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Authors: Stanley, W. T., Kihaule, P. M., Howell, K. M., and Hutterer, R.

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SMALL MAMMALS OF THE EASTERN ARC MOUNTAINS, TANZANIA

W.T. Stanley
Division of Mammals, Field Museum
Chicago, Illinois, 60605, USA

P.M. Kihaule, K.M. Howell
Department of Zoology, University of Dar es Salaam
P.O. Box 35064, Dar es Salaam, Tanzania

R. Hutterer
Zoologisches Forschungsinstitut und Museum Alexander Koenig
Adenauerallee 160, D-53113 Bonn, Germany

ABSTRACT

The Eastern Arc Mountains (EAM) contain some of the most biologically diverse and endemic-rich montane ecosystems in all of Africa. Because of the staggering degree of biodiversity, how little we know about the biota of the EAM and the rapid degradation of the remaining montane forests of these mountains, we are studying the natural history and biogeography of the small mammals (shrews and rodents) of this archipelago. We are also interested in specific questions such as the effects of forest fragmentation on and elevational distribution of EAM small mammals. To date we have surveyed the South Pare, East Usambara, West Usambara, Nguru, Uluguru and Udzungwa Mountains. We have documented a rodent fauna that is widespread across the archipelago, although restricted to montane and submontane habitats. Shrew species are much more patchy in distribution with each EAM or subset of mountains holding at least one seemingly endemic species, suggesting that speciation has contributed to the current pattern of species richness in insectivores. However, further analysis is required to discern how dispersal, extinctions and/or speciation have contributed to this pattern. Importantly, we have found very few introduced, exotic or savannah dwelling species in our surveys of undisturbed forests, even in forests in close proximity to disturbed areas or human habitation.

INTRODUCTION

The Eastern Arc Mountains (EAM) are a chain of isolated mountain groups that run from the Taita Hills in Kenya to the Udzungwa Mountains in southern Tanzania. These mountains, formed by faulting uplift some 25 to 100 million years ago (Griffiths, 1993; Hamilton, 1989), contain some of the most biologically diverse and endemic-rich montane ecosystems in all of Africa (Rodgers & Homewood, 1982; Stuart, 1981). Although biologists have long been intrigued with the level of endemism exhibited by the flora and fauna of this

archipelago, very little is known about the natural history of many of the organisms found in the EAM (but see Lovett, 1985; 1988; 1996; Newmark, 1991; Scharff, 1992; Stuart *et al.*, 1993).

In 1991 we commenced a study of the effects of forest fragmentation on small mammals (shrews and rodents) in the Usambaras (Goodman *et al.*, 1995) and have since broadened the study to examine the natural history and biogeography of the small mammals of the entire archipelago. Although studies of older museum collections have revealed previously undescribed and apparently endemic shrews in the Usambaras (Dippenaar, 1980; Hutterer, 1986), Udzungwas (Hutterer *et al.*, 1991) and Ulugurus (Jenkins, 1984), and Kingdon (1974) documents much natural history information, our knowledge of the small mammal fauna of the EAM is woefully incomplete and further investigation is needed to thoroughly document these important groups. Further, given the staggering degree of endemism in the EAM, and the rapid degradation of the remaining montane forests of Tanzania, surveys of forested habitats in these unique areas are critical.

To date, we have visited six Eastern Arc mountains: the South Pare, East Usambara, West Usambara, Nguru, Uluguru and Udzungwa Mountains, and have intensively surveyed and sampled local small mammal populations in forest sites above 900 m in elevation. By doing so we have documented the small mammals of the six sites (Stanley *et al.*, 1996; Stanley *et al.*, 1998), provided material for the examination of biogeographic history of the EAM, and gathered data for the preparation of effective conservation strategies for the remaining forests in each area. These surveys will also provide a basis for future studies of the biogeography of East African montane areas. In this paper we provide a general overview of the faunas we have documented during our surveys.

METHODS

In order to standardise at least some aspects of our sampling methodology we have selected sites within the EAM with remaining tracts of forest at similar elevations (1,000–2,000 m) and have conducted our surveys during the months of July through September. Within a forest reserve, we have selected areas that have been least impacted by human activity.

