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A checklist of the shrews of Rwanda and biogeographical considerations on African Soricidae

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Abstract. A checklist of the shrews of Rwanda is given. Sixteen species are recognized of which seven are new records for the country. Species richness is high in the remnant montane forest areas; all Central African endemic species are restricted to this habitat. Conservation of the highly threatened forests is therefore essential for the survival of the unique small mammal fauna of Rwanda and its neighbour countries. A comparative analysis of the species numbers of most African countries and their species-area relationship show that Rwanda, Uganda, Zaire and Cameroon house a high proportion of the entire shrew fauna of Africa. This finding is in accordance whith the postulated existence of Pleistocene refuge areas in the Cameroon Mountains and the Albertine Rift.

Key words. Mammalia, Soricidae, Rwanda, checklist, species richness, species-area relationship, montane forest.

Introduction

Unlike other vertebrate groups such as birds (e.g. Prigogine 1985), the small mammals of the Central African countries are poorly known. Basic data like species numbers, population densities, habitat requirements etc. are not generally available and numerous taxonomic problems make it often difficult to identify the species and to recognize them in the field. To increase the knowledge of small mammals of Central Africa, members of the University of Antwerpen worked in Rwanda from 1980 to 1984 to collect and study mainly rodents, insectivores and bats (Van der Straeten & Verheyen 1983; Baeten et al. 1984; Hutterer & Verheyen 1985). The present report summarizes all the data on shrews and discusses biogeographical and conservational aspects of the findings. The information supplied by previous authors (Lönnberg & Gyldenstolpe 1925; Gyldenstolpe 1928; Frechkop 1944; Pirlot 1964; Elbl et al. 1966; Heim de Balsac 1968; Heim de Balsac & Verschuren 1968; Dieterlen & Heim de Balsac 1979; Hutterer 1986b) is included as far as the territory of Rwanda is concerned.

The assessment of the species number and the species composition recorded from a certain country like Rwanda would require reliable data from other countries in Africa. Unfortunately these data are meagre as far as the literature is concerned. We therefore decided to compile species lists for most African countries and islands from the scattered literature and from our own data files. Using these data we are now able to perform a first biogeographical analysis of the variation of shrew communities in Africa.

Material and methods

Eighty-eight shrews were collected in Rwanda during October/December 1981 (E. Van der Straeten, J. Hulselmans), May/July 1982 (E. V., W. Verheyen, A. Wilson), and March 1984 (M. Michiels), being 2.5 % of the total catch of small terrestrial mammals. Specimens (in alcohol,

skulls extracted) will be deposited in the Museum voor Midden Afrika, Tervuren (KMMAT). Additional material from Rwanda was studied in the museum collections of Basel (NMB), Berlin (ZMB), Bonn (ZFMK), Stuttgart (SMNS), Tervuren, Washington (USNM) and Zürich (ZMUZ). Fig. 1 shows the localities in Rwanda from where shrews have been reported. All localities except for no. 3 (Gabiro) and no. 14 (Mutara) were visited by the Belgian teams.

For the comparison of the species compositions of shrews in two different habitats the coefficient of community $CC = 2S_{ab}/(S_a + S_b)$ was used, where S_{ab} is the number of species in both samples, S_a the number of species which occur in sample a, and S_b the number of species which occur in sample b (Whittaker 1975; Happold 1985). CC values range from 1.0 (exact similarity) to 0.0 (no similarity).

Species numbers of shrews were compiled for 39 countries and 5 islands of Africa from all available literature sources and unpublished file data by the senior author. Specimen numbers were based on a new checklist of African Soricidae comprising 137 species; this list, not as yet published, deviates to 27 % from the last comprehensive checklist of Heim de Balsac & Meester (1977). Species numbers are listed in the Appendix. These numbers are composed of the number of species definitely recorded, and the number of species which occur in all probability. The conditions for the inclusion of a species in the second group was that (1) the referred species was definitely recorded from a neighbour country, and (2) that the same type of vegetation zone was present in both countries. The data on area size were taken from Murray (1981) and other geographical sources.

According to the equilibrium theory of island biogeography (MacArthur & Wilson 1967; Simberloff 1974), species-area relations were described with the power function $\log S = \log C + z \log A$, where S is the number of species or species richness, A is area, C is the intercept and z is the slope of the regression line (Connor & McCoy 1979; Lawlor 1986). The least-squares method was used for the calculation of the regression lines.

Records of Soricidae from Rwanda

Sylvisorex granti Thomas

Specimens: 1 ♀, Kitabi, 30 Oct. 1981, edge of Nyungwe Forest. This is the first record from Rwanda but the species was known from mountain regions on the west side of the Albertine Rift. The species may be regarded as a Central African endemic although two subspecies of debatable status occur in mountains of Cameroon and East Africa; these forms may in fact be species rather than subspecies.

Sylvisorex lunaris Thomas

Specimens: 2, sex unknown, Karisoke and Visoke, 7 Jun., 11 Jul. 1982, montane forest. *Sylvisores lunaris* was known before from Rwanda by a single male collected by Elbl et al. (1966) at Uwinka, Nyungwe Forest. The new specimens come from the Virunga Mountains National Park, where the species had been formerly collected at least twice in the Zairese part: Lönnberg & Gyldenstolpe (1925) recorded it as *Sylvisorex ruandae* from bamboo forest on the northern slope of Mt. Sabynyo, now in Zaire. *S. ruandae* is currently regarded as part of *S. lunaris* (Heim de Balsac & Meester 1977). There is a further specimen from Kabara, Virunga Mts., in the Brussels Museum (IRSNB 13.855) not mentioned in the literature before; this place is situated in mountain forest between the volcanoes Mikeno and Karisimbi and is famous for its gorilla population (see Schaller 1963, fig. 9, for an aerial view). *Sylvisorex lunaris* is also known from the Echuya Swamp, western Uganda, from the Kahuzi range, Zaire, and the Ruwenzori range, Zaire und Uganda (Dieterlen & Heim de Balsac 1979). The species has a very restricted range (Fig. 2) and may be classified as a Central African endemic.

