Biodiversity Surveys in the East Usambara Mountains: Preliminary Findings and Management Implications

Authors: Johansson, S. G., Cunneyworth, P., Doggart, N., and Botterweg, R.

Source: Journal of East African Natural History, 87(1) : 139-157

Published By: Nature Kenya/East African Natural History Society

URL: https://doi.org/10.2982/0012-8317(1998)87[139:BSITEU]2.0.CO;2

Journal of East African Natural History **87**: 139–157 (1998)

BIODIVERSITY SURVEYS IN THE EAST USAMBARA MOUNTAINS: PRELIMINARY FINDINGS AND MANAGEMENT IMPLICATIONS

S.G. Johansson
East Usambara Catchment Forest Project
P.O. Box 5869, Tanga, Tanzania

P. Cunneyworth, N. Doggart
Frontier-Tanzania
P.O. Box 9473, Dar es Salaam, Tanzania

R. Botterweg
FAO
P.O. Box 2, Dar es Salaam, Tanzania

ABSTRACT

Geographically referenced biodiversity information is important for conservation management and zoning. Biodiversity surveys were initiated in the East Usambara Mountains in 1995 to provide baseline information on the biological values of the forests for management planning and monitoring, and to train field staff in the use of biological inventory techniques. They were conducted in ten-week field phases. Vegetation plots were laid along a grid of 450 m x 450/900 m. Forest disturbance was assessed using the grid transects. Selected groups of fauna were surveyed using standard methods. Inventories have been completed in ten forests covering 11,076 ha. New species have been discovered, and several range extensions have been documented. Data on local distribution of endemics and threatened species has been incorporated in management plans for Forest Reserves. About 35 foresters have been trained. During 1997 a database was developed for data entry, retrieval and mapping.

INTRODUCTION

The East Usambara Mountains are located on the northeast coast of Tanzania between 4°48'–5°13'S and 38°32'–38°48'E. The forests form part of a globally recognised biodiversity hot spot and a centre of high plant diversity (WWF & IUCN, 1994; Mittermeier *et al.*, 1998). The diversity of flora and fauna, and the number of endemic species is high (*e.g.* Rodgers & Homewood, 1982; Iversen, 1991). This has been associated with relatively stable environmental conditions for seven million years or more, and the presence of several phytogeographical elements, particularly the Swahilian regional centre of endemism (formerly Zanzibar-Inhambane regional mosaic), the Afromontane archipelago-like and the Zambezian and Somalia-Masai regional centres of endemism (Rodgers & Homewood, 1982; Kingdon, 1990; Iversen, 1991; Lovett & Wasser, 1993).

The present land-use is derived from the relatively low pre-colonial population density, which enabled the Germans to take over large parts of the Amani plateau at the southern part

of the East Usambara Mountains. The forests of the German estates developed over time into the present network of forest reserves, while the agricultural areas became the tea estates of today, or developed into small-holder cultivation. Commercial logging was undertaken until the mid-1980s, while pitsawing continued up to the 1990s. Rodgers & Homewood (1982) estimated that 50 % of the public land forests disappeared between 1954 and 1978, and according to the Amani Forest Inventory and Management Planning Project (AFIMP, 1988) only slightly over 5,000 ha was intact by 1988.

The forests have become increasingly fragmented, which is currently perhaps the major threat to biological diversity (*cfr* Newmark, 1992, 1993; Laurance & Bierregaard, 1997). At the moment only four or five major forest blocks remain. Out of about 42,000 ha of natural forests, approximately 32,000 ha (76 %) are protected in Amani Nature Reserve and 13 forest reserves (FR) managed by the Forestry and Beekeeping Division (FBD) with support from the East Usambara Catchment Forestry Project (EUCFP) since 1991 (Johansson & Sandy, 1996).

Because of their conservation value, fragmented nature and vulnerability of populations of both flora and fauna, it was necessary to identify local areas of specific biodiversity value both within the whole East Usambara Mountains, as well as in individual reserves, as a basis for conservation management and zoning. Such geographically referenced, systematic inventory data previously only existed on trees (AFIMP, 1988). However, because the AFIMP still considered harvesting as a management option about 8,000 ha, which were considered 'inaccessible' for utilisation, were excluded from the inventory in 1986/87. The East Usambara Biodiversity Surveys (EUBS) were started by EUCFP and Frontier-Tanzania (FT) in mid-1995 with the aim of providing baseline information on the biological values of different forests for management planning and long-term monitoring, and to train EUCFP staff in the use of biological inventory techniques. In 1997, a database was developed for storage, retrieval, analysis and mapping of the survey data. It is based on MS Access and MapInfo software, and forms the basis for a geographical information system on biodiversity in the East Usambara Mountains. This paper describes the methods used and presents preliminary findings from the EUBS.

METHODS

General survey method

The surveys were carried out in ten-week field phases. The field work involved short-term expatriate volunteer research assistants, and EUCFP, FT, University of Dar es Salaam (UDSM), and Tanzania Forestry Research Institute (TAFORI) staff. For taxonomic identification the programme relied on a national and international network of taxonomists. The methods were developed from those used by FT in the Tanzania Coastal Forest Research Programme (*e.g.* Clarke & Stubblefield, 1995; SEE, 1998), and those of the Uganda Forest Biodiversity Surveys (Howard & Davenport, 1996) aiming at systematic sampling, replicability and ease of comparison. The original methods were modified after an evaluation in 1996 (Howard, 1996) and are described in detail by SEE (1998). Surveys undertaken during 1994 by FT, using the earlier FT methods (SEE, 1998), therefore provide additional information on the biodiversity of Magoroto forest (591 ha), located in the SE corner of the East Usambara Mountains.

Systematic surveys of flora and fauna have been completed in nine forest reserves which cover 10,485 ha (excluding Magoroto, where only general survey have been conducted), or

36 % of the total protected forest area (table 1, figure 1). So far reports have been completed on six forests (Cunneyworth, 1996a, b, c; Cunneyworth & Stubblefield, 1996a, b, c).

