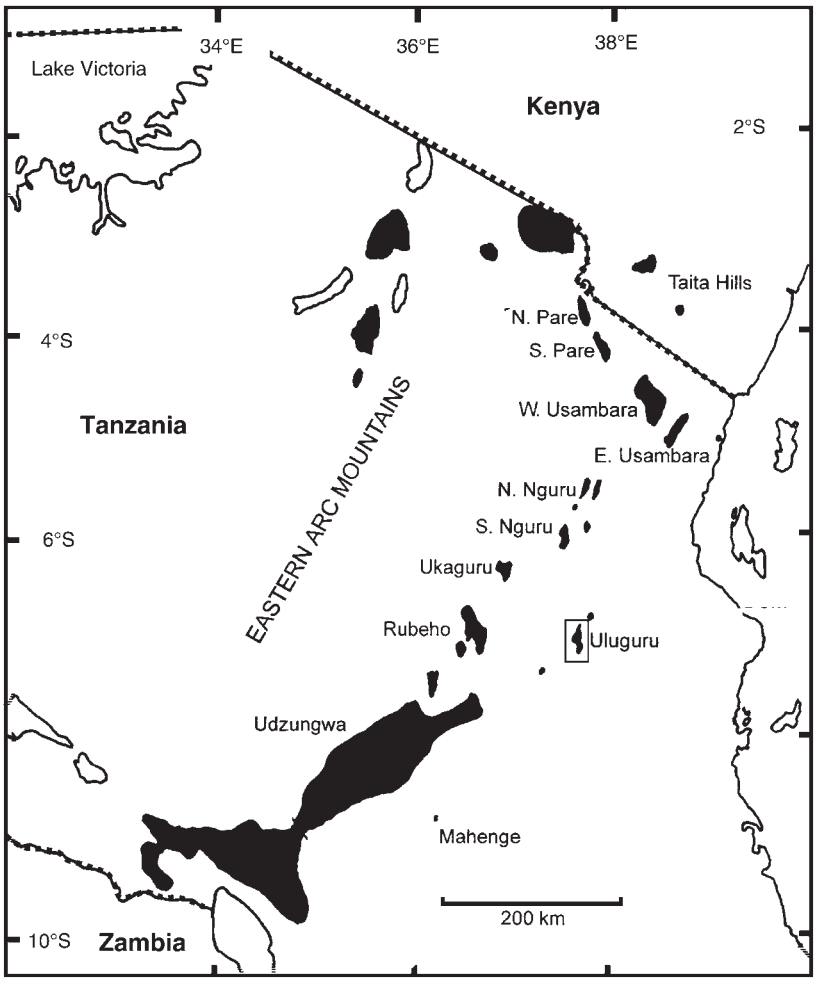

Fig. 1 The Eastern Arc Mountains of Kenya and Tanzania. The small rectangle indicates the position of the Uluguru Mountains (see Fig. 2).

especially in the northern part of the Reserve and the adjacent forests, that significant areas of submontane forests still exist down to *c.* 1,000 m.

The Uluguru Mountains receive one of the highest rainfalls in Tanzania, and form the most important water catchment forest in the country, supplying the Ruvu River. This is the principal water supply to Dar es Salaam, where 3–4 million people and most of the industry of Tanzania is based (Jackson, 1970; Temple, 1972a, b; Bensted-Smith & Msangi, 1989). The eastern face of these mountains receives >3,000 mm of rain per year, with at least 100 mm of rain in every month, and the forests are thus per-humid, which is unusual in Africa.

In an assessment of the water catchment and biological values of Tanzanian Catchment Forest Reserves, which are administered by central government, the reserves on the Uluguru Mountains were ranked at the highest level of importance (Lovett & Pócs, 1993; Lovett, 1998; Pócs, 1998). These mountains have recently been assessed as the third most important mountain block for the conservation of endemic fauna in the Eastern Arc Mountains (Burgess *et al.*, 1998b). Plant and animal species endemic to the Uluguru Mountains occur throughout the altitudinal range of the mountains and, although found in both forest and non-forest habitats, are concentrated in the natural forests.

The Uluguru Mountains Biodiversity Conservation Project (UMBCP) is a collaboration between the Wildlife Conservation Society of Tanzania (which represents BirdLife International in Tanzania), the Danish Ornithological Society (BirdLife Denmark), the Morogoro Regional Catchment Forest Project Office, the Morogoro Natural Resources Office and the University of Sokoine in Morogoro. Funding for the project comes from the Danish Development Agency, DANIDA. One of the aims of the project is to collect and distribute data on the status and condition of the Uluguru forests and their biodiversity. The project has pursued this aim since 1999, but it builds upon two decades of field work and data compilation (Pócs, 1976a, b; Rodgers *et al.*, 1983; Lovett & Pócs, 1993, Lovett & Wasser, 1993; Svendsen & Hansen, 1995; Burgess *et al.*, 1998a, b, c; Burgess & Clarke, 2000).

