

# Diversity and distribution of rodent and shrew species associated with variations in altitude on Mount Kilimanjaro, Tanzania

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## Abstract

A total of 750 rodents and shrews were trapped in several sites on Mount (Mt.) Kilimanjaro and in two lowland sites between October 2002 and August 2003. Species diversity variations with altitude and their distribution were established. Diversity of species varied with vegetation type, being highest in the forest and lowest in the lowland areas. The distribution patterns and species diversity of the rodents and shrews were also influenced by habitat complexity and heterogeneity. Species richness was higher in the forest compared to the other areas. The study generally shows that the Mt. Kilimanjaro has high rodent and shrew species diversity and richness.

**Keywords:** distribution; Mt. Kilimanjaro; rodents; shrews; species diversity; Tanzania.

## Introduction

Rodents and shrews are important contributors to biodiversity of ecosystems in sub-Saharan Africa (Linzey and Kesner 1997). They not only provide food for avian, reptiles and mammalian predators but also are important primary consumers of seeds and herbage (Krebs 2001). Because of food and cover requirements, rodents and shrews are likely to be adversely impacted by overuse of habitat by either domestic or wild species of larger mammals. In East Africa, mountain landscapes, such as the Kilimanjaro, Elgon, Meru, Usambara and Uluguru contain a number of endemic species with high disjunctive distribution (Clausnitzer and Kityo 2001, Stanley et al. 2005).

Mountains offer refuge for many species of small mammals (Stanley et al. 2005) during unfavorable climatic periods (Clausnitzer and Kityo 2001), e.g., when the surrounding areas become too arid, forest species become isolated in high-altitude forest patches. However, if the lower altitudes are covered with large rain forests, some savanna species could find refuge in the moorland grass-

lands above the forest limit. These isolation processes result in different distribution patterns under different altitudes on mountains (Delany and Happold 1979). This is due to the fact that the altitudinal gradient on the mountains is expressed by the formation of different vegetation zones, namely disturbed forest, intact forest and moorland grasslands. The expression of each zone depends on the latitude, the climatic situation and the extent of human influence.

Mount Kilimanjaro in Tanzania, provides a site that is relatively unimpacted by humans (Child 1965, Mwasaga 1983), except at the lower area of the mountain where it has been disturbed for agriculture when compared to other mountains, such as the Usambara Mountain (Makundi et al. 2007). Other unimpacted areas of the mountain, however, are home to a large number of small mammal species (Child 1965, Greenway 1965). However, species diversity of rodents and shrews in Mount (Mt.) Kilimanjaro, in contrast with the lower areas, has not been documented. This paper reports on species diversity and their distribution in relation to altitude on mountain Kilimanjaro.