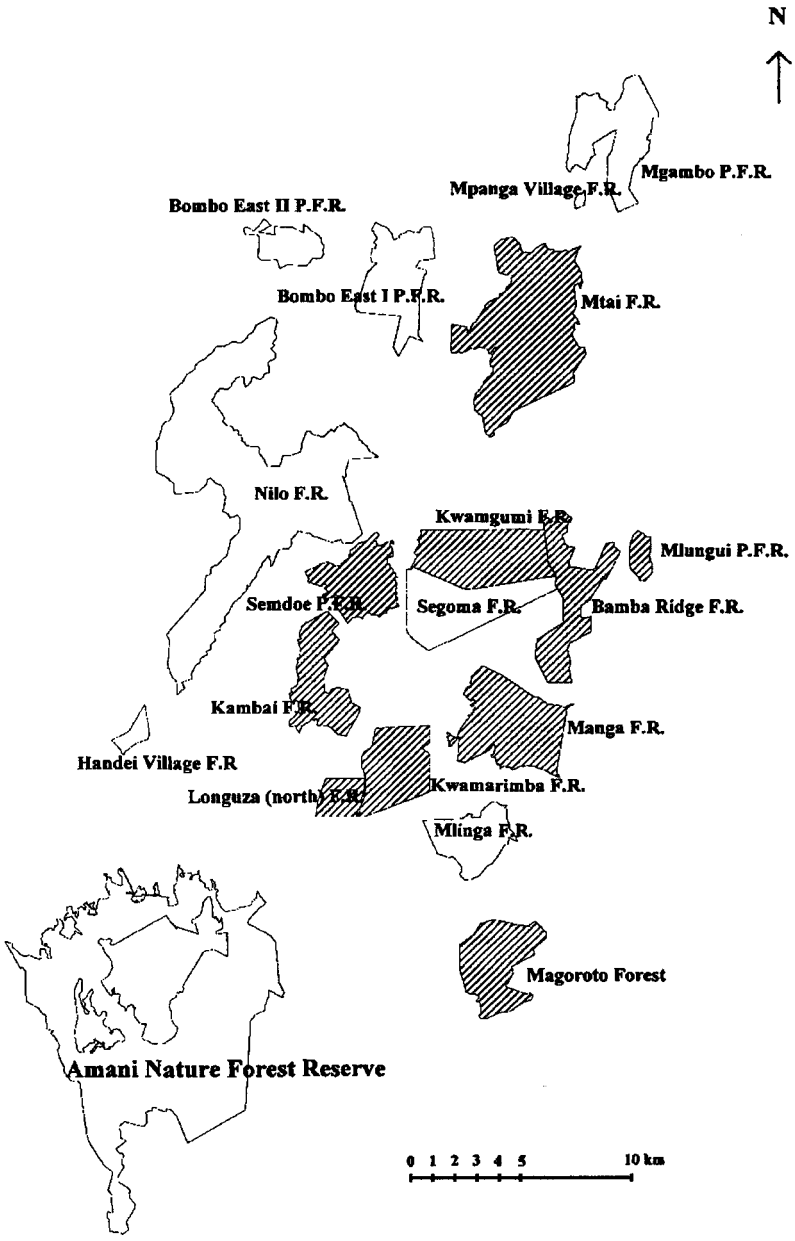

Figure 1. Forest Reserves in the East Usambara Mountains. Shaded reserves denote areas where biodiversity surveys were completed by December 1997.

Table 1. Forests surveyed in the East Usambaras by December 1997.

F c	Status [1]	Area ha	Altitudinal range (asl)	Study period	No. of plots	Sample %	Grid size [2]	Field days [3]	Report
F	FR	1131	150 -1,065	07-09.95	32	0.28	1	50	1996
F	FR	1046	200 - 870	01-03.96	49	0.47	1	52	1996
F	FR	887	95 - 445	10-12.95	52	0.59	1	51	1996
F	FR	1129	150 - 915	10-12.96	49	0.43	2	57	In prep.
F	FR	360	95 - 345	10-12.95	18	0.5	1	51	1996
F	EF	591	700 - 880	07-09.94	na	na	na	50	1996
F	FR	1616	110 - 320	07-09.97	33	0.2	2	56	In prep.
F	FR	200	200 - 450	07-09.95	5	0.25	1	50	1996
F	FR	3146	180 - 1,016	07-09.96	100	0.32	1	112	In prep.
				01-03.97			2		
S	FR	970	180 - 460	07-09.97	20	0.21	2	56	In prep.
				10-12.97					
-		**11076**			**358**	**0.34**		**535**	

[1] FR - forest reserve; EF - estate forest.
[2] 1 - 450 m x 450 m; 2 - 450 m x 900 m; na - earlier FT methods.
[3] for Bamba Ridge and Mlungui, and Kwamarimba and Longuza (north) the days are for the combined.

Table 2. Number of species identified in the surveyed forests.

Forest	Area, ha	Trees, shrubs	Mammals	Reptiles	Amphibians
Bamba Ridge	1131	167	28	26	23
Kambai	1046	162	36	18	15
Kwamarimba	887	165	16	17	11
Longuza (north)	360	106	10	9	1
Magoroto	591	109	27	29	29
Mlungui	200	56	5	9	3

Table 3. Total number of species endemic to East and West Usambara (EWU), including near-endemic, primary forest dependent and non-forest species identified in the surveyed forests.

Forest	Number of		EWU endemic		Near-endemic [1]		Primary forest dependent [1]				Non-forest species [1]	
	Families	Species	Total	%	Total	%	Total	%	End.	%	Total	%
Bamba Ridge	38	167	1	0.6	39	23.3	45	26.9	18	40.0	25	15.0
Kambai	38	162	2	1.2	35	21.6	47	28.7	17	36.2	18	11.1
Kwamarimba	38	165	4	2.4	39	23.6	37	22.4	14	37.8	20	12.1
Longuza (north)	28	106	0	-	25	23.6	20	18.9	9	45.0	18	17.0
Magoroto	33	109	5	4.6	30	27.5	48	44.0	24	50.0	7	6.4
Mlungui	25	56	0	-	16	28.6	13	23.2	5	38.5	7	12.5

[1] According to Iversen (1991).

Botanical survey methods

Each surveyed forest was divided into a grid of 450 m x 450 m, which after evaluation (Howard, 1996) was changed to 450 m x 900 m to speed up the survey programme. These represent an approximate sampling intensity of 0.5 % and 0.25 % respectively. A sample plot of 20 m x 50 m (0.1 ha) was laid out in the corner of each grid square (see figure 2). In each plot all trees with a diameter at breast height (dbh) > 10 cm were measured, tagged and identified to species. Species accumulation curves were monitored to check sampling intensity. Identification was carried out in the field, primarily by a botanist from TAFORI with considerable experience of working in the East Usambaras. Specimens were taken when identification was not obvious and now also for all endemic and near-endemic species.