Small mammals were sampled using a standardised regime involving two techniques: pitfall traps and standard small mammal traps. Shrews and small rodents were captured using pitfall lines. One pitfall line consisted of eleven 15 l buckets, each 260 mm high with an inside diameter of 260 mm at the bucket rim. These were buried in soil so that the rim was level with the ground. The buckets were centred 5 m apart. A 50 m long drift fence, of black plastic, 0.5 m high, traversed the line and bisected each bucket (figure 1). The buckets had small drainage holes in the bottom.

Larger rodents, and occasionally shrews, were captured with three types of traps: Museum Specials, 14 x 7 cm; Victor Rat Traps, 17.5 x 8.5 cm; and medium-sized Sherman Traps, 23 x 9.5 x 8 cm. Trap lines consisted of between 50 to 100 traps, and Museum Specials and Victor Rat Traps made up approximately 85 % of the line, and the remaining 15 % were Sherman Traps. Approximately 80 % of the traps were set on the ground and 20 % on vines and tree limbs. Height off the ground, distance from the edge of the forest and between traps, and information on microhabitat were recorded for each trap. Each pitfall line and trap line was labelled for ease of data capture and analysis. The trap/bucket line and trap/bucket number were noted for each animal trapped.

Trap-lines and pitfalls were checked twice each day: once immediately following sunrise and again in the late afternoon. Traps were baited daily with a mixture of freshly fried coconut and peanut butter in the late afternoon. A trap or pitfall in use for a 24-hour period from sunrise to sunrise is referred to as a trap-night or bucket-night, respectively. The trapping methodologies employed focus on smaller non-volant mammals. Large rodents such as *Cricetomys gambianus* or squirrels were not a focus of our surveys.

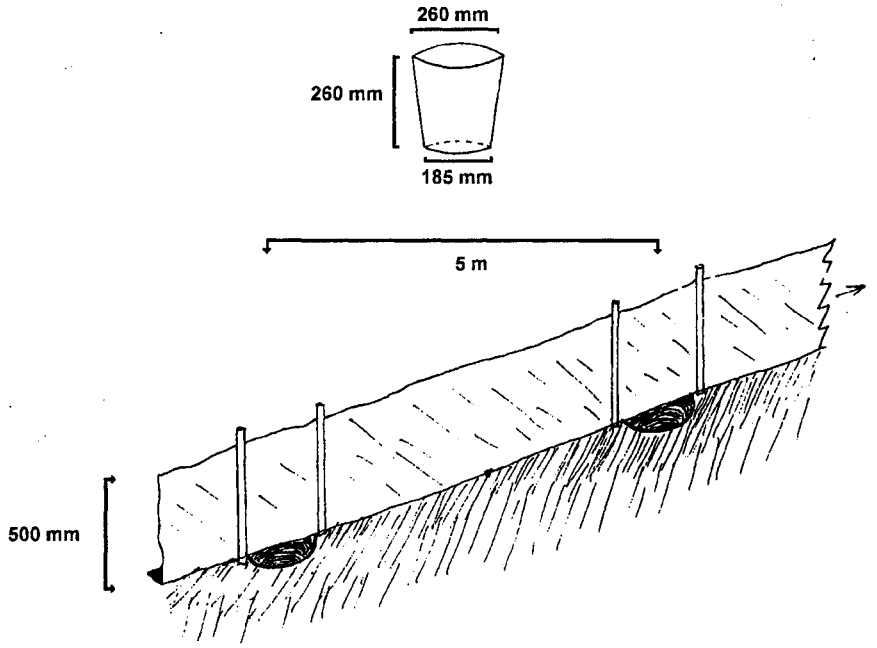

Figure 1. A representation of the style of pitfall lines used during this study. The lines are 50 m long and consist of 11 buckets to a line.

Standard museum measurements were taken for each specimen, including total length, length of head and body, tail length, length of hind foot, ear length, and weight (DeBlase & Martin, 1974). The reproductive condition of each specimen was determined by noting the length, width, and position (scrotal or abdominal) of the testes in males, and the presence or absence of embryos or placental scars, as well as the number, size and condition of the teats in females.

Specimens were either prepared as study skins and skeletons or preserved in 10 % formalin. Fluid-preserved specimens were individually wrapped in cheesecloth to avoid mixing of ectoparasites. Tissues including heart, liver, and kidney were stored in liquid nitrogen. Specimens were deposited in the Field Museum and the University of Dar es Salaam.