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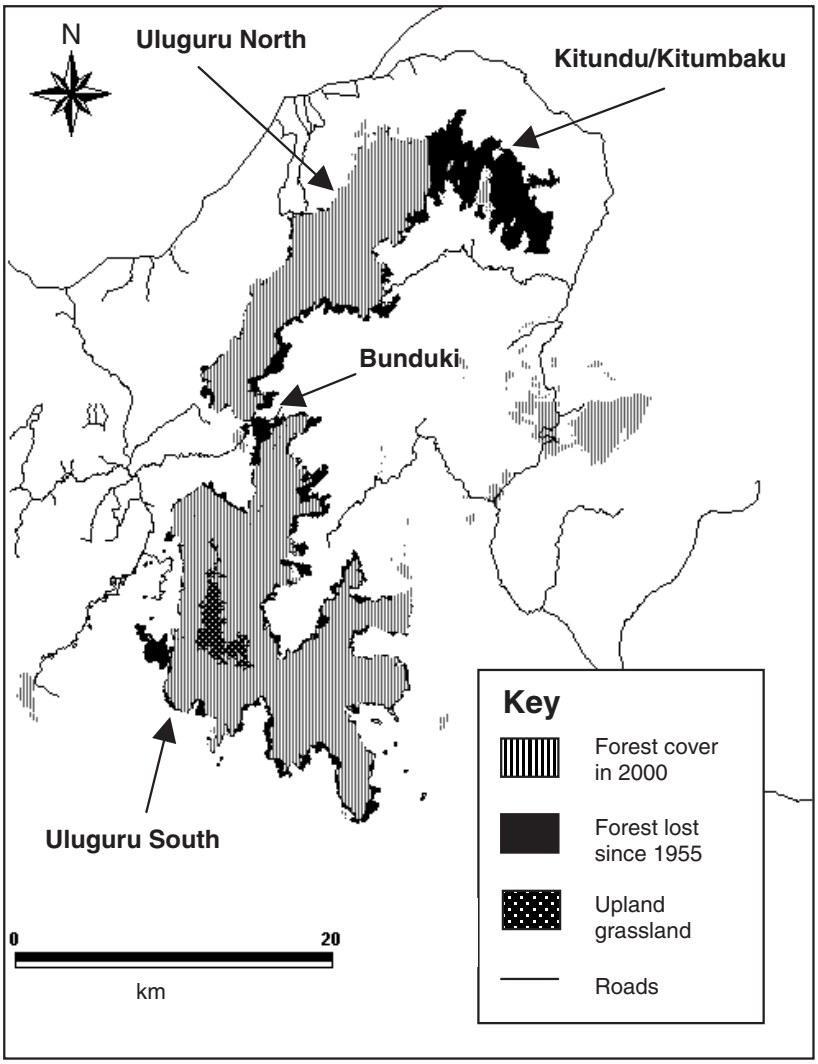

Fig. 2 The distribution of forest cover in the Uluguru Mountains in 1955 and 2000, indicating the main areas of forest loss.

In this paper we use the new data collected by the UMBCP to summarize and assess the changes that have occurred in forest cover since 1955, and update information on the total number of plant and vertebrate animal species endemic to the Uluguru Mountains and on their altitudinal ranges. These results enable us to assess whether any endemic species have been lost from the Uluguru Mountains, and whether reasons can be determined for any such losses.

Methods

Forest cover and status

We determined forest cover from aerial photographs taken in 1955 and 1977, digitised with the geographical information system ArcInfo (ESRI, 2000). Present-day forest cover was assessed from field surveys of the borders of all forest reserves on the Uluguru Mountains from late 1999 through to the middle of 2001. Patches of forest remaining on farmed lands outside the Forest Reserves were also mapped during 2000 (Hymas, 2000). A topographical model of the Uluguru Mountains was built with ArcInfo and, in combination with the digitized photographs, was used to determine forest cover in 100 m bands of altitude in 1955 and 1977. The status of the land of the Uluguru Mountains was assessed from the records of the Tanzanian government. All Forest Reserves were mapped with ArcInfo, and details of their area, date gazetted, management history, and current land-use were summarized from literature and field visits (Hymas, 2000; Doggart *et al*., 2001). If field surveys located areas of forest outside government Forest Reserves then the ownership of these areas was also established and the areas were described.

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Biological data

Historical data on the endemic vertebrate animal and plant species of the Uluguru Mountains were obtained from the literature. Vertebrate animal data comes mainly from expeditions undertaken in the early 1900s (Allen & Loveridge, 1927; Barbour & Loveridge, 1928; Loveridge, 1942), and from scientific investigations in the late 1970s and early 1980s (Rodgers *et al*., 1983; Stuart & Jensen, 1985). Data include an assessment of the altitudinal range of each species. Data collected from all forest reserves by the UMBCP during 1999–2000 was used to confirm whether the endemic vertebrate species still occur in these mountains (Doggart *et al*., 2001). These data are held at the Tanzanian Biodiversity Database at the University of Dar es Salaam and the biodiversity database of the UMBCP in Morogoro. Summary reports are available at http://www.africanconservation.com/uluguru. In addition to these data, recent records of some endemic species were taken from Svendsen & Hansen (1995), Stanley *et al.* (1998), and from the Tanzania Biodiversity Database (K. Howell, in lit.).