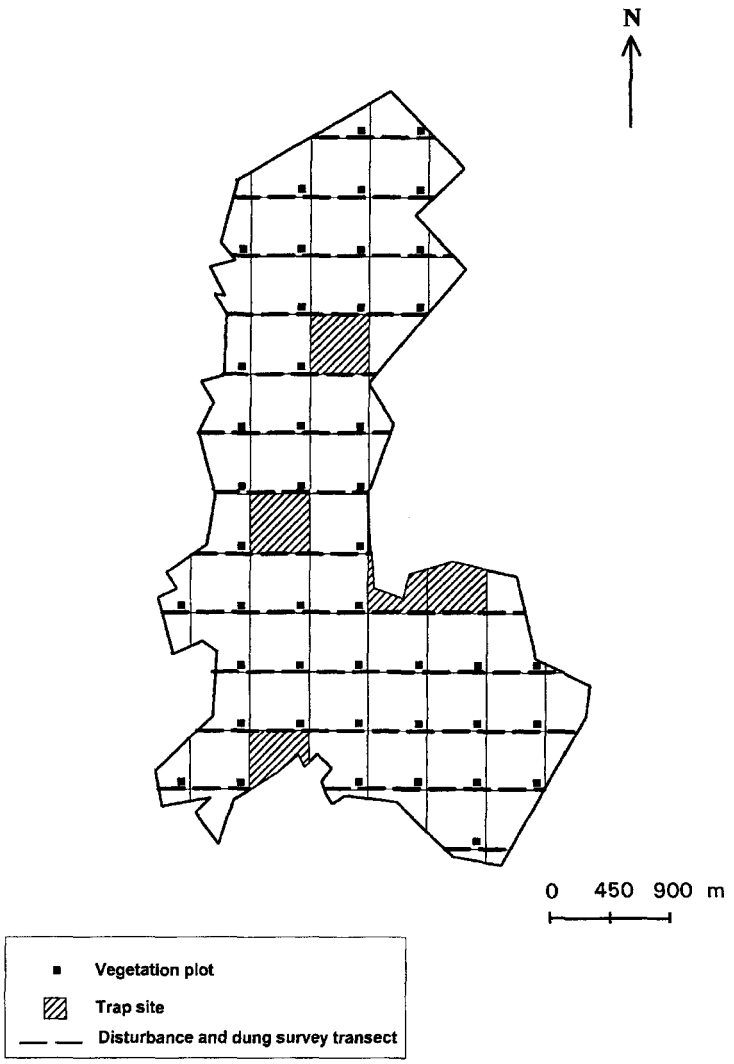

Figure 2. Biodiversity survey methods and grid system for Kambai Forest Reserve.

Forest disturbance was assessed for five metres on either side of E-W transects extending from border to border of the forest reserves. Cut and naturally fallen poles and timber trees

were counted and the diameter measured at the point of cut in 50 m sections along the transect. Poles were defined as stems with 5–15 cm dbh and 2 m of straight trunk, while timber was defined as stems with a dbh >15 cm and 3 m of straight trunk. Other disturbances, such as animal traps, fire and pit sawing sites, were also noted. In Magoroto, Mlungui, and Bamba Ridge disturbance was assessed by counting cut and naturally fallen poles and timber on a 5 m belt along three 250 m transects spaced 30 m apart. Three to five grid quadrants were sampled.

Faunal survey methods

Within each forest, five grid quadrants were selected and each was sampled for ten nights. In order to sample small mammals, three lines of 33 snap-traps were set out, with each trap at 2–5 m intervals from each other. Fried coconut and peanut butter was used as bait. They were set in the evening and checked in the morning. The typical sampling intensity was 5,000 trap-nights. To sample bats, nets of 3, 7, 9 and 12 m length were placed near roost sites and across flight 'corridors'. They were set up at dusk, observed throughout the night, and were shut at dawn. The typical sampling intensity was 60 hours. Mammal dung surveys were carried out 2 m either side of the N-S or E-W transects to identify the presence of mainly small forest ungulates not normally observed or trapped. All dung observed was recorded by location and habitat type in 50 m sections of the transect. Samples were identified by comparing to a voucher specimen collection. In addition, opportunistic sampling of mammals was also done.

Amphibians, reptiles and shrews were sampled using bucket pitfall traps. Three lines, each consisting of 11 plastic buckets (10 litre), were sunk to ground level at 5 m intervals. A continuous piece of plastic sheeting ran perpendicular to the ground forming a 'runner' channelling an animal into a bucket. Each collected specimen was weighed, measured and identified, and the habitat was noted. The typical sampling intensity was 1,650 bucket-nights. At least one specimen of every vertebrate species collected was deposited at the UDSM. Other specimens were loaned to the institution at which the relevant taxonomist is working (mammals: Frankfurt Zoological Museum and Chicago Field Museum of Natural History; amphibians: Natural History Museum of London; reptiles: Natural History Museum of Bulawayo).

Butterflies were sampled using Blendon butterfly traps (38 cm round base, 69 cm high) using rotting banana as bait. Five traps were set in the forest canopy and checked daily. The typical sampling intensity was 250 trap-days. Sweep netting was also done. Specimens were deposited at the African Butterfly Research Institute in Nairobi. To sample molluscs and millipedes, three 1 m x 1 m (molluscs) and 3 m x 3 m (millipedes) plots were surveyed. The leaf litter and upper layer of soil was searched and specimens collected for identification. Millipedes were deposited at the Virginia Museum of Natural History and molluscs with the University of Copenhagen Zoological Museum.

Endemic and threatened species

The classification of plant species into endemic and near-endemic, and into ecological type, such as forest dependent, non-forest species etc., follows Iversen (1991) and Hawthorne (1993). Distribution is discussed primarily based on the Flora of Tropical East Africa (Turrill & Milne-Redhead, 1952) and Iversen (1991). Ecological type, endemic and IUCN status for fauna were compiled from Kingdon (1989) and the National Biodiversity Database at the UDSM. Species recorded in the surveys were classified according to their CITES category

into Appendix I (endangered) and Appendix II species (vulnerable), and according to their IUCN (1996) categories of threat.

RESULTS

In each reserve between 56 and 167 species of trees and shrubs were recorded. The respective ranges of mammals, reptiles and amphibians were 5–36, 9–29, and 1–29. The number of species for the main groups (trees, mammals, reptiles, amphibians) included in all surveyed forests is presented in table 2.

Flora

Species richness

The number of families was higher in the larger forest blocks (*e.g.* Bamba Ridge, Kambai, Kwamarimba), or in the SE part of the East Usambara Mountains, such as in Magoroto (table 3). The same pattern could be observed with species numbers. In most surveyed forests species accumulation curves did not level off completely suggesting that a number of rarer species are not being recorded at a sampling intensity of 0.5 % or 0.25 %. In some reserves, such as Kambai and Kwamarimba FRs, the last 10–15 plots added only ten new species suggesting that most species had been included in the sample. In others, it required only the last two to four plots to add the same number of new species, which would indicate that a number of species were still not included at the sampling intensity used.