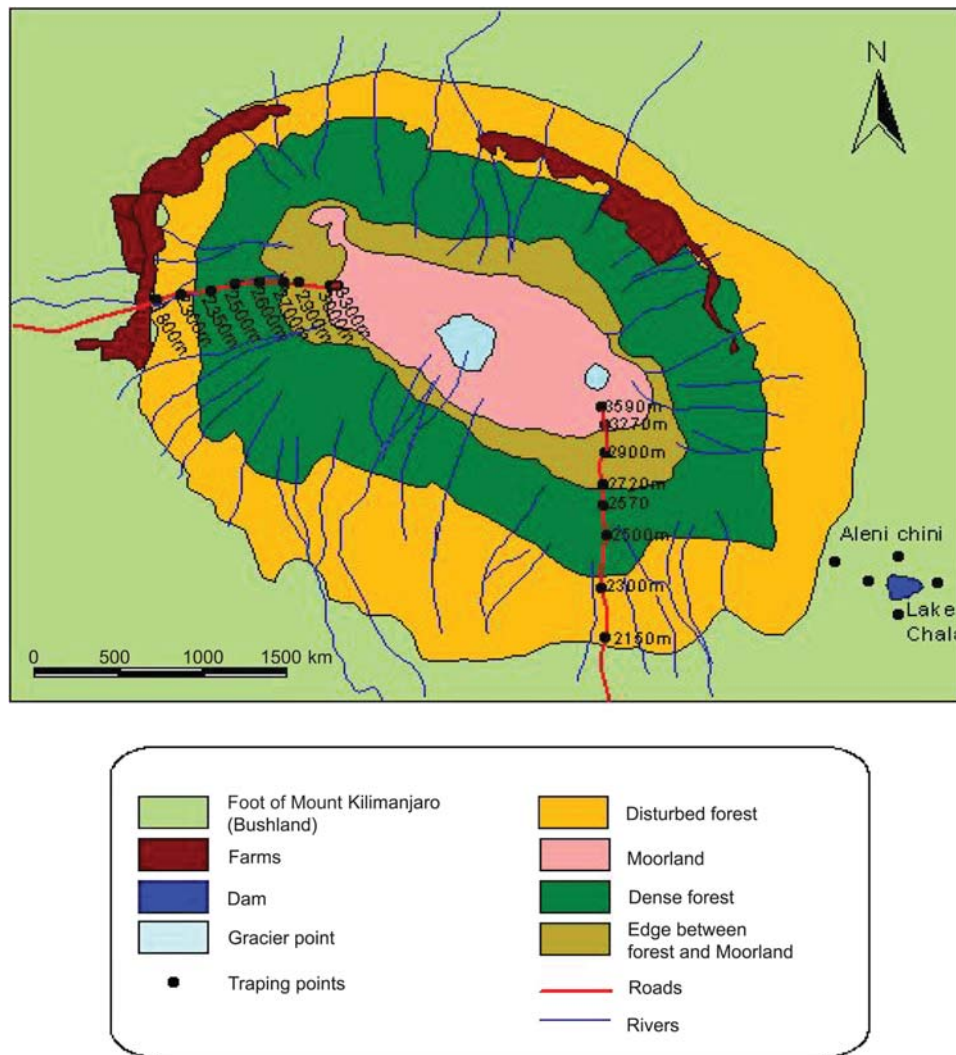
## Materials and methods

### Study area

Kilimanjaro Mountain is located in north-east Tanzania, at latitude 3°07' S and longitude of 37°35' E, at an altitude of 5895 m a.s.l. (Morris 1970). The mountain covers an area of 756 km<sup>2</sup>, and has one extinct volcano – Shira (3962 m), and two dormant volcanoes, namely Mawenzi (5149 m) and Kibo (5894 m) (Sampson 1965). The base of the mountain measures 50×80 km (Greenway 1965) and it has a snow-capped summit. Broadly, the vegetation types from lowest to highest points of the mountains are montane forest, moorland, upper moor, alpine bogs and alpine desert towards the peaks (Greenway 1965) (Figure 1).

Trapping was conducted along the defined routes of Shira and Marangu during wet and dry season, respectively. On the lowland, trapping was conducted in lower Rombo both at wet and dry season and Lake Chala areas during dry season. The choice of trapping sites on the mountain was based on accessibility, as the sites are on mountain climbing routes. Trapping was conducted in three types of habitats, disturbed forest, intact forest and moorland. In the lowland areas, the trapping was conducted in fallow and bush lands.

Animals were trapped with either Sherman (H.B. Sherman Traps Inc., Tallahassee, FL, USA) or pitfall traps and/or digging. On all trapping sites, 100 Sherman traps were placed per site in 10 lines, each with 10 trapping stations, 10 m apart for 2 consecutive nights. Traps were



**Figure 1** Map of Mount Kilimanjaro, Tanzania showing sites where trappings were carried out.

baited daily using a mixture of peanut butter and maize bran. The smaller rodents and shrews were captured using pitfall traps placed along the trap lines to each trapping site in the mountain. The pitfall traps (n=21)

were made of 10-l plastic buckets (250 mm high×220 mm rim) and were arranged 5 m apart, in a pitfall line. The trap nights for location were 2 nights. However, this method was not used in lowland sites.

**Table 1** Trap success of rodents and shrews at different altitudes on Mt. Kilimanjaro.

Vegetation and altitudes (m a.s.l.)	Captured individuals	Trap nights <sup>1</sup>	Trap success (%)
Disturbed forest – 1800	39	200	19.5
Disturbed forest – 2150	108	300	36.0
Disturbed forest – 2300	55	400	13.75
Disturbed forest – 2350	58	200	29
Edge of disturbed and dense forest – 2500	38	400	9.5
Dense forest – 2570	14	100	14.0
Dense forest – 2600	13	200	6.5
Dense forest – 2700	9	200	4.5
Dense forest – 2720	15	100	15.0
Edge of dense forest and moorland – 2900	11	200	5.5
Moorland – 3000	4	200	2
Moorland – 3270	15	100	15.0
Moorland – 3300	7	200	3.5
Moorland – 3590	4	100	4.0
Fallow land – Aleni Chini	27	200	13.5
Bush land – Lake Chala	13	100	13.0

<sup>1</sup>Combined trap nights for both Sherman and pitfalls.