A provisional list of the endemic plants of the Uluguru Mountains was derived from the List of East African Plants (LEAP, 1995), augmented by visits to Lushoto, Arusha and Dar es Salaam herbaria in Tanzania (Temu & Nsolomo, 2000). This provisional list was revised by J.L. using both published and completed, but unpublished, parts of the Flora of Tropical East Africa, together with other taxonomic literature. A total of 206 angiosperm and pteridophyte families were checked, of which 14 were unpublished at the time of checking, and only parts 1 and 2 of Compositae were available. Family accounts not checked that have known Uluguru endemic species are Acanthaceae and Gesneriaceae.

Analytical units

In the analysis of faunal endemism we classified the forests of the Uluguru Mountains by elevation into lowland (<800 m), submontane (800–1,400 m), montane (1,400–1,800 m) and upper montane (>1,800 m) zones (Lovett, 1993a). If an endemic species has an altitudinal range of 500–2,000 m it is assessed in all four altitudinal bands; if its altitudinal range is less, then it falls in fewer of these bands. The habitat of endemic plant species was categorized as forest and non-forest, and the altitudinal range of taxa was categorized into 200 m bands of altitude.

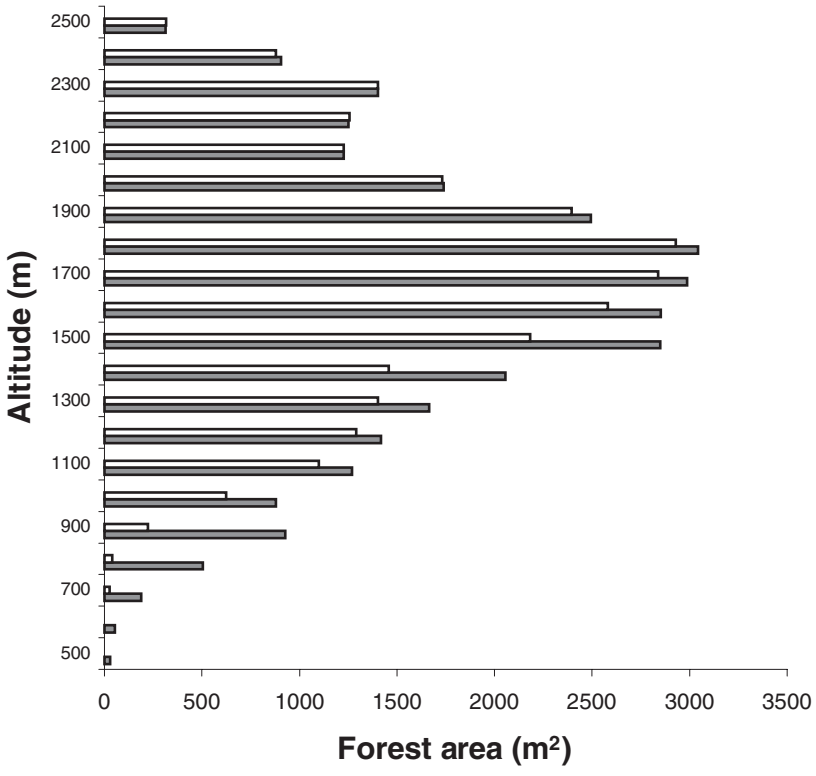

Fig. 3 Area of forest on the Uluguru Mountains in bands of 100 m altitude, in 1955 (grey bars) and 1977 (white bars).

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Results

Forest cover

There has been extensive loss of forest on the Uluguru Mountains (Figs. 2 & 3). Using climatic data and the presence of forest patches to define historical forest limits we estimate the potential natural closed forest cover in the Uluguru Mountains to be *c.* 500 km². In 1955 the forest cover was 300 km², 200 km² less than the estimated potential cover. Between 1955 and 1977 the area of forest declined by a further 40 km² to 260 km². Field assessments of the current geographical extent of the remaining forest indicate that *c.* 230 km² remains. i.e. <40% of the potential forest area. The rate of forest loss was 1.7% per annum over 1955–1977, and 0.6% per annum over 1977–2000. Loss of forest over 1955–1977 occurred almost entirely outside the Forest Reserves, over altitudes of 500–1,600 m (Fig. 3), and forest loss since 1977 has also occurred at the lower altitudes. Today some middle altitudes contain almost no forest at all.

Most of the loss has been caused by change in land use from forest to farms, and the apparent recent slowing of forest loss may be due to the fact that, as forest is lost outside the Uluguru Forest Reserves there is less forest available for conversion into farmland. Farmers grow maize, cassava, bananas and oranges at lower elevations, and at the cooler temperatures of higher altitudes they grow crops such as cabbage, potatoes and peas. Over large areas of the Uluguru Mountains fallow fields become infested by bracken *Pteridium aquilinum*, and are used for farming on rotations of several years.