The surveys demonstrated that a high proportion of the species recorded depend on primary forest; on the average 27 % of the total number of species, 41 % of these endemic or near-endemic. The proportion of primary-forest-dependent species ranged from 18.9 % in Longuza to 44.0 % in Magoroto, while 6.4–17.0 % were non-forest species. Between 0 and 4.6 % of the species were strict Usambara endemics, whereas 21.6–28.6 % were near-endemics. Out of the primary-forest-dependent species 36.2–50.0 % were endemic or near-endemic. A map of the distribution of forest-dependent near-endemic tree species in Kambai Forest Reserve is shown in figure 3.

Endemics

A total of 11 different plant species endemic to the East Usambara (5), East and West Usambara (4) or the coastal forests (2) were found (table 4).

Table 4. Species endemic to the East Usambara (EU), East and West Usambara (EWU) or shared with coastal forests (CF) identified in the surveyed forests (for abbreviations see table 1).

Species	Forest[1]	EU	EWU	CF
Cola usambarensis Engl.	Bam, Kam, Mar	X		
Cynometra brachyrrhachis Harms	Mar			X
C. longipedicellata Harms	Mar	X		
Dolichometra leucantha K. Schum.	Mag	X		
Englerodendron usambarense Harms	Mag		X	
Nesogordonia holtzii (Engl.) Caperon	Kam, Lon, Mar			X (?)
Rinorea angustifolia (Thouars) Baill.	Kam, Mar		X	
R. scheffleri Engl.	Mag	X		
Sapium armatum Pax & K. Hoffm.	Mar			X
Vitex ferruginea Schum.	Mag		X	
Zimmermannia capillipes Pax	Mag		X	

Biogeography

Field identifications have recorded a number of species outside of their previously recorded ranges. These specimens are awaiting confirmation but provisionally the botanists suggest that the range of the following species extends into the East Usambara forests. In Magoroto, the following species of interest were recorded: *Psychotria megistantha* Petit, a shrub known only from southern Tanzania; *Zanthoxylum mildbraedii* (Engl.) Waterm., a tree recorded from rain forests of Uganda, Kenya, Zaire, and Rwanda, which is a new record for Tanzania; and *Cola stelacantha* Brenan, a forest-dependent tree limited to five locales in southern and east-central areas of Tanzania.

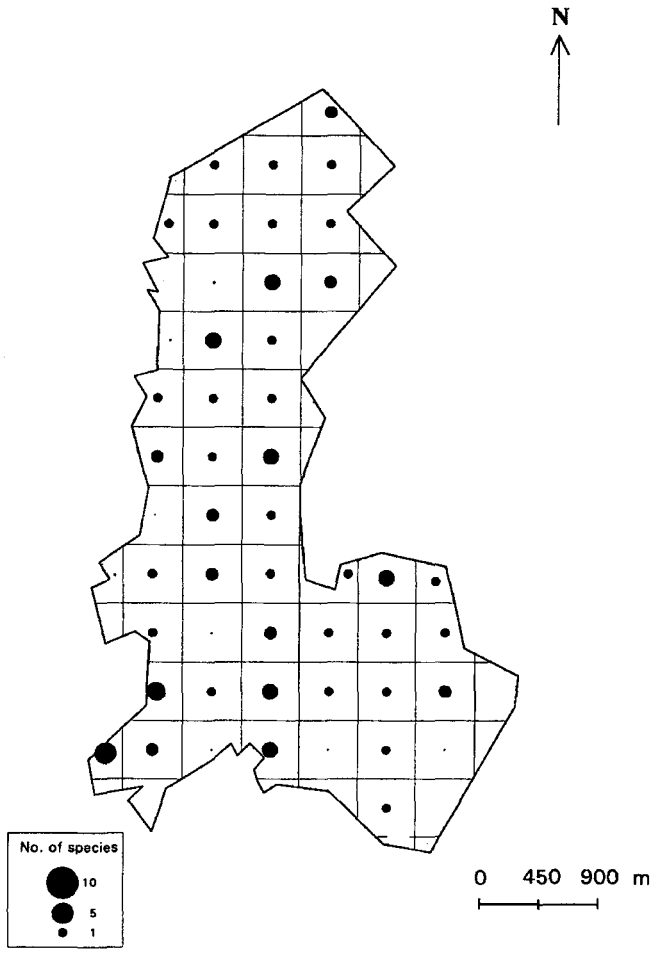

Figure 3. Distribution of forest dependent near-endemic tree species in Kambai Forest Reserve.

In Bamba Ridge, *Cola discoglypremnophylla* Brenan & A.P. Jones represents a range extension. According to FTEA it is a rare species limited to southern Tanzania and Mozambique, although it appears common in the Selous Game Reserve (Rodgers, pers. comm.). *Dichapetalum stuhlmannii* Engl., which was found in Mlungui, may represent a range extension. According to the FTEA the distribution in the Usambara Mountains was

restricted only to the West but was neither recorded in West nor East Usambara by Iversen (1991), nor by Ruffo *et al.* (1989). *Dichapetalum macrocarpum* M. Krause is a shrub typical of *Brachystegia* woodland, bushland and thicket of southern Tanzania, and also found in Mozambique. The Mlungui record represents a range extension in NE Tanzania. Other interesting species in Mlungui were: *Olax gambecola* Baill., a shrub typical of rain and riverine forest in Uganda, and of the Coast and Morogoro Regions; and *Tricalysia pedicellata* Robbrecht, a forest-dependent tree previously known from the Coast and Morogoro Regions. Both represent range extensions. *Monodora minor* Engl. & Diels, recorded in Kambai, was previously considered restricted to coastal forests.

Fauna

Species richness

The correlation between the size of the reserve and the faunal species richness was weaker than for the botanical survey. Although the larger forest blocks, such as Bamba Ridge and Kambai Forest Reserves, have the highest numbers of vertebrates, Magoroto with only 591 ha also has a high number of animal species. The total number of animal species is presented in table 5.

Table 5. Total number of species of fauna (mammals, reptiles and amphibians), including endemic, near-endemic, forest-dependent, forest-dwelling and non-forest species identified in the surveyed forests.

Forest	Number of		EWU endemic[1]	Near-Endemic[1]	Forest dependent[1]		Forest species	Non-forest species[1]
	Families	Species	Total	Total	Total	End. or near-end.	Total	Total
Bamba Ridge	33	77	3	19	27	20	43	1
Kambai	29	69	2	15	23	15	35	3
Kwamarimba	25	44	-	14	10	9	28	1
Longuza (north)	14	20	0	1	3	-	10	1
Magoroto	36	85	1	23	32	22	35	7
Mlungui	11	17	1	3	4	3	8	1

[1] According to the National Biodiversity Database at UDSM.

The list of species found is given as an appendix, together with their conservation status and endemicity.