RESULTS

Each of the two techniques we used to survey small mammals were effective with different groups. Most of the shrews we collected were caught in pitfall buckets, whereas most rodents were caught in traps (figure 2). Traps caught only 8.5 % of the shrews recorded and only

2.5 % of the medium-size rodents (30–70 g) were caught in pitfalls. The only rodents caught routinely in buckets were the smaller taxa such as *Mus* and *Dendromus* (under ten grams in weight). In fact, all of the *Dendromus* we have collected were caught in buckets. For *Mus* and *Dendromus* altogether 60.7 % were caught in buckets and 39.3 % were caught in traps. *Crocidura olivieri*, the largest of the shrews that inhabit Eastern Arc forests, was caught in relatively equal numbers in traps and buckets (figure 3).

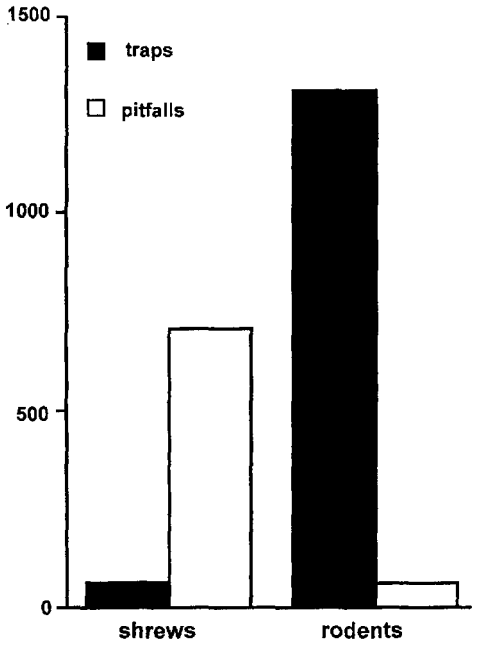

Figure 2. Results of the two different trapping methodologies used during this study. Most medium sized rodents are caught in traps and most shrews and small rodents are caught in pitfall buckets. See table 1 for a list of the rodents recorded.

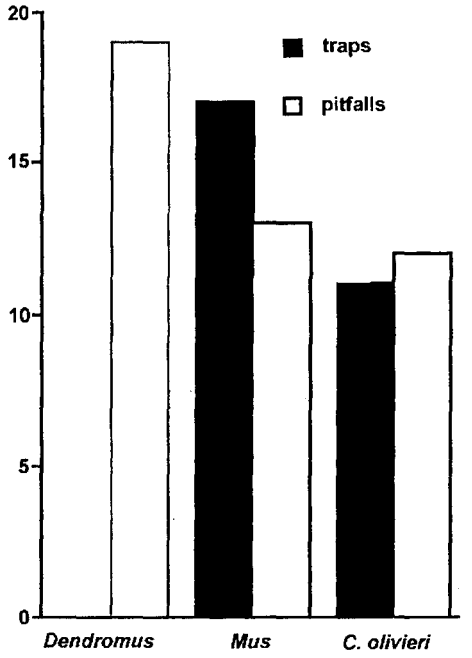

Figure 3. A comparison of the effectiveness of two trapping techniques for the two smallest rodent genera and the largest shrew we encounter.

During our surveys we recorded several small mammal species in each of the EAM sampled (table 1). The three most common rodent genera encountered in any Eastern Arc forest we have surveyed were *Hylomyscus, Lophuromys* and *Praomys*. Based on trap success *Praomys* was the most common in all of our surveys except in the Udzungwas where *Lophuromys* was slightly more abundant. *Hylomyscus* and *Lophuromys* were also abundant relative to other genera within the fauna, and *Beamys*, *Grammomys* and *Graphiurus* were less common. Our results from the South Pare Mountains were an exception in that we encountered more *Grammomys* than we did *Lophuromys* during our survey (figure 4).

While some of the species we recorded in each mountain range were already known to occur in the EAM (Hutterer, 1986; Jenkins, 1984; Kingdon & Howell, 1993; Rogers & Homewood, 1982), others were either unknown from the EAM entirely or had not been recorded from all of the mountains where we found them. For example, before our study *Crocidura elgonius* was unknown from the EAM. The Usambara (both East and West) Mountains are probably the best documented of the EAM in terms of small mammals.