Evergreen forest on the Uluguru Mountains is now almost entirely confined to Catchment Forest Reserves, managed centrally by the Tanzanian government. Our assessment of the vegetation in the 22 Forest Reserves (Table 1) shows that 15 have predominantly natural evergreen forest cover and seven are either woodlands, plantations or are deforested. Forest formerly existed on village lands, but these have largely been cleared. For example, in the past 10–15 years *c.* 20 km² of forest has been lost on the Kitundu/Kitumbaku Hills outside the Uluguru North Forest Reserve in the north-east (Fig. 2). This large area of forest was formerly under the authority of the traditional Chief who maintained the forest for the ancestors of the Luguru tribe, but political changes since 1964 have meant that his authority has been gradually eroded. The loss of chiefly power, and associated forest clearance, has accelerated in recent decades (Hymas, 1999). Other patches of forest remain in the farmlands around the Uluguru Mountains, but these are small and are still being cleared for small-holdings, except where they have traditional religious significance or are found on rocky outcrops. Farmlands do not offer suitable habitat for the Uluguru endemic vertebrates, but some endemic plant species may persist along streams or on rocky outcrops.

Biodiversity

Of the endemic vertebrate species in the Uluguru Mountains (Table 2) the highest diversity is in the montane forest band (Fig. 4). Recent surveys of birds (Svendsen & Hansen, 1995; Doggart *et al.*, 2001), mammals (Stanley *et al.*, 1998; Perkin, 2000; Doggart *et al.*, 2001), reptiles (Doggart *et al.*, 2001) and amphibians (Channing, 2000; Doggart *et al.*, 2001) have recorded 11 of the 16 known Uluguru endemic animal species (Table 2). Of the near-endemic species shared only with other Eastern Arc Mountains we have managed to locate all of the mammal, reptile and amphibian species (Doggart *et al.*, 2001). The recent surveys also discovered four rare species (the bat *Myonycteris relicta*, the rodent *Beamys hindei*, the chameleon *Chamaeleo deremensis* and the snake *Atheris ceratophorus*), which were previously only known from other montane Eastern Arc or lowland coastal forests (Doggart *et al.*, 2001). The discovery of species not previously recorded on the Uluguru Mountains shows that the area is yet to be adequately surveyed.

However, recent surveys have failed to rediscover species that occurred on the Uluguru Mountains in the past, including several endemic species. Recent surveys of birds (Stuart & Jensen, 1985; Svendsen & Hansen, 1995; Doggart *et al.*, 2001) have failed to locate the Endangered Tanzanian Mountain Weaver *Ploceus nicolli*, which inhabits mature submontane and montane forest, and the Vulnerable Banded Green Sunbird *Anthreptes rubritorques* known from submontane forest. Four endemic species of vertebrate have also not been recorded in the last 10 years: the sub-species of golden mole *Chrysochloris*

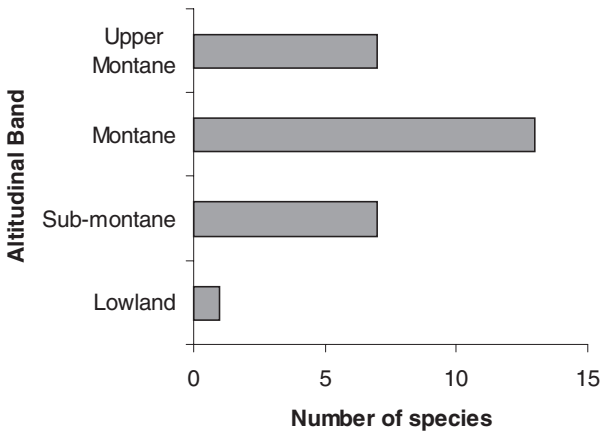

Fig. 4 Number of endemic vertebrate taxa in the major altitudinal zones of forest on the Uluguru Mountains.

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Table 1 Forest Reserves of the Uluguru Mountains, with notes on their current status (from Lovett and Pócs, 1993, updated from field surveys in 1999 and 2000).