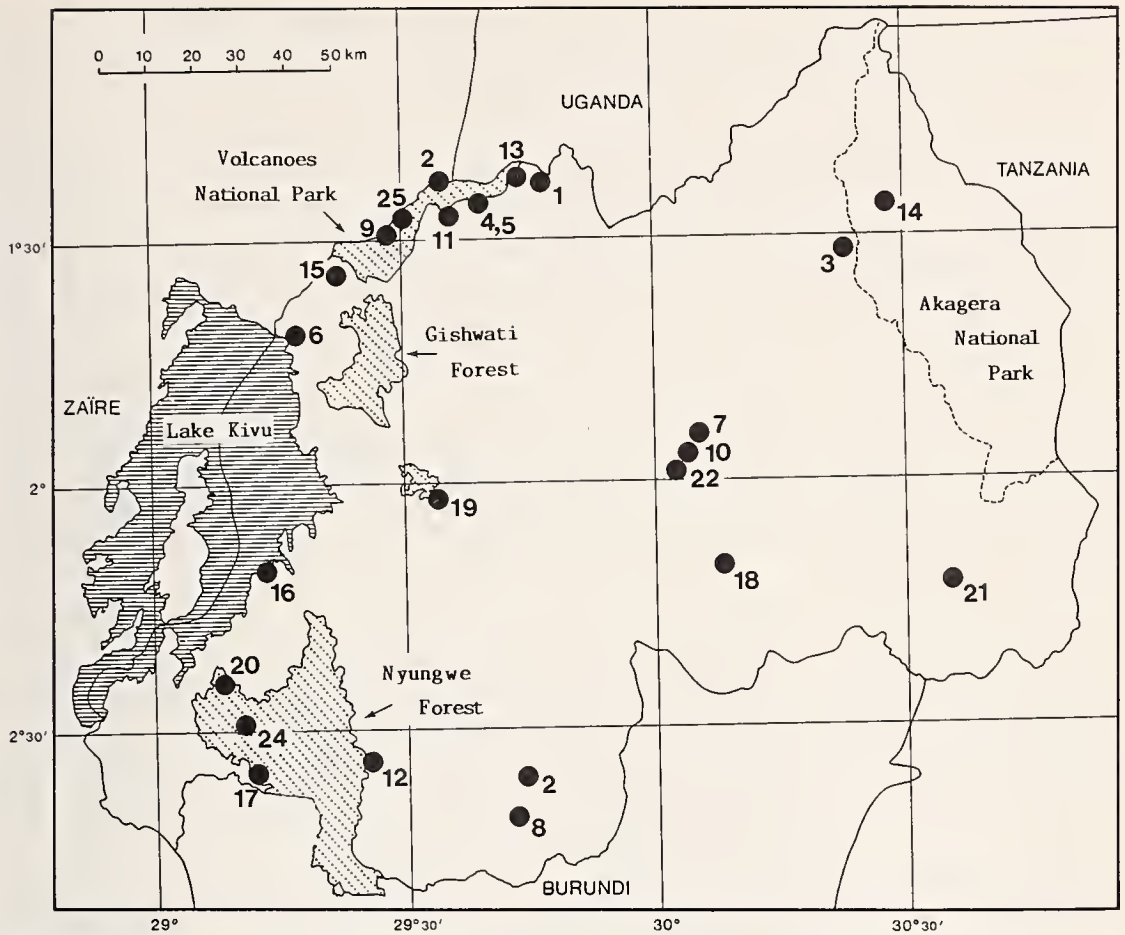

Fig. 1: Map of Rwanda showing the collecting localities listed in the gazetteer. Montane forest regions shown as dotted areas.

Gazetteer

1. Bugarama	01.23 S 29.47 E	1850 m	14. Mutara	01.26 S 30.28 E	1480 m
2. Butare	02.36 S 29.44 E	1700 m	15. Mutura	01.34 S 29.22 E	2200 m
3. Gabiro	01.31 S 30.24 E	1400 m	16. Nduba	02.13 S 29.13 E	1700 m
4. Gahinga	01.24 S 29.40 E	2700 m	17. Ntango	02.36 S 29.13 E	1900 m
5. Gasiza	01.25 S 29.40 E	2360 m	18. Nyamata	02.10 S 30.06 E	1500 m
6. Gisenyi	01.42 S 29.16 E	1480 m	19. Nyange	02.03 S 29.33 E	2000 m
7. Kabuye	01.54 S 30.04 E	1450 m	20. Routabansou-		
8. Kansi	02.41 S 29.44 E	1700 m	gera	02.26 S 29.11 E	1750 m
9. Karisoke	01.29 S 29.29 E	3100 m	21. Rukira	02.13 S 30.35 E	1550 m
10. Kigali	01.57 S 30.04 E	1500 m	22. Ruliba	01.57 S 30.00 E	1400 m
11. Kinigi	01.26 S 29.36 E	2250 m	23. Sabynyo	01.24 S 29.35 E	2400 m
12. Kitabi	02.34 S 29.26 E	2200 m	24. Uwinka	02.29 S 29.12 E	2450 m
13. Muhabura	01.22 S 29.42 E	2200 m	25. Visoke	01.27 S 29.30 E	2700 m

Sylvisorex megalura (Jentink)

Specimens: 1 ♂, Bugarama, 18 June 1982, park area. This is the first definite locality record from Rwanda although the species was said to occur in "Rwanda" (Heim de Balsac & Meester 1977). Their reference may have been based on a specimen in the Tervuren Museum (KMMAT 81-38-M2) from Astrida (= Butare) taken in 1952.