**Table 2** Distribution of different species of rodents and shrews according to altitude on Mt. Kilimanjaro.

Species	Allen Chini	Lake Challa	1800	2150	2300	2350	2500	2570	2600	2700	2720	2900	3000	3270	3300	3590
<b>Rodent species</b>																
<i>Lophuromys flavopunctatus</i>			X	X	X	X	X	X	X	X	X			X		X
<i>Praomys delectorum</i>			X	X	X	X	X	X	X	X	X					
<i>Grammomys dolichurus</i>			X	X	X	X										
<i>Mus triton</i>					X									X		
<i>Dendromus mesomelas</i>						X										
<i>Dendromus insignis</i>								X								
<i>Gerbilliscus nigricauda</i>	X	X														
<i>Lemniscomys striatus</i>	X															
<i>Arvicanthis nairobae</i>	X															
<i>Otomys angoniensis</i>						X										
<i>Otomys cf. tropicalis</i>										X		X	X	X		
<i>Graphiurus murinus</i>						X				X						
<i>Rhabdomys pumilio</i>						X				X		X	X	X		X
<i>Tachyoryctes</i> sp.																
<i>Mastomys natalensis</i>	X	X														
<i>Acomys wilsoni</i>	X	X														
<b>Shrew species</b>																
<i>Myosorex zinki</i>									X							
<i>Crocidura olivieri</i>								X								
<i>Petrodromus tetradactylus</i>		X		X	X	X										
<i>Crocidura allea</i>											X			X		

**Table 3** Shannon-Wiener species diversity index values for rodents and shrews at different altitudes on Mt. Kilimanjaro.

Altitude	Species	Number	$p_i$	$\ln$	$p_i \times \ln$
1800	<i>Lophuromys flavopunctatus</i>	6	0.15	-1.897	-0.285
1800	<i>Praomys delectorum</i>	31	0.79	-0.236	-0.186
1800	<i>Grammomys dolichurus</i>	2	0.05	-2.998	-0.150
					$\Sigma=0.621$
2150	<i>Lophuromys flavopunctatus</i>	17	0.133	-2.04	-0.271
2150	<i>Praomys delectorum</i>	36	0.281	-1.269	-0.357
2150	<i>Grammomys dolichurus</i>	1	0.008	-4.852	-0.039
2150	<i>Crocidura olivieri</i>	32	0.250	-1.386	-0.347
2150	<i>Graphiurus murinus</i>	22	0.172	-1.761	-0.303
2150	<i>Tachyoryctes</i> sp.	20	0.156	-1.856	-0.290
					$\Sigma=1.607$
2300	<i>Mus triton</i>	1	0.05	-2.996	-0.15
2300	<i>Crocidura olivieri</i>	1	0.05	-2.996	-0.15
2300	<i>Graphiurus murinus</i>	1	0.05	-2.996	-0.15
2300	<i>Praomys delectorum</i>	10	0.53	-0.63	-0.34
2300	<i>Grammomys dolichurus</i>	2	0.11	-2.21	-0.24
2300	<i>Lophuromys flavopunctatus</i>	4	0.21	-1.56	-0.33
					$\Sigma=1.36$
2350	<i>Praomys delectorum</i>	27	0.47	-0.755	-0.355
2350	<i>Graphiurus murinus</i>	1	0.02	-3.912	-0.078
2350	<i>Dendromus mesomelas</i>	1	0.02	-3.912	-0.078
2350	<i>Lophuromys flavopunctatus</i>	18	0.31	-1.171	-0.363
2350	<i>Grammomys dolichurus</i>	8	0.14	-1.966	-0.275
2350	<i>Crocidura olivieri</i>	1	0.02	-3.912	0.078
2350	<i>Otomys angoniensis</i>	2	0.03	-3.507	-0.105
					$\Sigma=1.332$
2500	<i>Myosorex zinki</i>	1	0.03	-3.51	0.11
2500	<i>Praomys delectorum</i>	22	0.73	-0.31	0.23
2500	<i>Lophuromys flavopunctatus</i>	5	0.17	-1.77	0.30
2500	<i>Graphiurus murinus</i>	2	0.07	-2.66	0.19
					$\Sigma=0.83$
2570	<i>Crocidura olivieri</i>	1	0.071	-2.639	-0.187
2570	<i>Praomys delectorum</i>	1	0.071	-2.639	-0.187
2570	<i>Lophuromys flavopunctatus</i>	9	0.643	-0.442	-0.284
2570	<i>Dendromus mesomelas</i>	3	0.214	-1.540	-0.330
					$\Sigma=0.988$
2600	<i>Praomys delectorum</i>	3	0.23	-1.470	-0.338
2600	<i>Rhabdomys pumilio</i>	8	0.62	-0.478	-0.296
2600	<i>Myosorex zinki</i>	1	0.08	-2.526	-0.202
2600	<i>Lophuromys flavopunctatus</i>	1	0.08	-2.526	-0.202
					$\Sigma=1.038$
2700	<i>Otomys cf tropicalis</i>	2	0.22	-1.514	-0.333
2700	<i>Rhabdomys pumilio</i>	7	0.78	-0.248	-0.194
					$\Sigma=0.627$
2720	<i>Praomys delectorum</i>	16	0.400	-0.916	-0.367
2720	<i>Graphiurus murinus</i>	1	0.025	-3.689	-0.092
2720	<i>Crocidura allex</i>	1	0.025	-3.689	-0.092
2720	<i>Lophuromys flavopunctatus</i>	20	0.500	-0.693	-0.347
2720	<i>Dendromus insignis</i>	1	0.025	-3.689	-0.092
2720	<i>Grammomys dolichurus</i>	1	0.025	-3.689	-0.092
					$\Sigma=1.082$
2900	<i>Rhabdomys pumilio</i>	9	0.82	-0.198	-0.163
2900	<i>Otomys cf tropicalis</i>	1	0.09	-2.408	-0.217
2900	<i>Lophuromys flavopunctatus</i>	1	0.09	-2.408	-0.217
					$\Sigma=0.597$
3000	<i>Otomys cf tropicalis</i>	1	0.25	-1.386	-0.347
3000	<i>Rhabdomys pumilio</i>	3	0.75	-0.288	-0.216
					$\Sigma=0.563$
3270	<i>Otomys cf tropicalis</i>	6	0.182	-1.705	-0.310
3270	<i>Rhabdomys pumilio</i>	9	0.273	-1.299	-0.355
3270	<i>Mus triton</i>	1	0.030	-3.497	-0.105
3270	<i>Crocidura allex</i>	3	0.091	-2.398	-0.218
3270	<i>Lophuromys flavopunctatus</i>	13	0.394	-0.932	-0.367
					$\Sigma=1.460$
3300	<i>Rhabdomys pumilio</i>	6	0.86	-0.151	-0.130
3300	<i>Dendromus insignis</i>	1	0.14	-1.966	-0.275
					$\Sigma=0.405$