Endemics

Three species endemic to the East and West Usambara Mountains were found. *Boulengerula boulengeri* Tornier, a caecilian, and the ground frog, *Hoplophryne rogersi* Barbour & Loveridge were recorded in Bamba Ridge and Kambai Forest Reserves. The endemic snake *Prosymna semifasciata* has previously only been collected in Kwamgumi Forest Reserve. All three species are forest-dependent. A total of 36 near-endemic species, five mammals, 17 reptiles and 14 amphibians, were recorded. Out of these 32 (89 %) were forest-dependent. In the butterfly survey conducted at Mlungui, four near-endemic, forest-dependent species were recorded: *Baliochilia amanica* Stempffer & Bennett, *B. latimarginata* Hawker-Smith, *Ceratrichia bonga* Evans, *Pentila rogersi* ssp *parapetreia* Rebel.

Biogeography

A number of rare and poorly known species were recorded during the surveys. The paratype of a new species of blind snake, *Leptotyphlops macrops* Broadley & Wallach was collected in Magoroto which extends its range from the coastal forests of Kenya and Tanzania. Another snake, *Prosymna semifasciata* Broadley, was found at Mlungui. This is the second specimen of this species. The second specimen, and the first female, of the gecko *Lygodactylus kimhowelli* Pasteur was collected in Kambai. The only previously known site of this species was the Amboni Caves forest, north of Tanga.

In Magoroto the mops free-tailed bat, *Tadarida brachyptera* Peters, was recorded and this is the third record for Tanzania and the first for the East Usambara Mountains. The bats, *Scotophilus nucella,* recorded in Kambai Forest Reserve, and *Eptesicus flavescens* Seabra collected in Longuza Forest Reserve were the first records for Tanzania. In Bamba Ridge Forest Reserve the bat, *Miniopterus m. minor* Peters is the first record for the East Usambara Mountains. In Kwamarimba Forest Reserve, *Typhlops pallidus* Cope, the pallid blind-snake, which is previously known from Sudan, Kenya and Zanzibar, was found. This is the first record from mainland Tanzania. The forest fossorial skink, *Melanoseps loveridgei* Brygoo & Roux-Esteve, was also found in Kambai. This represents a NE range extension.

Threatened species

The amphibian *Nectophrynoides tornieri* Roux was the only species which is listed under CITES Appendix I. Category II species found in the surveys were: *Bradypodion fischeri* Reichenow; *B. tenue* Matschie; *Chamaeleo melleri* Gray; and the Nile monitor lizard, *Varanus niloticus* Linnaeus (table 6).

Table 6. Species of fauna which are listed in the CITES Appendices (for abbreviations see table 1).

Species	Forest	Animal group	CITES I	CITES II
Nectophrynoides tornieri (Roux)	Bam, Mag	Amphibian	X	
Bradypodion fischeri (Reichenow)	Mag	Reptile		X
B. tenue (Matschie)	Bam, Mag	Reptile		X
Chamaeleo melleri (Gray)	Bam	Reptile		X
Varanus niloticus (Linnaeus)	Bam, Kam, Lon, Mag	Reptile		X

Disturbance

A total disturbance transect length of more than 47 km was assessed, which represents a sampling intensity of 1.1 % of the surveyed forest area (table 7). The number of cut poles ranged from 51.9 poles/ha in Kwamarimba to 1,100.5 poles/ha in Magoroto, while the range of the number of naturally fallen poles was much smaller (109–233 poles/ha). Timber cutting was most frequent in Magoroto. In all other areas it ranged between 5.6–35.6 cut timber/ha. The number of naturally fallen poles or timber was highest in Mlungui and Longuza (poles). Fire had affected Longuza, Kwamarimba and Kambai.

Training

Out of a permanent FBD staff of about 42 working within the East Usambara Mountains, 35 have participated in the EUBS. A total of 2,307 staff man-days have been used, and apart

from the permanent survey team, most EUCFP field staff have spent two weeks or more in the field.

Table 7. Number of cut and naturally fallen poles and timber in the surveyed forests.

Forest	Area, ha	No. of transects	Transect length, m	Poles, mean ha^{-1}		Timber, mean ha^{-1}	
				Cut	Fallen	Cut	Fallen
Magoroto	591	3	1,870	1 100.5	149.7	189.3	58.8
Bamba Ridge	1,131	5	3,750	209.6	137.6	24.5	35.2
Mlungui	200	3	2,250	240.9	218.7	35.6	119.1
Kwamarimba	887	4	12,290	51.9	109.0	6.6	55.3
Longuza (north)	360	5	7,185	53.9	233.0	16.7	49.0
Kambai	1,046	13	19,925	76.6	170.5	5.6	67.6
Total/Mean	4,215	33	47,270	288.9	169.8	46.4	64.2

DISCUSSION

Survey methods

The EUBS represent the first systematic and comprehensive effort to survey forest biodiversity for management purposes in Tanzania. The methods have become progressively more systematic, quantitative and focused. The earlier expeditionary FT approach was more oriented towards species discovery. The new methods are simple, standardised and repeatable. This is important since fieldwork depends on volunteer research assistants or professional forestry staff with limited experience of biological survey work, supervised by a small but more experienced team. The systematic rather than a stratified or strategic sampling approach, although more laborious and probably more expensive, was preferred for simplicity of data collection, interpretation and presentation (cfr Hamilton & Bensted-Smith, 1989; Howard, 1996). The methods used now in the EUBS also have the advantage of being comparable with other biodiversity inventories (cfr Stork & Samways, 1995).

The grid plan of vegetation plots has been an effective and straightforward method of vegetation sampling. As the dominant ecological matrix, trees have been the focus of the botanical work because so much was already known about the species, their distribution and biogeographical significance. Trees also show a high degree of endemism (cfr Iversen, 1991; Lovett, 1989, 1993; Ruffo *et al.*, 1989; WWF & IUCN, 1994). Furthermore, much quantitative and qualitative data exist on the forests, which assists in the interpretation (AFIMP, 1988; Hamilton, 1989; Ruffo *et al.*, 1989; Iversen, 1991).

It is clear that at the current sampling intensities a number of species were not recorded. This is of particular concern with regard to endemic species. The surveys have not recorded any specimens of 12 endemic tree or shrub species listed by Iversen (1991). A majority of these are sub-montane species and thus may be restricted to reserves that are predominantly sub-montane forest, such as Amani Nature Reserve and Nilo Forest Reserve (and which have not been surveyed by the current programme). Nevertheless, the species accumulation curves have levelled to such an extent that the sampling effort to 'capture' each additional species is high. Based on recommendations by Howard (1996), an increasing emphasis is now placed on opportunistic sampling in addition to the systematic botanical work. This may prove a more effective way of improving the sampling success but has the disadvantage that it is difficult to standardise the sampling effort.