Rodgers & Homewood (1982) listed five species of *Crocidura* known from either East or West Usambaras, or from both (*C. fuscomurina*, *C. olivieri*, *C. hildegardeae*, *C. hirta* and *C. xantippe)*. Hutterer (1986) discussed the known distribution of *C. tansaniana* and predicted that future surveys would likely record this species in other Eastern Arc forests. Our surveys found *C. tansaniana* in the West Usambaras and the first records of *C. elgonius* in the archipelago. More species have been added to the faunal lists of ranges that have not received as much attention, such as the South Pare or the Nguru Mountains. Another example is *Sylvisorex howelli,* which was previously known to occur in the Uluguru and East Usambara Mountains (Jenkins, 1984; Hutterer, 1986). We have recorded this species in both these ranges as well as the West Usambara and Nguru Mountains.

Table 1. A list of the species recorded from each of the mountains surveyed. SP = South Pare Mountains, WU = West Usambara Mountains, EU = East Usambara Mountains, NG = Nguru Mountains, UL = Uluguru Mountains, UZ = Udzungwa Mountains.

SPECIES	SP	WU	EU	NG	UL	UZ
Crocidura elgonius		X	X			
C. fuscomurina			X			
C. hildegardeae	X	X	X			X
C. hirta	X	X	X			
C. monax		X	X	X	X	X
C. olivieri	X	X	X	X	X	X
C. tansaniana		X	X			
C. telfordi					X	X
C. usambarae	X		X			
C. xantippe		X	X			
Myosorex sp.					X	X
Sylvisorex howelli		X	X	X	X	
S. megalura		X	X	X	X	X
Beamys hindei	X	X	X	X		X
Dendromus mesomelas	X					X
D. mystacalis			X			
D. nyikae		X				X
Otomys anchietae						X
Hylomyscus denniae	X	X	X	X	X	X
Grammomys ibeanus	X	X	X		X	X
G. macmillani	X	X	X			X
Lophuromys flavopunctatus	X	X	X	X	X	X
Mastomys natalensis		X	X			X
Mus triton						X
M. minutoides	X	X	X			
Praomys delectorum	X	X	X	X	X	X
Rattus rattus			X			X
Graphiurus murinus	X	X	X	X	X	

Our surveys have supported earlier observations of the faunal composition of the EAM (Kingdon & Howell, 1993). Many rodent species are broadly distributed across the archipelago, whereas the shrews are more patchily distributed. In all the forests we have visited we have observed the same three rodent species including *Hylomyscus denniae*, *Lophuromys flavopunctatus*, and *Praomys delectorum* (table 1). Species such as *Grammomys ibeanus*, *G. macmillani*, *Beamys hindei* and *Graphiurus murinus* have not been recorded in

all the mountains however, in each case there was only one or two mountain ranges where the species was not found. *Grammomys ibeanus* and *Beamys* were not observed in the Uluguru Mountains and *Graphiurus* was not seen in the Udzungwa or Nguru Mountains.