Name of Forest Reserve	Ownership*	Govt. Declaration Number	Area (ha)	Brief description of the vegetation and status of the reserve
Bunduki I-iii	CFR	Cap. 132 1950	111	Plantation and natural forest. Plantation is being logged on licence. Fuel and pole gathering.
Bunduki iv	CFR	Cap. 132 1950	6	Plantation and natural forest. Plantation is being logged on licence. Fuel and pole gathering.
Bunduki v	CFR	Cap. 132 1950	4	Plantation and natural forest. Plantation is being logged on licence. Fuel and pole gathering.
Bunduki vi	CFR	Cap. 132 1950	3	Plantation and natural forest. Plantation is being logged on licence. Fuel and pole gathering.
Chamanyani	CFR	Cap. 132 1950	796	Mainly woodland with a few riverine forest strips. A little logging. Fuel and pole gathering.
Kasanga	CFR	1907	70	Mainly a plantation, but with some natural forest regrowth. Being logged and farmed. Fuel and pole gathering.
Kimboza	CFR	1907	386	Some natural forest and some plantation. Joint Forest Management experiments here. Fuel and pole gathering.
Mindu	CFR	CFR	2285	Outlying hill west of Ulugurus. Mainly woodland with a little forest on the top. Some damage from logging. Fuel and pole gathering.
Mkungwe	CFR	1954	1967	Outlying hill east of Ulugurus. Lowland to submontane forest in good condition. Some new pit sawing. Fuel and pole gathering.
Mvuha	CFR	Cap. 132 1950	852	Mainly woodland with a few riverine forest strips. A little logging. Fuel and pole gathering.
Nyandiduma	CFR	Cap. 132 1950	48	A plantation of *Eucalyptus* that is being cut. Fuel and pole gathering.
Nyandira	CFR	German colonial	195	A plantation of *Eucalyptus* that is being cut. Fuel and pole gathering.
Palangwe East	CFR	1963	768.5	Woodland that burns ever year. Not valuable for water catchment. Fuel wood gathering.
Palangwe West	CFR	1963	184	Woodland that burns ever year. Not valuable for water catchment. Fuel wood gathering.
Ruvu	CFR	1955	3094	Woodland and lowland forest. A lot of mining damage and some logging. Fuel and pole gathering.
Shikurufumi	CFR	1948	260	Plantation and secondary forest. Fuel and pole gathering.
Uluguru North	CFR	German colonial and 1961	8357	Large area of submontane to upper montane forest. Farmland encroachment and illegal hunting, pit sawing and fuel and pole gathering.
Uluguru South	CFR	German colonial	17293	Large area of montane to upper montane forest with some grasslands. Farmland encroachment and illegal hunting, pit sawing and fuel and pole gathering.
Vigoza	CFR	Cap. 132 1950	9	Former plantation, now cleared and farmed. Fuel and pole gathering.
Mangala	DFR	?1968	35	Local authority reserve largely managed by the village with lowland forest under threat from conversion to farmland. Fuel and pole gathering.
Milawilila	DFR	?1968		Local authority reserve largely managed by the village with lowland forest under threat from conversion to farmland. Fuel and pole gathering.
Ngambaula	DFR	?1968		Local authority reserve largely managed by the village with lowland forest under threat from conversion to farmland. Fuel and pole gathering.
Nguru Ya Ndege	DFR	1962	38190	Outlying hill west of Ulugurus. Mainly woodland with a little forest on the top. Lots of damage from timber, charcoal, fuelwood and pole cutting.
Konga	Village	1910	5	De-gazetted and now managed by the village. Good lowland forest, with some tree cutting for local use.

*CFR, Catchment Forest Reserve managed by the central government Forest and Beekeeping Division Catchment Forestry Project; DFR, Local Authority Forest Reserve managed by the local government Morogoro Rural District; Village, a former Forest Reserve that has been de-gazetted, but which still contains forest.

stuhlmanni tropicalis, the snakes *Typhlops uluguruensis*, *Typhlops* sp. nov. (D. Broadley, pers. com.), and *Prosymna ornatissima*, and the amphibian *Hyperolius tornieri*.

Of the 135 plant taxa endemic to the Uluguru Mountains (Table 3) two are species in monotypic genera: *Rhipidiantha chlorantha* and *Dionychastrum schliebenii*. The need for additional botanical exploration is illustrated by the fact that 31 of the endemic taxa are too imperfectly known to be adequately described, the habitat of five taxa is not recorded, and the altitudinal range of one species is not known. The currently available data indicates that the endemic plant species generally have restricted altitudinal ranges, occupying a mean of 2.2 200 m altitudinal bands. Sixty taxa are known from only

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Table 2 Vertebrate taxa endemic to the Uluguru Mountains, with author and date of description, occurrence in closed mature forest only or in closed forest and forest edge, and occurrence in the four altitudinal zones of montane habitat.

Species	Described	Forest habitat*	Altitudinal zone			
			Lowland (0–800 m)	Submontane (800–1400 m)	Montane (1400–1800)	Upper Montane (>1800)
Birds						
Malaconotus alius	Friedmann, 1927	FF		x	x	
Nectarinia loveridgei	Hartert, 1922	FF		x	x	x
Mammals						
Crocidura telfordi	Hutterer, 1986	FF			x	
Myosorex geata	Allen & Loveridge, 1927	FF			x	x
[1]*Chrysochloris stuhlmanni tropicalis*	Allen & Loveridge, 1927	F			x	x
Reptiles						
Lygodactylus williamsi	Loveridge, 1952	FF	x			
[1]*Prosymna ornatissima*	Barbour & Loveridge, 1928	F		x		
Rhampholeon uluguruensis	Tilbury & Emmrich, 1996	FF		x	x	
[1]*Typhlops uluguruensis*	Barbour & Loveridge, 1928	F		x		
[1]*Typhlops* sp. nov.	Broadley *in lit.*	F		x		
Amphibians						
[1]*Hyperolius tornieri*	Ahl, 1931	FF			x	
Nectophrynoides cryptus	Perret, 1971	FF			x	x
Nectophrynoides minutus	Perret, 1972	FF			x	x
Nectophrynoides sp.nov.	Howell *in lit.*	FF			x	
Probreviceps uluguruensis	Loveridge, 1925	FF			x	x
Scolecomorphus uluguruensis	Barbour & Loveridge, 1928	FF			x	
Totals			1	6	12	6

*FF, closed mature forest only; F, closed mature forest and forest edge.
[1]Taxa that have not been recorded in the last 10 years.

one 200 m band, 25 from 2 bands, 26 from 3 bands, 11 from 4 bands, 8 from 5 bands, 3 from 6 bands and 1 from 7 bands. Most endemic taxa occur in forest (121), 20 occur in other habitats, and 11 occur both in forest and in other habitats. Limiting the list to species endemic only to the Uluguru Mountains may under-record the botanical importance of non-forest habitats; for example, the Lukwangule Plateau grasslands contain some near-endemics such as *Moraea callista* and *Panicum lukwangulense* that also occur in a restricted number of localities in high mountains further south.