Another specimen from Butare is in the Zürich Museum. *Sylvisorex megalura* is commonly found in open forest, moist savanna, and swamps. It is one of the widely distributed shrew species in tropical Africa (Fig. 2).

Sylvisorex vulcanorum Hutterer & Verheyen

Specimens: 3 ♀, 3 of unknown sex, Karisoke, 9—12 June 1982, Visoke, 4 June 1982, Kinigi, 31 May 1982, Uwinka, 9 Dec. 1981; all from mountain forest or edge of mountain forest. This recently described species is only known from the material listed above and a single museum specimen from the Zairese part of the Virunga Mountains (Hutterer & Verheyen 1985). The discovery of this tiny shrew is remarkable insofar as it is known only from the mountains east of Lake Kivu, while several other shrew species (*Crocidura kivuana*, *C. stenocephala*) occur only west of Lake Kivu in the Kahuzi Mountains. It is perhaps only a matter of time until *S. vulcanorum* will be found in other regions as well, but intensive collecting in the Kivu area by Pirlot, Rahm, Verschuren and Dieterlen (see Dieterlen & Heim de Balsac 1979) has never yielded this shrew.

Scutisorex somereni Thomas

Not collected during the recent campaign, but the species was recorded by Pirlot (1964) from gallery forest on the eastern side of Lake Kivu, and by Elbl et al. (1966), Rahm (1965, 1966) and Dieterlen & Heim de Balsac (1979) from Uwinka, Nyungwe Forest. 16 specimens, all from Uwinka, were examined at the SMNS, USNM, ZFMK, and ZMUZ.

Ruwenzorisorex suncoides (Osgood)

This extremely rare shrew was collected only once in Rwanda: Elbl et al. (1966) recorded it from Uwinka, Nyungwe Forest, where they found it near a brook in mountain forest. This genus is endemic to the Albertine Rift; it is known by five specimens from Kalongi, Ruwenzori Mountains, from Irangi, Zaire, and from Uwinka, Rwanda (Hutterer 1986a).

Paracrocidura maxima Heim de Balsac

Specimens: 1 ♀, Routabansougera, 16 July 1982, along brook at edge of primary forest. The specimen represents the first recent record from Rwanda, as briefly mentioned by Hutterer (1986b). A historical specimen from Gisenyi in the Berlin Museum (ZMB 37015) was collected in 1930. At that time there was probably forest around the city of Gisenyi, but it is unlikely that the species still occurs there today. *P. maxima* has a very restricted distribution similar to that of *Ruwenzorisorex suncoides*.

Crocidura cf. *fuscomurina* (Heuglin)

Specimens: 3, sex unknown, Rukira, 22—25 Nov. 1981, 19 July 1982, tree savanna. This is the first record of a member of the *fuscomurina* group from Rwanda. The taxonomy of this group of very small shrews is difficult (see Hutterer 1983) and the identification must therefore remain tentative. *Crocidura planiceps* Heller, described from Rhino Camp, Uganda, might also occur in Rwanda, but the skulls of the three specimens at hand are in better accordance with the holotype of *fuscomurina* (figured by Hutterer 1983) than with the holotype of *planiceps* (figured by Hollister 1918).

Crocidura hildegardeae Thomas

Specimens: 1 ♀ and 6 of unknown sex, Butare, 8 Nov. 1981, Rukira, 22—25 Nov. 1981, 19 July 1982, Nyange, 2 Dec. 1981, Kansi, 17. Dec. 1981, in garden, cultures, and tree savanna. This species was recorded by Elbl et al. (1966) from Uwinka, Nyungwe Forest. However, their single specimen (now USNM 340802) represents *C.* cf. *nigrofusca* rather than *C. hildegardeae.* A specimen (USNM 535395) from Mimuli (near Mutara), not mentioned by these authors, proves the presence of *C. hildegardeae* in Rwanda, though. Another specimen was collected by Dieterlen at Butare (SMNS). The species seems to be rather common in the cultivated zones and moist savannas of Rwanda.

Crocidura lanosa Heim de Balsac

The species was not found during the recent campaign but the type series was taken at Uwinka, Nyungwe Forest (Heim der Balsac 1968), where it was also found by Dieterlen & Heim de Balsac (1979). Specimens from this locality are in the NMB, SMNS, USNM, and ZMUZ. This remarkable species is at once recognized by its large size and its long and woolly pelage. For the present it is only known from the Nyungwe Forest, Rwanda, and the Kahuzi Mountains, Zaire.

Crocidura nanilla Thomas

Specimens: 1, sex unknown, Butare, 7 Nov. 1981, in garden. This is the first record of the species in Rwanda but it is known from Uganda, Kenya and Zaire and some West African countries (Heim de Balsac & Meester 1977). Gyldenstolpe (1928) mentioned *C. nanilla* from Kabare, near Bukavu, Zaire, which is close to Rwanda. *C. nanilla* is one of the smallest African shrews and therefore uncommen in collections.

Crocidura cf. *nigrofusca* Matschie

Specimens: 1, sex unknown, Bugarama, 18 June 1982, in cultivated park area. This is the species which Dieterlen & Heim de Balsac (1979) recorded from Butare and Gabiro under the name *C. turba* Dollman. A further specimen from Uwinka (USNM 340802) was listed by Elbl et al. (1966) as *C. hildegardeae.* The taxonomic treatment of this species is rather difficult. Heim de Balsac & Meester (1977), referring to unpublished results of N. J. Dippenaar, used the name *C. zaodon* Osgood for the large blackish shrews occurring in Rwanda, Zaire and Uganda. Dippenaar (1982) presented some evidence to distinguish between *C. turba* and *C. zaodon* in Zambia. Using his graphs, the Rwanda specimen falls well into the range of *C. zaodon.* However, an examination of the holotypes of *Crocidura nigrofusca* Matschie (ZMB) and *C. luluae* Matschie (NMB) by R. Hutterer led him to the conclusion that these two names represent the same species called *C. zaodon* by Heim de Balsac & Meester (1977) and Dippenaar (1982). We therefore use *C. nigrofusca,* which seems to be the oldest available name, as pending a taxonomic revision of this difficult group.