A major problem with the initial approach of the faunal surveys was the lack of focus, and efforts were dissipated across a broad spectrum of taxa and methods (Howard, 1996). Since the purpose of the faunal surveys was also to identify areas of particular biodiversity value, a greater emphasis on endemic species was adopted. Collection of a number of taxa was discontinued, including fish and Crustacea. Small terrestrial mammals were included because of ease of sampling and ability to get sufficient sample sizes. They also include potential indicator species, such as *Rattus rattus*, and there are possibilities for discovering new species since only limited studies have so far been done. The same largely applies to bats. The ungulate surveys were included because experience from elsewhere suggests that small forest ungulates are good indicators for forest disturbance and in monitoring hunting pressure. Reptiles and amphibians are groups that show a high degree of endemism in the East Usambara Mountains and they have been studied well enough to enable comparison and interpretation of the results. Similarly the millipedes and molluscs exhibit a high degree of endemism. Birds have not been included in the survey as they are better suited to specialist expeditions.

One of the bottlenecks for biodiversity surveys is the global shortage of taxonomic capacity (Stork & Samways, 1995). Presently in Tanzania, there is in-country capacity to identify plants. The number of qualified staff is, however, small and it can be difficult to secure time from these botanists. In addition, the published East African flora is still incomplete and there has been some inconsistency in the identification of some species, notably within the family Sterculiaceae. Collecting specimens from every tree recorded would considerably increase the costs but specimens are now taken from all endemic and near-endemic trees and from any tree where species identification is not obvious. Faunal taxonomy still largely depends on the network of international experts. Because much of this work is done on voluntary basis, it may sometimes and with certain groups, take a considerable time to get the final species lists compiled.

Data recording procedures have been considerably improved. The past FT forms and procedures were complicated and difficult to transfer into digital form. New data recording sheets were designed in connection with the development of a computerised biodiversity database at the end of 1996, and presently data recording is simple and consistent from field to data entry.

Findings

No new plant species were recorded but there were some interesting range extensions that contribute to our knowledge of species distributions. The occurrence of species, such as *Nesogordonia holtzii* and *Monodora minor* in the East Usambara Mountains forests, which according to the definition used by Hawthorne (1993) do not belong to the coastal forests, probably reflects a continuum between the coastal forests and the sub-montane Eastern Arc flora. The lowland forests (<800 m) at the foothills of the East Usambara Mountains share many species with coastal forests, including a number of endemics (Hawthorne, 1993; Lovett, 1993), and have been regarded as a part of that vegetation by some authors (*e.g.* in Burgess & Clarke, in press). The numbers of endemics and near-endemics recorded in the EUBS corresponds well with earlier work by Iversen (1991) and Lovett (1989, 1993).

The zoological surveys have clarified the ranges of a number of vertebrate species such as *Typhlops pallidus*. Surprisingly few endemics were found but 36 near-endemics were recorded. The surveys also provide data on the abundance of species listed as globally threatened, such as *Prosymna semifasciata*, or species under CITES restrictions, such as *Varanus niloticus*.

The surveys have shown that poles, but also timber, are still extracted from the forest reserves. The surveys provide a quantitative measure of this on-going direct use of the forests and highlights problem areas that may require increased management focus. Disturbance was higher in the Magoroto Estate Forest as compared to the forest reserves. This is quite surprising considering that the estate is privately owned. The reason is probably that the Magoroto Estate is a mosaic of plantations, cultivation, residential areas and natural forest, where the level of management and control has been weak for years. In areas where villages are squeezed between forest reserves and sisal estates, such as in Bamba Ridge and Mlungui, disturbance is also greater. In Mlungui disturbance was also high due to its small size.

Almost all EUCFP staff have received on-the-job training in biological inventory methods and techniques. During the surveys the staff responsible for a specific forest as a rule participate in the field work, which provides them with detailed biodiversity information about the reserve. Furthermore, most of the staff have a traditional forestry training with little emphasis on biodiversity conservation, especially the faunal aspects of conservation. The survey work has made the foresters more aware, and increased their knowledge and understanding of biodiversity. While several EUCFP staff are now thoroughly familiar with the survey methods, the next step is to build up capacity in managing and applying the data.

Implications for conservation management

The most significant value of the survey for management planning is that it provides quantitative, geographically referenced information on local distribution of species, especially endemics and near-endemics. These data make it possible to identify important biodiversity areas on the basis of more reliable information. The surveys indicate the importance of the larger forest blocks, such as Kambai and Bamba Ridge. The surveys also points to the importance of the southern part of the EUM, which is evident from the high number of families and plant species, even in the highly disturbed Magoroto Forest (*cfr* AFIMP, 1988). It also shows that the forest reserve system still has a definite comparative conservation advantage as compared to the public land forests, which are badly fragmented into small patches, or even estate land, especially if management is not strong or does not take forest conservation into consideration. It also suggests that one of the most important conservation issues remaining in the East Usambara Mountains is the establishment of the proposed forest corridors linking the larger forest blocks, especially between the southern and northern parts (*cfr* Newmark, 1992, 1993).

Many protected areas lack basic species inventories as a basis for monitoring or conservation management. For example, in Africa only 1.6 % of protected areas have limited species inventories of higher plants and 1.2 % of trees, while the corresponding figures for comprehensive systematic inventories is only 0.6 % and 0.4 % respectively. Corresponding information on fauna is similar, where only mammal and bird inventories show higher figures of 4.3 % and 3.8 % in limited, and 0.3 % and 0.9 % in comprehensive inventories (Heywood, 1995). One of the purposes of the EUBS was to integrate biodiversity information and disturbance assessment in biodiversity monitoring and management. The information on species' local distribution and human disturbance is already used in management planning, especially zoning of forest reserves (*e.g.* Bamba Ridge and Kwamarimba Forest Reserves). Areas with high biodiversity value within the East Usambara Mountains or the individual reserve will be more closely monitored and protected, while those areas where forest disturbance and pressure from local forest adjacent communities is high may be developed into community use zones.

After some initial problems the survey methods are now well in place, and the use of resources (expertise, funds, time) is relatively effective. The use of volunteers in inventory work represents the kind of lateral thinking that may be required when professional human resources are a bottleneck (Stork & Samways, 1995). The average survey performance was 1,385 ha per each ten-week field phase. This is equivalent to about 20.7 ha of forest per day and 1.5 days per sample plot (0.1 ha). Nevertheless, costs are high, and a rough estimate based on the 10,485 ha of Forest Reserves, which have been surveyed so far, is about 6,000 TShs per ha, or equivalent to 9–10 USD. This is about two thirds of the cost to survey higher plant and vertebrate species of a 40 km^2 national park in Australia, but considerably higher than the cost (< 1 USD per ha) of surveying the woody plants to species level in a small 490 ha forest in Sri Lanka as reported by Jayasuriya *et al.* (1997). Surprisingly, the global biodiversity assessment (Heywood, 1995), although recognising resources as a major bottleneck for biodiversity inventories and management, does not devote a single chapter of its 1,140 pages to the costs involved.