Of the plant families not checked, both Acanthaceae and Gesneriaceae contain Uluguru endemics. In the Acanthaceae *Isoglossa ixodes*, *I. oreacanthoides* and *Sclerochiton ulugurensis* are endemic species and *Epiclastopelma* is an endemic genus with two species: *E. glandulosum* and *E. macranthum*. In the Gesneriaceae *Saintpaulia goetzeana* and several *Streptocarpus* species are endemic, and *Linnaeopsis* is an endemic genus with three species: *L. alba*, *L. heckmanniana* and *L. subscandens*. Many species are near-endemics. For example, the recently described *Zenkerella perplexa*, thought to be endemic to Bondwa in the northern Uluguru Mountains (Temu, 1990), has also been located on Malundwe Hill south of the Mountains (Lovett, 1993b). Some genera are near-endemics, for example the monotypic *Urogenitas ulugurensis* is known only from the Uluguru, Ukaguru and Nguru Mountains, and the monotypic *Neobenthamia gracilis* is known only from the Uluguru and Nguru Mountains.

Discussion

One of our aims was to investigate whether the biodiversity of the Uluguru Mountains has changed over the last 50 years. Results of forest status and biodiversity surveys indicate that, despite the extensive loss of forest in lowland and submontane areas (Figs. 2 & 3), many of the endemic animal taxa still survive. However, four of the Uluguru endemic animal species, three of them, snakes, have not been located (Table 2). Although snakes can be difficult to locate, the fact that their preferred habitat of low to middle altitudes (700–1,000 m) has been intensively deforested is a cause for concern. Two bird species previously recorded (*P. nicolli* and *A. rubritorques*) have not been located for decades and, although they occur elsewhere, they might be extinct in the Uluguru Mountains.

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Table 3 Preliminary list of plant taxa endemic to the Uluguru Mountains (see text for details of compilation), with an indication of those taxa that are as yet imperfectly known, occurrence in forest or other habitat, and occurrence in altitudinal bands of 200 m from <400 to >2,400 m. A taxon is endemic at the lowest taxonomic level indicated, with the exception of the monotypic genera *Rhipidiantha* and *Dionychastrum*.

Taxon	Imperfectly known	Forest	Other habitat	Altitudinal bands (m)											
				<400	400	600	800	1000	1200	1400	1600	1800	2000	2200	>2400
Acridocarpus congestus		x							x	x	x				
Arisaema ulugurense		x	x										x	x	
Balthasaria schliebenii var. *schliebenii*		x								x	x	x			
Baphia pauloi		x		x											
Blotiella coriacea			x								x				
Bulbophyllum concatenatum		x								x	x	x			
Callipteris ulugurica		x					x	x							
Canthium sp. B	x	x								x	x				
Chassalia discolor subsp. *grandifolia*		x		x											
Chassalia sp. A	x	x												x	
Chassalia violacea var. *parviflora*		x						x	x	x	x	x			
Chassalia violacea var. *violacea*		x							x	x	x	x			
Clerodendrum suffruticosum		x	x						x	x	x				
Coccinia ulugurensis		x	x						x						
Coffea sp. A	x	x		x											
Coffea sp. E	x	x			x										
Commiphora ulugurensis		x		x											
Cremaspora sp. A	x	x										x			
Crotalaria hemsleyi			x						x	x					
Cryptotaenia calycina var. *dissecta*		x												x	
Cynometra ulugurensis		x				x									
Cyphostemma gracillimum			x			x	x	x							
Cyphostemma masukuense subsp. *ulugurense*		x	x										x	x	
Cyphostemma sp. P	x	x		x											
Diaphananthe orientalis		x										x			
Dionychastrum schliebenii			x											x	x
Diospyros corylicarpa		x			x										
Diplazium ulugurense		x									x				
Dorstenia dionga		x							x	x	x				
Dorstenia ulugurensis		x									x	x			
Drypetes usambarica var. *stylosa*		x		x											
Ehretia rosea	x			x											
Epipactis ulugurica		x	x										x	x	x
Garcinia bifasciculata		x		x											
Genus unknown	x	x		x											
Gravesia hylophila		x	x					x	x	x					
Gravesia pulchra var. *pulchra*		x							x	x	x				
Gravesia riparia		x								x					
Grumilea blepharostipula	x	x									x				
Grumilea chaunothyrsus	x	x								x					
Grumilea euchrysantha	x	x						x							
Grumilea pallidiflora	x			x											
Ilex mitis var. *schliebenii*		x													x
Impatiens barbulata		x									x	x			
Impatiens cinnabarina		x		x	x										
Impatiens humifusa		x					x	x	x						
Impatiens ioides		x							x	x	x	x			
Impatiens lukwangulensis		x									x	x	x	x	x

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Table 3 (*continued*)