(Table 3 continued)

Altitude	Species	Number	$p_i$	ln	$p_i \times \ln$
3590	<i>Graphiurus murinus</i>	1	0.063	-2.773	-0.175
3590	<i>Rhabdomys pumilio</i>	7	0.438	-0.827	-0.362
3590	<i>Crocidura allea</i>	1	0.063	-2.773	-0.175
3590	<i>Lophuromys flavopunctatus</i>	6	0.375	-0.981	-0.368
					$\Sigma=1.080$
Allen Chini	<i>Mastomys natalensis</i>	1	0.036	-3.332	-0.119
Allen Chini	<i>Acomys wilsoni</i>	14	0.500	-0.693	-0.347
Allen Chini	<i>Gerbilliscus nigricauda</i>	9	0.321	-1.135	-0.365
Allen Chini	<i>Petrodromus tetradactylus</i>	1	0.036	-3.332	-0.119
Allen Chini	<i>Leminiscomys striatus</i>	1	0.036	-3.332	-0.119
Allen Chini	<i>Arvicanthis nairobae</i>	2	0.071	-2.639	-0.189
					$\Sigma=1.257$
Lake Chala	<i>Mastomys natalensis</i>	2	0.200	-1.609	-0.322
Lake Chala	<i>Acomys Wilson</i>	3	0.300	-1.361	-0.361
Lake Chala	<i>Petrodromus tetradactylus</i>	2	0.200	-1.609	-0.322
Lake Chala	<i>Gerbilliscus nigricauda</i>	3	0.300	-1.204	-0.361
					$\Sigma=1.366$

*Tachyoryctes* sp. were captured by digging from the ground where root rat hills were observed. The observations of root rat hills were carried out systematically in each site.

The trapped animals were collected early morning and identified to genus level following the established taxonomic nomenclature (Kingdon 1974, 1997, Wilson and Reeder 2005), weighed (to the nearest gram), the state of the vagina or position of the testes noted and the following measurements were taken: head and body length, tail, hind foot and ear length (to nearest millimeter) (Nagorsen and Peterson 1980). All collected specimens were prepared as scientific voucher specimens in the form of fluid preserved specimen. Initially, the specimens were preserved in 10% formalin with transfer later to 70% ethanol.