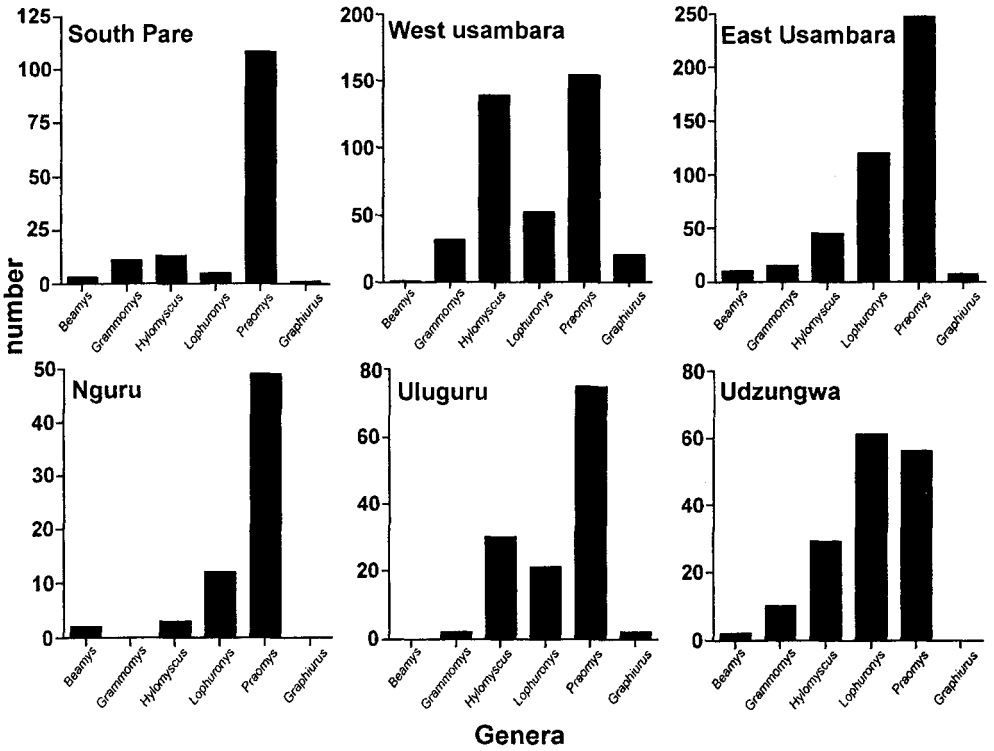

Figure 4. A comparison of the relative abundance (based on trap success) of the six most common rodent genera documented in montane forests of the mountains surveyed during this study.

The rodent species that we have found in all the mountains surveyed seem to be generally restricted to higher elevations. Our work in the Udzungwa Mountains supports this observation. Rodents were non-randomly distributed along an elevational gradient in the Udzungwa Scarp Forest Reserve in July–September 1995 (Stanley *et al.*, in press). Table 2 gives the distribution of species collected during a survey of an elevational transect in this forest. Expected frequencies based on the null hypothesis of equal distribution across all elevations were compared with observed frequencies. For rodent species such as *Hylomyscus*, *Lophuromys* and *Praomys* significantly more were encountered at sites above 900 m.

Many shrew species on the other hand are patchier in distribution across the EAM. *Crocidura usambarae* is only known from northern Eastern Arc (South Pare, East and West Usambara); *Sylvisorex howelli* is only known from middle Eastern Arc (Usambaras, Ngurus, Ulugurus); the species of *Myosorex* we have collected is only known from Udzungwas and Ulugurus (Stanley *et al.*, in press). While some shrew species are generally more widespread than others (e.g. *Crocidura olivieri* and *C. monax*) the distribution of the majority of shrews we encountered is more disjunct than rodents.

Very few introduced or exotic species were encountered during our surveys even when we were working in forests in close proximity to disturbed areas or human habitation. Species considered to be introduced or exotic are such commensals as *Mus musculus* and *Rattus rattus*. We have never encountered *Mus musculus* and only 0.5 % of the rodents collected have been *Rattus*. Species found in association with agricultural areas such as *Mastomys natalensis* are rarely found in submontane or montane habitats. During our survey of the Uzungwa Scarp Forest Reserve *Mastomys* was found in significantly higher abundance at elevations below 900 m (table 2). Rodents that are common in savannah habitats such as *Arvicanthis, Tatera*, and *Lemniscomys* have not been encountered during our surveys of the forests of the EAM, including the lower forest (down to 300 m) in the Uzungwa Scarp Forest Reserve.

*Table 2. Elevational distribution of rodent species in the Uzungwa Scarp Forest Reserve in July-September, 1995. Expected frequencies based on the null hypothesis of equal distribution across all elevations were compared with observed frequencies. Probabilities are for χ^2 tests. Sites with frequencies greater than expected are in boldface. +1 in species number indicates that Grammomys macmillani was inferred to occur at that elevation (even though we did not observe it) because we found it at the lowest and highest sites. . * $p < 0.05$.*

ALTITUDES (m) SPECIES	600	910	1460	2000	TOTALS
Otomys anchietae	0	0	0	1	1
Dendromus mesomelas	0	0	0	2	2
Dendromus nyikae	0	1	0	0	1
Beamys hindei	0	1	1	0	2
Acomys spinosissimus	1	0	0	0	1
Hylomyscus denniae	0	**13**	**11**	5	29*
Grammomys dolichurus	2	0	0	0	2
Grammomys ibeanus	0	0	2	4	6
Grammomys macmillani	1	0	0	1	2
Lophuromys flavopunctatus	0	0	**18**	**45**	63*
Mastomys natalensis	**12**	3	0	0	15*
Mus triton	0	0	2	**17**	19*
Mus musculoides	1	2	0	0	3
Praomys delectorum	1	12	**32**	10	56*
Rattus rattus	0	0	0	1	1
Total number individuals	19	32	66	82	203*
Total number species	6	6+1	7+1	9	15