Taxon	Imperfectly known	Forest	Other habitat	Altitudinal bands (m)											
				<400	400	600	800	1000	1200	1400	1600	1800	2000	2200	>2400
Impatiens pallide-rosea subsp. *pallide-rosea*		x											x	x	x
Impatiens pseudohamata		x												x	
Impatiens serpens		x								x	x	x	x	x	
Impatiens simbiniensis		x								x					
Impatiens thamnoidea		x										x	x		
Impatiens tricaudata		x													x
Impatiens ulugurensis		x									x	x	x	x	x
Jasminum rotundatum	x	x	x					x							
Keetia sp. C	x	x								x	x				
Lasianthus cereiflorus		x						x	x	x	x				
Lasianthus glomeruliflorus var.?	x	x							x	x	x				
Lasianthus glomeruliflorus var. *glomeruliflorus*		x									x				
Lasianthus grandifolius		x											x		
Lasianthus macrocalyx		x										x	x	x	x
Lasianthus microcalyx		x											x	x	x
Lasianthus sp. A	x	x								x					
Lasianthus wallacei		x									x	x			
Lasianthus xanthospermus		x													x
Lingelsheimia sylvestris		x		x											
Lobelia gilgii			x							x	x	x	x	x	x
Lobelia graniticola			x										x	x	x
Lobelia lukwangulensis		x	x									x	x	x	x
Lobelia morogoroensis		x					x	x	x	x	x	x			
Margelliantha globularis		x							x						
Meineckia acuminata		x							x	x	x				
Memecylon myrtilloides		x							x	x	x	x			
Mimusops penduliflora		x				x									
Necepsia castaneifolia subsp. *kimbozensis*		x		x											
Oncella gracilis		x									x				
Ophrypetalum odoratum subsp. *longipedicellatum*		x	x	x	x										
Pauridiantha symplocoides var.?	x	x							x						
Pavetta bruceana		x											x	x	
Pavetta constipulata var. *constipulata*		x							x	x	x				
Pavetta constipulata var. *uranoscopa*		x					x	x							
Pavetta crebrifolia var. *kimbozensis*		x			x										
Pavetta filistipulata		x						x	x	x					
Pavetta sparsipila		x							x	x					
Peddiea puberula		x							x	x	x	x	x		
Pentas ionolaena		x	x						x	x	x	x	x		
Pentas pseudomagnifica		x	x										x	x	x
Pentas ulugurica		x						x	x	x	x				
Phyllanthus thulinii			x							x	x	x			
Pilea goetzei		x							x	x	x	x	x		
Pittosporum goetzei		x											x	x	
Polystachya longiscapa			x					x	x	x					
Polystachya lukwangulensis		x												x	
Polystachya porphyrochila		x								x					
Pseudonesohedyotis bremekampii		x							x	x	x	x	x	x	x

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Table 3 (*continued*)

Taxon	Imperfectly known	Forest	Other habitat	Altitudinal bands (m)											
				<400	400	600	800	1000	1200	1400	1600	1800	2000	2200	>2400
Pseudosabicea arborea		x									x	x	x		
Psychotria brucei		x									x	x	x	x	
Psychotria castaneifolia		x							x						
Psychotria cephalidantha	x														
Psychotria diploneura		x											x		
Psychotria elachistantha		x							x	x	x	x			
Psychotria megistantha		x								x	x	x	x	x	x
Psychotria sp. D	x	x												x	x
Psychotria sp. I	x	x								x					
Psychotria sp. N	x	x								x					
Psychotria tanganyicensis subsp. *longipes*		x										x			
Rhipidantha chlorantha		x								x	x				
Rinorea sp. A	x	x		x											
Rytigynia lichenoxenos subsp. *lichenoxenos*		x										x	x	x	
Rytigynia nodulosa		x							x	x	x	x	x		
Rytigynia sp. F	x	x								x	x				
Stapfiella ulugurica		x										x	x		
Stolzia angustifolia		x										x			
Stolzia atrorubra		x										x	x	x	
Stolzia moniliformis		x							x	x	x	x			
Stolzia oligantha		x									x	x			
Stolzia viridis		x									x	x			
Synsepalum ulugurense	x	x								x	x				
Syzygium micklethwaitii subsp. *subcordatum* var. *subcordatum*		x											x	x	x
Syzygium parvulum		x										x	x	x	
Syzygium sp. A	x	x							x						
Tarenna quadrangularis		x							x	x	x				
Ternstroemia polypetala var.?	x	x										x	x	x	
Thylachium alboviolaceum	x			x											
Thylachium densiflorum							x								
Thylachium macrophyllum	x		x		x										
Tridactyle sarcodantha		x										x			
Turrea kimbozensis		x		x	x										
Turrea mombassana subsp. *schliebenii*		x								x					
Vepris mildbraediana	x	x										x			
Vepris morogorensis var. *subalata*		x		x											
Vepris sp. A	x	x									x				
Vernonia tricholoba		x												x	
Vitex sp. A	x	x		x											
Totals	31	121	20	19	7	3	6	13	33	46	48	42	32	30	18