Crocidura occidentalis (Pucheran)

Specimens: 10 ♂, 24 ♀, 31 of unknown sex; Bugarama, 16 June 1982, Butare, 16 Nov. 1981, Gahinga, 24 June 1982, Gasiza, 22 June 1982, Gisenyi, 2 March 1984, Kabuye, 24 March 1984, Karisoke, 7—8 June 1982, Kigali, 19—22 March 1984, Kinigi,

31 May to 1 June 1982, Kitabi, 1—4 Nov. 1981, Muhabura, 20 June 1982, Mutura, 23—25 Oct. 1981, Ntango, 24 May, 1982, Nyamata, 11 Nov. 1981, Nyange, 3 Dec. 1981, Routabansougera, 19 Oct. 1981, 14—17 July 1982, Rukira, 22—26 Nov. 1981, 19—20 July 1982, Ruliba, 29 March 1984, Sabynyo, 17 June 1982, Uwinka, 23 May 1982, Visoke, 5 June 1982; from gardens, park area, rice farm, pyrethrum plantation, eucalyptus forest with dense undergrowth, papyrus stands along river, tree savanna, dry forest, secondary growth at edge of primary forest, montane forest, montane bamboo forest. This is by far the most common shrew in Rwanda and elsewhere in tropical Africa. It occurs in all available habitats but the cultivated zones are generally preferred. Previously, *C. occidentalis* was recorded by Frechkop (1944) from Gabiro, Akagera National Park, by Elbl et al. (1966) from Uwinka, Nyungwe Forest, and by Dieterlen & Heim de Balsac (1979) from Mutara, also in the Akagera Park. Pregnant females were found in July (1 x), October (3 x) and November (3 x). The mean embryo number was 2.3 with a range from 2—3 (n = 7).

Crocidura roosevelti (Heller)

Not collected, but Heim de Balsac & Verschuren (1968) recorded this species from the Akagera National Park. No exact locality was given by the authors, and we did not trace the specimen, neither in the Tervuren nor in the Brussels Museum.

Crocidura sp.

A single specimen (ZMUZ 17448), collected at Mimuli (near Mutara) on 8 Nov. 1964 by u. Goepel, could not be identified. The specimen, a female, is similar to *C. nigrofusca* in overall size and cranial characters but is distinctly ligher coloured. The dorsal hair is dark brown (not blackish) and the ventral hair greyish brown. In colour it is similar to *C. hirta* (a species not yet recorded from Rwanda) but the teeth, particularly the small first upper incisor, do not fit with *C. hirta*. The specimen, which was collected in tree savanna, indicates the presence of a further species in Rwanda.

Suncus murinus (Linnaeus)

The Berlin Museum has a skull of *Suncus murinus* collected by R. Kandt at "Kivu-See" (ZMB, uncatalogued) about 1900. The collector (see Kandt 1921) spent some time in the region east of Lake Kivu, in what is now Rwanda. It is possible that this commensal Asian shrew came via the trade routes from the Kenyan/Tanzanian coast, as has been demonstrated for the black rat (*Rattus rattus*) by Dieterlen (1979). This is the first and only evidence that the Asian house shrew once reached Lake Kivu.

Habitat preference and niche partition

Although shrew ecology was not the main subject of the work in Rwanda, the collected data do allow some interesting statements on this subject. As shrews are predominantly insectivore and terrestrial, they form a well defined ecological guild which is in little or no competition with similar sized terrestrial mammals like rodents. It is therefore admissible to consider ecological relationships only within this group.

In Table 1 we have listed the habitats in which the different species were found. The shrews can be arranged into three main groups: (1) species which occur almost

Table 1: Occurrence of shrews in different habitats in Rwanda; *Suncus murinus* omitted. ● Central African endemic, ○ widely distributed species.

Species	Remnant montane forest(1)	Eucalyptus forest	Moist savannas	Cultivated land and settlements
Sylvisorex granti	●			
Sylvisorex lunaris	●			
Sylvisorex megalura				○
Sylvisorex vulcanorum	●			
Scutisorex somereni	●			
Ruwenzorisorex suncoides	●			
Paracrocidura maxima	●			
Crocidura cf. *fuscomurina*		○	○	
Crocidura hildegardeae			○	○
Crocidura lanosa	●			
Crocidura nanilla				○
Crocidura cf. *nigrofusca*	○	○	○	
Crocidura occidentalis	○	○	○	○
Crocidura roosevelti			○	
Crocidura sp.			○	

(1) includes forest patches and secondary growtn along borderlines of shrinking forests.

exclusively in the montane forest zone, (2) species which occur only in the savanna zone and (3) species which occur in both zones. Seven species live in the forest zone, five in the savanna zone, and two in both. The coefficient of community between forest and savanna zone is CC = 0.27 which is rather low. For example, similar values were found for primates, carnivores and artiodactyls of the rainforest and the Guinea savanna of Nigeria (Happold 1985). Anewed calculation of the shrews of the same vegetation zones (Hutterer & Happold 1983) results in a CC value of 0,2.