DISCUSSION

Faunal surveys are a critical first step in the documentation of forest faunas. Based on our results the pitfall traps we used are effective when surveying insectivore fauna, but are not as successful with larger rodents (Stanley *et al.*, 1996; Stanley *et al.*, 1998). We assume that the larger rodents are able to jump out of the buckets and if the depth of the bucket used is increased a wider variety of taxa will be captured. There are other advantages associated with the use of pitfall lines. Animals other than mammals, such as amphibians and reptiles and invertebrates can be surveyed. Depending on the nature of the study, animals can be released after they have been identified and studied. For the purposes of documentation of small

mammal fauna of Eastern Arc forests, a regime that combines both traps and pitfalls has been effective at documenting most if not all of the mid-sized to small mammal fauna at a given site. Neither technique used alone would be sufficient for both insectivores and rodents and both significantly complement the other when used for faunal surveys of small mammals, as has been shown in other studies (Kalko & Handley, 1993).

Based on our surveys and historical records of EAM small mammal species, two general patterns of distribution have emerged. There is a rodent fauna that is broadly distributed across the Eastern Arc but many shrew species are restricted to subsets of these montane islands. While some of the shrew species recorded are probably endemic to the EAM (*e.g.* *Sylvisorex howelli* and *C. telfordi*) we await the results of future surveys before making a statement about the total number of endemic species occurring in the EAM. Based on surveys to date, five species are very restricted in distribution and may be endemic to EAM. These are *Crocidura tansaniana*, *C. telfordi*, *C. usambarae*, *Myosorex* sp. and *Sylvisorex howelli*. We have found no rodent species that exhibit such a restricted distribution. Further analysis is required to determine the reasons for the differences observed in the distribution of these two groups. One hypothesis is that the rodents are better dispersers and were able to cross gaps in habitat during times of forest expansion, whereas shrews are more constrained in habitat requirements and are less able to cross any sizeable gaps. We assume there is no dispersal occurring today among Eastern Arc mountains by either rodents or shrews (*i.e.* the 'gap' between two given mountains is too large for even rodents to cross). While this assumption needs to be tested, our work in the Udzungwas lends support to the idea. Rodents were non-randomly distributed along an elevational gradient in the Uzungwa Scarp Forest Reserve (Stanley *et al.*, in prep) and species that were common in the montane habitats at 2,000 m were either very rare or altogether absent at elevations of 600 m or below. Intensive surveys are needed in areas between Eastern Arc mountains to determine if species such as *Lophuromys flavopunctatus* or *Praomys delectorum* are present. If rodents did historically move among mountain ranges with greater success than shrews, relationships among rodent populations should be closer than relationships among shrew populations on different Eastern Arc mountains. The material we are collecting will be used to test this and similar hypotheses. Such material will also be used to determine if the shrew species we are recording are recently speciated or a fauna that is older than the EAM rodent fauna.

Although we have gathered important data regarding small mammals in the EAM, more surveys are needed for several reasons. Although certain species were not recorded during our surveys, subsequent surveys are needed to confirm that these species are absent on these mountains. *Beamys*, *Grammomys* and *Graphiurus* were not recorded during some of our surveys (table 1). As populations of these genera are not as dense as other murine rodents we collect and are the least common rodent in the overall fauna we encounter we are not convinced that these species do not occur on the mountains where we have not observed them. In the South Pare Mountains, we documented *Graphiurus* on the last day of the second survey of the forest. In the Ngurus *Beamys* was also captured on the last day of a survey. It is possible that future surveys of the Ngurus, for example, will document *Grammomys*. With regard to shrews, we were surprised that we did not encounter *Crocidura desperata* in the bamboo forests of the Uzungwa Scarp Forest Reserve, as this species was found in similar habitat in forests just south of this reserve (Hutterer *et al.*, 1991).

Surveys are needed to document faunas in smaller EAM not yet surveyed and non-EAM that are in the proximity of the archipelago. There is some information on the fauna of the latter such as Mount Meru and Kilimanjaro (*e.g.* Demeter & Hutterer, 1986; Shore & Garbett, 1991), but surveys using methodologies similar to those used in this study would put

these mountains in perspective to the larger EAM and would provide material to examine biogeographic hypotheses posed by other workers (*e.g.* Kingdon, 1981). Future surveys and data analysis are planned to further investigate the history of the small mammal fauna of the EAM. The results of these studies will have implications for conservation strategies designed to protect this fauna and the unique habitat in which it is found.

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