From the preliminary experience so far it can be concluded that the EUBS have achieved their objectives. However, the surveys require considerable time and costs, and without a more detailed analysis it is difficult to conclude whether this objective could not have been achieved with a focus on a narrower range of taxa. It is also obvious that they will not provide comprehensive information on the taxa included in the surveys since they basically are a management tool. Nevertheless, it seems clear that they will provide a sufficient set of data to incorporate biodiversity in conservation and management of the protected forests in the East Usambara Mountains.

ACKNOWLEDGEMENTS

A considerable number of people have participated in various stages of the EUBS. We thank especially the volunteers, the taxonomists, and the Frontier-Tanzania and EUCFP staff. We wish to particularly acknowledge Julian Bayliss, co-ordinator of the EUBS during the first year, and Luciana Mshana and Raymond Kilenga from EUCFP. Thanks to Quentin Luke and Dr Leo Junikka for assistance with plant species authorities, and Prof. Kim Howell on the fauna. Dr Neil Burgess, Prof. Jon Fjeldså, Dr Matti Nummelin, and Dr Alan Rodgers provided constructive comments on the manuscript.

REFERENCES

Amani Forest Inventory and Management Plan Project (1988). *East Usambara Mountains. Forests and Forestry; Forestry and Land Use; Maps and Diagrams*. Forestry and Beekeeping Division & Joint Venture Finnmap-Silvestria, Dar es Salaam & Helsinki.

Burgess, N.D. & G.P. Clarke (eds) (in press). *The Coastal Forests of eastern Africa*. IUCN Forest Conservation Programme, Gland and Cambridge.

Clarke, G.P. & L.K. Stubblefield (1995). *Status reports for seven coastal forests in Tanga Region, Tanzania*. Frontier-Tanzania Technical Report No. 16. The Society for Environmental Exploration & University of Dar es Salaam, London & Dar es Salaam.

Cunneyworth, P. (ed.) (1996a). *Kwamarimba Forest Reserve: A biodiversity survey*. East Usambara Catchment Forest Project Technical Paper No. 33. Forestry and Beekeeping Division & Finnish Forest and Park Service & Society for Environmental Exploration,

Dar es Salaam, Vantaa & London. Available from the East Usambara Catchment Forest Office, Tanga, Tanzania.

Cunneyworth, P. (ed.) (1996b). *Longuza Forest Reserve: A biodiversity survey*. East Usambara Catchment Forest Project Technical Paper No. 34. Forestry and Beekeeping Division & Finnish Forest and Park Service & Society for Environmental Exploration, Dar es Salaam, Vantaa & London. Available from the East Usambara Catchment Forest Office, Tanga, Tanzania.

Cunneyworth, P. (ed.) (1996c). *Kambai Forest Reserve: A biodiversity survey*. East Usambara Catchment Forest Project Technical Paper No. 35. Forestry and Beekeeping Division & Finnish Forest and Park Service & Society for Environmental Exploration, Dar es Salaam, Vantaa & London. Available from the East Usambara Catchment Forest Office, Tanga, Tanzania.

Cunneyworth, P. & L.K. Stubblefield (1996a). *Magoroto Forest: A biodiversity survey*. East Usambara Catchment Forest Project Technical Paper No. 30. Forestry and Beekeeping Division & Finnish Forest and Park Service & Society for Environmental Exploration, Dar es Salaam, Vantaa & London. Available from the East Usambara Catchment Forest Office, Tanga, Tanzania.

Cunneyworth, P. & L.K. Stubblefield (1996b). *Bamba Ridge Forest Reserve: A biodiversity survey*. East Usambara Catchment Forest Project Technical Paper No. 31. Forestry and Beekeeping Division & Finnish Forest and Park Service & Society for Environmental Exploration, Dar es Salaam, Vantaa & London. Available from the East Usambara Catchment Forest Office, Tanga, Tanzania.

Cunneyworth, P. & L.K. Stubblefield (1996c). *Mlungui Proposed Forest Reserve: A biodiversity survey*. East Usambara Catchment Forest Project Technical Paper No. 32. Forestry and Beekeeping Division & Finnish Forest and Park Service & Society for Environmental Exploration, Dar es Salaam, Vantaa & London. Available from the East Usambara Catchment Forest Office, Tanga, Tanzania.

Hamilton, A.C. (1989). Some results of the 1986/87 Forest Division/FINNIDA inventory. In A.C. Hamilton & R. Bensted-Smith (eds), *Forest Conservation in the East Usambara Mountains, Tanzania*. IUCN, Gland and Cambridge. Pp 231–239.

Hamilton, A.C. & R. Bensted-Smith (eds) (1989). *Forest Conservation in the East Usambara Mountains, Tanzania*. IUCN, Gland and Cambridge.

Hawthorne, W.D. (1993). East African coastal forest botany. In J.C. Lovett & S.K. Wasser (eds), *Biogeography and Ecology of the Rain Forests of Eastern Africa*. Cambridge University Press, Cambridge. Pp 57–99.

Heywood, V.H. (ed.) (1995). *Global Biodiversity Assessment*. United Nations Environment Programme, Nairobi.

Howard, P.C. (1996). *Baseline biological surveys in selected East Usambara Forest Reserves and forests, 1995–96*. Project evaluation report. East Usambara Catchment Forest Project Technical Paper No. 21, Forestry and Beekeeping Division & Finnish Forests and Park Service, Dar es Salaam & Vantaa.

Howard, P.C. & T. Davenport (eds) (1996). *Biodiversity Report Series*. Uganda Forest Department, Kampala.

IUCN (1996). *1996 IUCN Red List of Threatened Animals*. IUCN, Gland.

Iversen, S.T. (1991). The Usambara Mountains, N.E. Tanzania: phytogeography of the vascular plant flora. *Acta Universitatis Upsaliensis, Symbolae Botanicae Upsalienses* **29 (3)**.

Jayasuriya, M., A. Balmford & M. Green (1997). A promising short cut for assessing biodiversity. *Plant Talk* **(8):** 28–29.

Johansson, S.G. & R. Sandy (1996). *Protected areas and public lands. Land use in the East Usambara Mountains*. East Usambara Catchment Forest Project Technical Paper No. 28, Forestry and Beekeeping Division & Finnish Forests and Park Service, Dar es Salaam & Vantaa.

Kingdon, J. (1989). *East African Mammals. An Atlas of Evolution, vols I–IIID*. University of Chicago Press, Chicago (reprinted from earlier editions).