It is evident that the forest and savanna zones of Rwanda house different mammal communities. However, is there also evidence for a niche partition of the species of shrews within a single vegetation zone? Table 2 presents average weight data for the species collected in the forest and savanna zone of Rwanda. There is almost no overlap in weight between the species in the forest zone and little overlap between the species in the savanna zone. The overlap in the savanna zone is easily explained as this category is an assemblage of several sub-categories. So, the two species with a body weight of 7.0 g are distinguished by their morphology: *C. hildegardeae* is a terrestrial shrew, *Sylvisorex megalura* exhibits adaptations for a scansorial life (Vogel 1974).

More indirect evidence for a partition of the shrew species in the montane forest zone is presented in Table 3, showing the accumulation of species records in the Nyungwe Forest by different field parties over twenty years. No party collected the complete diversity of shrews but most parties added further species, probably as a result of setting traplines in a different part of the forest. The exact limits of the niches of each species are not known, but our data at least indicate their existence.

Probably the diversity of shrews in Rwanda is even larger both in the forest and the savanna zone; the gaps in the known size spectrum (Tab. 2) would provide space for further species of suitable size.

Table 2: Mean body weights (g) of shrews collected in Rwanda associated with the two main habitat categories; weight data from recent collections. Additional sources (Dieterlen & Heim de Balsac 1979; Hutterer 1981, 1986a) marked by an asterix.

Species	Average weight	
	Montane Forest zone	Savanna zone
Sylvisorex vulcanorum (N = 2)	3.5	
Crocidura nanilla (N = 1)		3.5
Sylvisorex granti (N = 1)	4.0	
Crocidura cf. *fuscomurina* (N = 3)		4.5
Sylvisorex megalura (N = 1)		7.0
Crocidura hildegardeae (N = 5)		7.0
Crocidura roosevelti (N = 1)*		9.0
Sylvisorex lunaris (N = 2)	12.0	
Paracrocidura maxima (N = 1)	16.0	
Ruwenzorisorex suncoides (N = 1)	18.2	
Crocidura cf. *nigrofusca* (N = 9)*		20.0
Crocidura lanosa (N = 33)*	22.6	
Crocidura occidentalis (N = 62)	————29.1————	
Scutisorex somereni (N = 7)*	60.1	

Table 3: Captures of shrews in the Nyungwe Forest, Rwanda, 1962—1982.

Species	Year of collection				
	1962[a]	1964[b]	1964[c]	1981[d]	1982[d]
Sylvisorex granti				+	
Sylvisorex lunaris	+				
Sylvisorex vulcanorum				+	+
Scutisorex somereni	+	+	+		
Ruwenzorisorex suncoides	+				
Paracrocidura maxima					+
Crocidura lanosa	+	+	+		
Crocidura cf. *nigrofusca*	+				
Crocidura occidentalis	+			+	+
Species collected	6	2	2	3	3
Accumulated number of species	6	6	6	8	9

[a]Elbl et al. 1966; [b]Dieterlen & Heim de Balsac 1979; [c]Claude, in litt.; [d]This study.

Habitat and distribution pattern

All seven species confined to the montane forest zone of Rwanda (Tab. 1) have a very limited distributional range. For example, *Sylvisorex vulcanorum* is only known from the Virunga Mts. and the Nyungwe Forest, *Sylvisorex lunaris* only from the Ruwenzori Mts., the Virunga Mts., the Kahuzi Mts. and the Nyungwe Forest (Fig. 2). Other species have a slightly wider range, for example *Scutisorex somereni* from Entebbe, Uganda, to central Zaire. All these species, and many others, have in common that their distribution is restricted to the forest block of Central Africa and the attached mountain ranges. The species which exhibit this type of distribution pattern we term "Central African endemics". An example is shown in Fig. 2.

Fig. 2: Distribution pattern of a "Central African endemic" shrew (*Sylvisorex lunaris*) and a "widely distributed species" (*S. megalura*). Localities from the literature and from authors' files.

On the other hand the two species which occur in savanna and forest and the five species which only occur in the savanna zone have a distribution that covers large parts of tropical Africa. The pattern of *Sylvisorex megalura* is shown as an example in Fig. 2. We term these "Widely distributed species".

In Rwanda, all species classified as "Central African endemics" were found in the montane forest zone. However, does this hold true for other regions as well? In Table 4 we have listed species numbers and respective percentages of "Central African endemics" for thirteen localities in Central Africa, representing primary montane environments, primary lowland forests, transition zones, and moist savannas. There is a general trend notable in the table that the portion of Central African endemics is high in primary montane and lowland forest zones, medium in transition zones, and zero in the savanna zones. The transition zones are of particular interest. One of them, Luluabourg, is situated at the southern border of the Central African forest block, and the region where shrew collections were made is an intermixture of gallery forest patches, savanna, and cultivated land. Most probably all Central African endemic species were collected within the gallery forest. Another region, west of Lake Kivu, is situated on the eastern slopes of the Kahuzi Mts., extending to the western coast of the lake. It is a mosaic of cultivated land, secondary growth, swamps, and galleries or patches of indigenous forest (Dieterlen & Heim de Balsac 1979). This region,

Table 4: A comparison of the numbers of shrew species recorded from forest and savanna regions in Central Africa (Zaire, Uganda, Rwanda).