Tissues including heart, liver and kidney were taken from the trapped animals and stored in buffer for DNA analysis. Specimens collected from the mountain are currently deposited at the University of Antwerp, Belgium, while those collected at lowland sites together with tissue specimens are currently deposited at the University of Rome, Italy.

**Data analysis**

The proportional contribution of rodent and shrew species was expressed as percentage trap success according to Telford (1989) and species diversity was estimated using the standard Shannon Wiener index.

$$H' = -\sum_{i=1}^s (p_i)(\log_2 p_i) \tag{1}$$

where  $H'$  is information content of sample, index of species diversity, or Degree of Uncertainty,  $s$  is total number of species  $p_i$  is proportion of total sample belonging to  $i$ th species.

A similarity/distance matrix was developed according to Jaccard (1901) and similarity coefficient according to Sneath and Sokal (1973) to determine the degree of community overlap. The similarity index of Jaccard between areas  $i$  and  $j$  is given by:

$$S_{ij} = \frac{a}{(a+b+c)} \tag{2}$$

where 'a' is the number of species present in both  $i$  and  $j$  altitudes,  $b$  is the number of species present in  $i$  but not in  $j$ , and  $c$  is the number of species present in  $j$  but not in  $i$ . Therefore, according to Sneath and Sokal (1973), distance matrix index could be calculated from the dissimilarity as follows:

$$D_{ij} = 1 - S_{ij} \tag{3}$$

**Results and discussion**

A total of 750 individual rodents and shrews were captured in 3600 trapping nights with an overall trap success ranging from 2% to 36% (Table 1). The number of individuals captured varied with altitude and vegetation. More individuals were captured in disturbed forest habitats as compared with other habitats. Dueser and Shugart (1978) and Isabirye-Basuta and Kasenene (1987) reported that the abundance and distribution of the small mammals depend mainly upon the nature and density of vegetation which, in turn, influence food and shelter availability. The vegetation in the studied areas with high trap success is primarily forest and tall grasses. The trap success in this study may have been limited because of the use of few trapping nights (2 nights) per site.

However, the combined trap success in this study was higher as compared with other studies carried out elsewhere in Africa with dry shrubs of 1% (Alibhai and Key 1985) and 1.7% (Martin et al. 1981), dry forests 4.6% (Fitzgibbon et al. 1995), and rainforest 0.2% (Martin et al. 1981). Apart from other uncontrolled sources of variability in trapping success (i.e., variation in capture probability, population size), our relatively great trap success may have been due to the relatively high density of the *Pracomys delectorum* rat, which in the disturbed forest sites encounter for a large portion of the captures.

The lowest trap success was in the moorland, which is at high altitude. Habitats with short and sparse grass



other shrews, *Crocidura allex* and *Myosorex zinki*, were captured in habitats with gassy moorland and at the intact forest, respectively (Table 2).

Species richness varied with altitude and vegetation types (Table 3). In the mountain, the highest number of species was found in the disturbed and intact forested areas with six or seven species, while the lowest was found on moorland with two or four species (Table 3). It can be noted in this study that the rodent and shrew communities of the disturbed forest differed sharply in composition and diversity from those in intact forest. This difference in community composition suggests that the alteration of the original forest in mountain leads to an increase in rodent species diversity, but at the expense of the original forest-adapted species (Delany 1986, Fitzgibbon et al. 1995).

Jaccard's similarity coefficients were markedly different, with greater variation between different vegetation types (Table 4). Areas with closely related vegetation showed no marked variation in species composition. Greater marked variation was observed when two or more locations differed in vegetation types. A similar observation was reported by Kennedy et al. (2003) in Kruger National Park. In the mountain, e.g., *Otomys* species and *P. delectorum* in this study occupied a wide range of the mountain as compared with other species.

## Conclusion

The high altitude areas of Mt. Kilimanjaro have complex ecosystems, high connectance and strong interactions, which influence species composition (May 1974). Diversity and distribution patterns of rodent and shrew species on Mt. Kilimanjaro appeared to be highly influenced by habitat complexity and heterogeneity at different altitudes. This study confirms previous studies that highest richness and diversity among rodent and shrews occurred in mountain forest and woodland areas contrary to lowland, anthropized zones and high altitude open areas (Dueser and Shugart 1978).

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