The fact that so many of the plant and animal species endemic to the Uluguru Mountains have a restricted forest distribution illustrates the threat posed by the extensive loss of forest. The Endangered Uluguru Bush Shrike *Malaconotus alius* provides an example of how the process of habitat loss and species decline may be linked. Ecological surveys of this species (Romdal *et al.*, unpub.) have shown that it prefers lower altitude forests with good canopy cover, but this is the forest that has been most affected by deforestation. There are many records of this species in the Uluguru North Forest Reserve and in the non-reserved forests that used to occur outside this Reserve, and a single record of the species from 2,100 m in the Uluguru South Forest Reserve above Tchenzema (Collar & Stuart, 1985; Stuart & Jensen, 1985). Surveys of Uluguru South in early 2000 failed to locate the species, although it is extant in Uluguru North (Burgess *et al.*, 2001). The clearance of the lower altitude

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forest at the southern end of the Uluguru Mountains to >1,500 m on the eastern face and *c.* 2,000 m on the western face might have resulted in this species becoming extirpated from this Reserve, leaving it confined to one reserve that has a total area of <100 km². The continuing deforestation of the lower altitude forests in Uluguru North (Figs. 2 & 3) is a cause for concern for the future of this species.

Studies of the altitudinal distribution of endemic plants in eastern Tanzanian forested mountains illustrates that endemic forest plants occur throughout the elevational range of the forests, and that many of these species are confined to a narrow range of altitude (Lovett *et al.*, 2001). The loss of forest over a particular range will therefore inevitably lead to species loss. As some of the lower altitudes on the Uluguru Mountains have lost almost all their forest cover over the last 40–50 years, plant species may have disappeared or become extinct. Further surveys of the endemic plant species of the Uluguru Mountains are required to determine how many can still be located and whether any have become extinct.

Although we have focused on the endemic vertebrates and plants of the Uluguru Mountains, there is also a rich invertebrate fauna with hundreds, and probably thousands, of endemic species (see references in Burgess *et al.*, 1998b). Similar to the plants, many species of endemic invertebrate can be expected to inhabit a narrow altitudinal range in the forest. With deforestation at particular altitudes, invertebrate species might have become extinct, or at least reduced in distribution to remnant forest patches along streams and on rocky outcrops.

The fact that almost all the forest on the Uluguru Mountains is now found within the boundaries of the Catchment Forest Reserves managed by the Tanzanian Government is a strong vindication of the value of these reserves for the conservation of biodiversity. This was not their original aim, as most of the forests were reserved for their water catchment functions and to prevent landslides and flooding downstream (Lovett & Pócs, 1993; Rodgers, 1993). However, the protection function of the Forest Department, backed up by legislation and by a government structure down to village level, has been remarkably successful for biodiversity conservation. Local people respect Reserve boundaries, even in remote areas where government forest officers rarely visit (pers. obs.). The importance of maintaining the reserves is further emphasized by comparison with the Shume-Magamba Reserve in the West Usambara Mountains of Tanzania, where 12,000 ha were excised from the Reserve in 1963, resulting in the almost total conversion of the forest to farmland (Lovett & Stuart, 2001; Lovett, unpub.).

In 1955 the Uluguru North and Uluguru South forests were connected across the Bunduki Depression (Fig. 2), and hence there could have been exchange of species between the two Reserves. This connection has been severed through conversion to farmland, and a dense human population now occupies the area. Most of the forest species of Uluguru South and North will now be confined to the Reserves, making them more vulnerable to extinction, because many of the forest specialist species will not venture across large gaps (Fjeldså, 1999).

In addition to their importance as a centre of endemic biodiversity, the Uluguru Mountains are also the most important water catchment in Tanzania. This is because the Ruvu River rises in these mountains, and then forms the principal water supply to the residents of Dar es Salaam, the largest city in Tanzania. However, despite this importance, the value of the forests as a catchment area for millions of people in Tanzania is poorly documented. Previous studies by Pócs (1974, 1976a, b) described how the forests assist in trapping water that then flows to Morogoro and Dar es Salaam, but there is only preliminary data on the water flow from the mountains (Jackson, 1970; Temple, 1972a, b), and there is no information of how water flows might have changed over time. Critically, it is not known whether deforestation of the Uluguru Mountains has caused any change in water flow from the mountains. Anecdotal evidence from local village elders in the region of Kitumbaku/Kitundu Hills, and from our own observations, indicates that, as the forests have been cleared, the cloud base has moved to ever higher altitudes.

To secure the future of the forests and biodiversity of the Uluguru Mountains the importance of the area needs to be better appreciated, both in Tanzania and further afield. The most readily appreciated reason to conserve these forests is their role in supplying water to the largest city in the country. Additional links need to be made between these immediate water values, the importance of the area for biodiversity conservation, and the modest funding needs of the managers of the Catchment Forest Reserves where the vast majority of the forest is now found.

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Biographical sketches

Neil Burgess has studied the biology of Tanzanian forests since 1989 and has been involved with conservation projects on the Uluguru Mountains since the early 1990s. Most recently he was a Technical Advisor on the Uluguru Mountains Biodiversity Conservation Project between 1999 and 2001.

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Jon Lovett undertook botanical fieldwork in the forests of Tanzania for more than 10 years, and first coined the phase 'Eastern Arc' to describe the range of mountains containing the Ulugurus. He has maintained close links with Tanzanian botanists and conservationists since returning to the UK to take up a position at the University of York.

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