Locality, range	Total number of species	Central African endemics	Widely distributed species	Percent Central African endemics
		Primary montane environments[a]		
Ruwenzori Mts.[b]	8	7	1	87.5
Virunga Mts.[c]	7	5	2	71.4
Kahuzi Mts.[d]	13	11	3	84.6
Nyungwe Forest[e]	9	7	2	77.8
		Primary lowland forests		
Medje[f]	9	7	2	77.8
Irangi[d]	10	7	3	70.0
Kisangani[g]	7	4	3	57.1
		Transition zones		
Cultivation zone west of Lake Kivu[d]	11	5	6	45.4
Idjwi Island[h]	7	3	4	50.0
Luluabourg[j]	6	3	3	50.0
		Savanna zones		
Garamba N.P.[k]	12	0	12	0.0
Rhino Camp[l]	5	0	5	0.0
Rwanda[e]	8	0	8	0.0

[a]Includes montane forest, bamboo forest, montane prairies etc.; [b]Thomas & Wroughton 1910, Osgood 1936; [c]Heim de Balsac 1968 and this study; [d]Dieterlen & Heim de Balsac 1979; [e]This study; [f]Hollister 1916; [g]Colyn, pers. comm.; [h]Rahm & Christiaensen 1966, Dieterlen & Heim de Balsac 1979; [j]Heim de Balsac & Meester 1977; [k]Heim de Balsac & Verschuren 1968; [l]Hollister 1918.

although highly converted by man, houses Central African endemics like *Sylvisorex lunaris*, *S. granti*, and occasionally *Paracrocidura maxima*. This is supported by a coefficient of community of CC = 0.60 for the shrew communities of the transition zone and the primary Kahuzi environments, calculated from the data of Dieterlen & Heim de Balsac (1979). This transitional region, interlocked with the primary environments of the higher altitudes, supports some Central African endemics, while others like *Ruwenzorisorex suncoides* and *Crocidura stenocephala* only occur in the undisturbed primary environments. This indicates that even within the category "Central African endemics" there exists a graduation in the breadth of the ecological niche of each species.

Summing up, the primary montane and lowland forest environments of Central Africa house all the endemic species, while the savanna environments house none of them. Transitional zones with close contact to primary environments may support some, but not all endemic species.

Species numbers, latitude, and species-area relationships

Fifteen species of shrews have now been recorded from Rwanda. To illustrate the dimensions one should remember that the same number is valid for the whole of Europe, from Portugal to the Ural Mountains. The diversity of shrews is therefore high in Rwan-

da, and the data presented before indicate an even higher species number which may reach up to twenty. How should one assess the particular number of 15 in relation to other countries in Africa?

It has generally been predicted that species diversity should vary with latitude (Fischer 1960); this prediction was therefore tested for the 39 African countries, for which species numbers of shrews are listed in the Appendix; latitude midpoints were taken from the centre of each country. The result is shown in Fig. 3; regression curves were calculated separately for the northern and the southern hemisphere. There is a significant increase in species number towards the equator on the northern hemisphere ($r = -0.75$, $p < 0.001$), and a lesse significant increase on the southern hemisphere ($r = -0.55$, $p < 0.05$). Latitude explains 56 % of the variation of the species number on the northern, and only 30 % of the variation on the southern hemisphere of Africa. The high species number of Rwanda comes up to the expectation, but no further evidence can be taken from this analysis.

If the same species numbers are brought in relation to the area of the country, the result shows an increase of species richness with increasing area. The picture gets clearer when islands are treated separately and continental countries are classified roughly into three main vegetation categories: (1) countries with a high portion of rain forest,

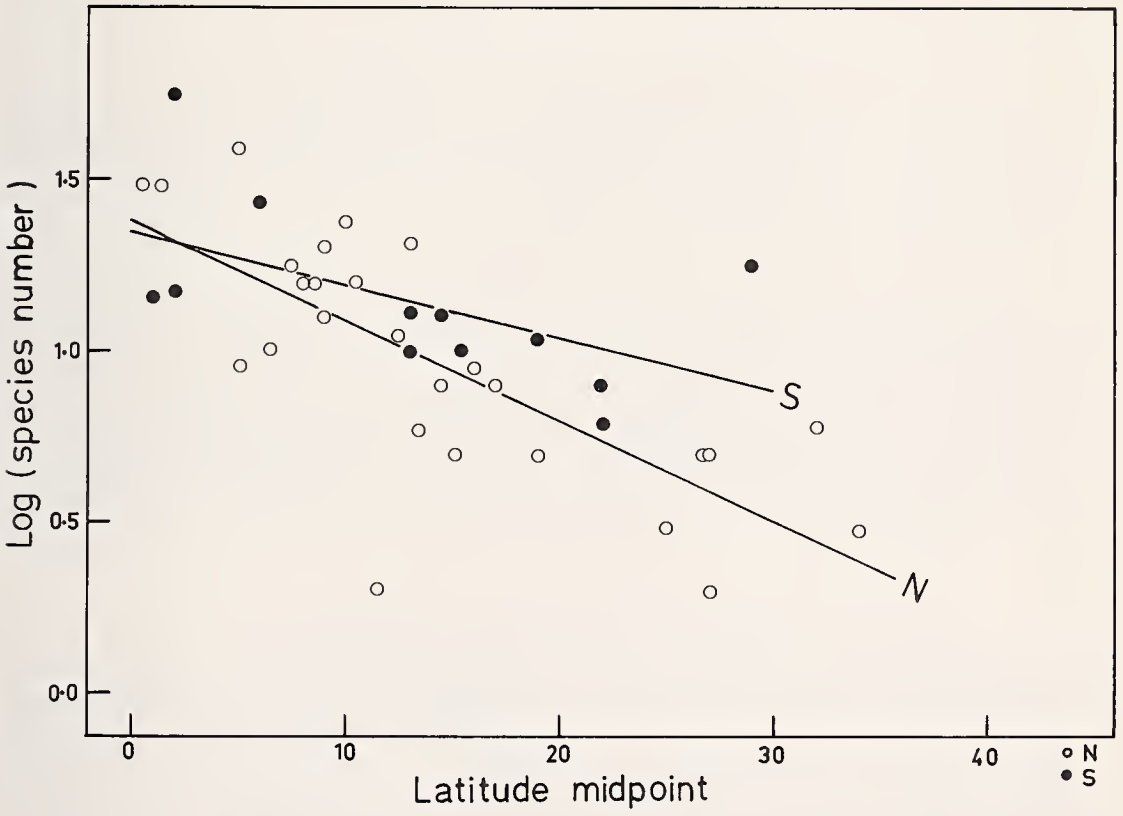

Fig. 3: Log species/latitude relation for the shrews of 39 African countries; regression lines drawn separately for the northern hemisphere (open symbols) and the southern hemisphere (black symbols).