Kingdon, J. (1990). *Island Africa*. Collins, London.

Laurance, W.F. & R.O. Bierregaard (eds) (1997). *Tropical Forest Remnants. Ecology, Management and Conservation of Fragmented Communities*. The University of Chicago Press, Chicago.

Lovett, J.C. (1989). The botanical importance of the East Usambara forests in relation to other forests in Tanzania. In A.C. Hamilton & R. Bensted-Smith (eds), *Forest Conservation in the East Usambara Mountains Tanzania*. IUCN, Gland and Cambridge. Pp 207–212.

Lovett, J.C. (1993). East African moist forest flora. In J.C. Lovett & S.K. Wasser (eds), *Biogeography and Ecology of the Rain Forests of Eastern Africa*. Cambridge University Press, Cambridge. Pp 33–55.

Lovett, J.C. & S.K. Wasser (eds) (1993). *Biogeography and Ecology of the Rain Forests of Eastern Africa*. Cambridge University Press, Cambridge.

Mittermeier, R.A., N. Myers, J.B. Thomsen, G.A.B. da Fonseca & S. Olivieri (1998). Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. *Conservation Biology* **3**: 516–520.

Newmark, W.D. (1992). *Recommendations for wildlife corridors and the extension and management of Forest Reserves in the East Usambara mountains, Tanzania*. East Usambara Catchment Forest Project Technical Paper No. 4, Forestry and Beekeeping Division and Finnish Forests and Park Service, Dar es Salaam and Vantaa.

Newmark, W.D. (1993). The role and design of wildlife corridors with examples from Tanzania. *Ambio* **22:** 500–504.

Rodgers, W.A. & K.M. Homewood (1982). Species richness and endemism in the Usambara Mountain forests, Tanzania. *Biological Journal of the Linnean Society* **18**: 197–242.

Ruffo K., C. Mmari, S.P. Kibuwa, J.C. Lovett, S. Iversen & A.C. Hamilton (1989). A preliminary list of the plant species recorded from the East Usambara forests. In A.C. Hamilton & R. Bensted-Smith (eds), *Forest Conservation in the East Usambara Mountains, Tanzania*. IUCN, Gland. Pp 157–179.

Society for Environmental Exploration (1998). *Methodology report*. Society for Environmental Exploration, London.

Stork, N.E. & M.J. Samways (1995). Inventory and monitoring. In V.H. Heywood (ed.), *Global Biodiversity Assessment*. United Nations Environment Programme, Nairobi. Pp. 453–543.

Turrill, W.B. & E. Milne-Redhead (1952, continued). *Flora of Tropical East Africa*. Government Bookshop, London.

WWF & IUCN. (1994). *Centres of Plant Diversity. A Guide and Strategy for their Conservation. 3 volumes*. IUCN Publication Unit, Cambridge.

APPENDIX

Species of fauna listed as critically endangered (CR), endangered (EN), vulnerable (VU) or lower risk (LR) by IUCN (1996), including their endemic status (E-endemic; N-near-endemic; W-wide spread) and ecological type (P-primary forest dependent; F-forest dwelling; ?-Data deficient) (for abbreviations see table 1).

Species	Forest	Category of threat	Endemic status	Ecological type
Mammals				
Crocidura xantippe Osgood, 1916	Kam	VU	N	?
Dendrohyrax validus Mollinson, 1905	Mag, Kam	VU	W	F
Galago zanzibaricus Matschie, 1893	Bam, Kam	VU	W	F
Miniopterus m. minor Peters, 1866	Bam	LR	W	F
Myonycteris relicta Bergmans, 1980	Bam	LR	N	P
Rhynchocyon petersi Bocage, 1880	Mag, Mar	LR	N	P
Reptiles				
Agama montana Barbour & Loveridge, 1928	Bam, Mag, Mlu,	VU	N	P
Aparallactus werneri Boulenger, 1895	Bam, Kam	VU	N	P
Bradypodion fischeri Reichenow, 1887	Mag	VU	N	P
Bradypodion tenue Matschie, 1892	Bam, Mag	VU	N	P
Chamaeleo melleri Gray, 1964	Mar	LR	W	F
Cnemaspis africana Werner, 1895	Mag	LR	N	P
Cnemaspis barbouri Perret, 1986	Kam	EN	N	P
Crotaphopeltis tornieri Werner, 1897	Bam, Lon, Kam	VU	W	P
Elapsoidea nigra Günther, 1863	Mar	VU	N	P
Leptosiaphos kilimensis Stejneger, 1891	Bam, Mag	VU	N	P
Lygodactylus kimhowelli Pasteur, 1995	Kam	EN	N	P
Mabuya m. maculilabris Gray, 1845	Kam	VU	W	F
Philothamnus macrops Boulenger, 1895	Bam, Mar, Mlu, Kam	VU	N	P
Prosymna semifasciata Broadley, 1995	Mlu	CR?	E	P?
Rhampholeon brevicaudatus Matschie, 1892	Bam, Mag, Mar, Kam	VU	N	P
Rhampholeon temporalis Matschie, 1892	Bam, Mag	EN	N	P
Typhlops gierrai Mocquard, 1897	Mag	VU	N	P
Amphibians				
Afrixalus ulugurensis Barbour & Loveridge, 1928	Mag	VU	N	P
Arthroleptides martiensseni Nieden, 1910	Mag, Kam	VU	N	P
Boulengerula boulengeri Tornier, 1896	Bam, Kam	VU	E	P
Bufo brauni Nieden, 1910	Mag, Mar, Kam	VU	N	P
Callulina kreffti Nieden, 1910	Bam, Mag	VU	N	P
Hoplophryne rogersi Barbour & Loveridge, 1928	Bam, Kam	VU	E	P
Leptopelis barbouri Ahl, 1929	Bam, Mag, Mar, Kam	VU	N	P
Leptopelis parkeri Barbour & Loveridge, 1928	Bam,	VU	N	P

Species	Forest	Category of threat	Endemic status	Ecological type
Leptopelis uluguruensis Barbour & Loveridge, 1928	Bam, Mag, Kam	VU	N	P
Leptopelis vermiculatus Boulenger, 1909	Mag, Kam	LR	N	P
Mertensophryne micranotis Loveridge, 1925	Bam, Mar, Kam	EN	N	P
Nectophrynoides tornieri Roux, 1906	Bam, Mag	VU	N	P
Phrynobatrachus krefftii Boulenger, 1909	Mag	VU	N	P
Probreviceps macrodactylus Nieden, 1926	Mag	LR	N	P
Scolecomorphus vittatus Boulenger, 1895	Bam, Mar	VU	N	P
Molluscs				
Lanistes farleri Craven	Kam	EN	-	-