(2) countries with a high portion of dry savannas and desert, and (3) countries with a mixture of different vegetation zones which do not allow a clear assignment to one of the first two categories. The classification of Africa's countries into one of the three classes is presented in Fig. 4. The Figure shows that absolute species numbers are higher in rain forest countries and lower in arid countries and also in small tropical islands. The correlation coefficients of the power functions are significant for islands, forest countries and mixed countries, but not for arid countries (Tab. 5). There is no significant correlation between the number of shrew species and the area of the arid countries of Africa. Therefore area explains nothing or little of the variation of the species number in arid countries, but 50 % of the variation in mixed countries, 55.3 % in forest countries, and 57 % in islands. However sample size is low in the island sample and therefore does not allow further interpretation.

The z value, which expresses the slope of the regression lines, increases stepwise from the arid countries to the islands (Fig. 4; Tab. 5). The high z value for the islands is probably caused by the higher effect of isolation and extinction in small and distant islands (Lawlor 1986) and will not be considered further. The relative difference in the z value between the forest countries and the arid countries is more substantiated. It shows that the species number increases stronger with area within the forest countries than within the arid countries (z values 0.30 versus 0.17). These differences in the slopes are similar to the ones calculated by Heaney (1984) for mammalian faunas of the Sunda Shelf islands and for mammals in various forest reserves on the mainland of the Malay Peninsula. His value for landbridge islands ($z = 0.235$) matches our value for the African forest countries, and his value for mainland forests ($z = 0.104$) matches our value for the African arid countries. Lawlor (1986) has hypothesized that similar differences in slope will be generally found in mainland faunas if compared with landbridge island faunas.

However, the pattern observed in the African forest shrews deviates insofar as the absolute species richness appears low in the arid countries with a z value characteristic for mainland faunas, and high in the forest countries with a z value characteristic of island faunas. The reverse is true for the examples given by Heaney (1984, 1986) and Lawlor (1986) for mainland and island faunas.

A twofold explanation is required for our result. First, the increase of species richness with decreasing latitude (Fig. 3) suggests that tropical forest countries generally provide a wider variety of habitats favourable for insectivores, including floristic, geomorphologic and climatic features.

Table 5: Correlation coefficients for log species — log area curves.

Geographical unit	N	Correlation coefficient	Slope	Intercept
Islands	5	0.76*	0.59	—1.38
Forest countries	12	0.74**	0.30	—0.33
Mixed countries	12	0.72**	0.25	—0.25
Arid countries	15	0.38	0.17	—0.28

*$P < 0.05$
**$P < 0.01$

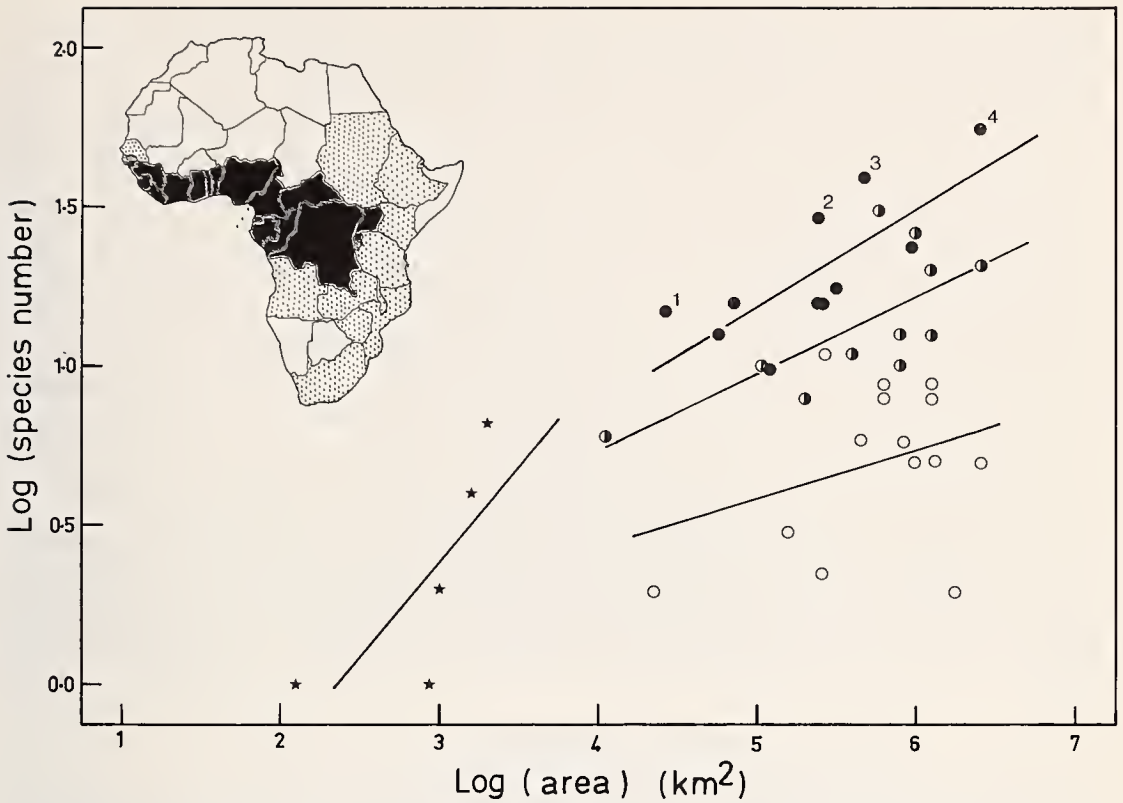

Fig. 4: Log species/log area relation of the shrew faunas of 39 African countries (dots) and 5 islands (stars). Countries classified into forest (black dots), arid (open symbols) and mixed (black-and-white symbols) countries as shown by the inset map. Data for the regression lines in Table 5. Small Arabic numerals indicate the position of (1) Rwanda, (2) Uganda, (3) Cameroon and (4) Zaire.

Secondly, the steeper slope of the forest country regression line (Fig. 4) implies that these countries house semi-insular faunas which are exposed to isolation and extinction. The second point applies especially to the montane forests and prairies on top of the Cameroon Mts., the mountain chain of the Albertine Rift, of East Africa and Ethiopia, all of which were isolated by the changing climates since the Pleistocene. It also applies to the fragmented lowland forests which were isolated either by savannas or by rivers.

Species richness and refuge areas

Although the effect of latitude and area on species richness is obvious, there remains a good part of the variation unexplained; therefore other factors influence it, too. The raw data of the species numbers (Appendix) as well as Fig. 4 demonstrate that the countries with high species numbers are unevenly distributed, also within the same latitude. The highest values are found in Zaire (40.9 % of the total number of species present), Cameroon (27.7 %), Kenya (22.6 %) and Uganda (21.9 %), followed by three countries with more than 15 %, eight more than 10 %, thirteen more than 5 % and eleven less than 5 %. If area is considered (Fig. 4), Rwanda, Uganda, Cameroon and

Zaire have the highest species numbers of shrews in Africa. A regression line calculated only for these four countries (numbered from 1 to 4 in Fig. 4) documents a highly significant correlation coefficient (r = 0.999) and a z of 0.299, underlining their 'island character' in terms of island biogeography. These four countries, comprising 10.3 % of the land surface of Africa, house 53 % of the African species of shrews. They include two important mountain ranges, the Cameroon Mts. and the Albertine Rift mountain chain, both of which are regarded as centres of endemism and as Pleistocene refuge areas for vertebrates (Rahm 1965, 1972; Eisentraut 1973; Hamilton 1981; Grubb 1982; Rodgers et al. 1982; Chapman 1983, Prigogine 1985; Stuart 1985). The refuge theory is also corroborated by our results, especially what regards the Albertine Rift chain as a central refuge. Fifteen species of insectivores are endemic to this region, of which seven species are known from Rwanda. Among the rodents, endemic species include *Delanymys brooksi*, *Dendromus kahuziensis*, *Lophuromys rahmi*, *Lophuromys woosnami*, *Lophuromys medicaudatus*, *Thamnomys venustus*, *Mylomys dybowskii*, and others. Many smaller mammal species are poorly known and their distributional status is therefore difficult to ascertain. The mammalian species richness of the region in question is also illustrated by the fact that a part of it, the Virunga National Park, houses 61 % of all the rodent species which are known from Zaire (Verschuren et al. 1983).

Implications for the conservation of small mammals

Results and speculations based on the theory of island biogeography have repeatedly been used to develop proposals for a conservation biology (Diamond 1975; Hamilton 1981; White 1981; Brown 1981; Struhsaker 1981; Chapman 1983; Blake & Karr 1984; Harris 1984; Heaney 1986). Most of these studies deal with birds or primates, rarely with small mammals. We therefore formulate some conclusions which should be considered for the conservation of small mammals in Central Africa, including Rwanda.

(1) Widely distributed savanna species have a good chance to survive in existing park areas and in cultivated land; no special conservation measures are required for them.
(2) The Central African endemic species are highly dependent on primary forest environments; only a preservation of these forest environments will maintain the endemic communities.
(3) The transition zones may support some endemics as long as they remain in close contact with undisturbed primary environments of sufficient size.

In the case of Rwanda, three forest regions are of special importance: the Nyungwe Forest, the Gishwati Forest, and the Volcanoes National Park (Fig. 1), which house all the endemic species. The Virunga Mts. are included in the National Park but despite its protection the forested areas have been reduced since 1958 to less than half by logging and by the establishment of pastures and pyrethrum plantations (Prigogine 1985). This forest reduction has, along with poaching and increasing disturbances by tourists, already affected the gorilla population (Harcourt et al. 1983; Stover 1986), which constituted one of the main causes for the establishment of the reserve. As the gorilla and the endemic shrews and rodents live in the same habitats, the conservation of the first includes the conservation of the second.

The Nyungwe Forest has also suffered considerable size reduction during the past decades. As Prigogine (1985) pointed out, the high population pressure does not favour the establishment of a new National Park; therefore a management plan, which takes into account the conservational and economical needs, seems to be only solution (Prigogine 1985).

The Gishwati Forest (maximum elevation 2990 m) was probably linked with the Virunga Forest in former times. No shrews were collected during a four nights' visit but *Lophuromys rahmi* was found (Van der Straeten & Verheyen 1983). Probably the same fauna as in the Virunga Mts. occurs in the Gishwati Forest. When we visited this forest, many people were living around its edge and the forest was very fast replaced by cultivated land. Most probably the Gishwati Forest will be the first of the three to disappear.

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Zusammenfassung

In einer Checkliste der Spitzmäuse von Ruanda werden 16 Arten aufgeführt, davon sind 7 Erstnachweise für dieses Land. Ein Vergleich der Faunen verschiedener Habitate zeigt, daß die Artenvielfalt in den Restbeständen der Bergwälder besonders hoch ist; alle als „Zentralafrikanische Endemiten" eingestufte Arten sind auf diese Bergwälder angewiesen. Der Schutz der in höchstem Maße bedrohten Bergwälder ist daher ausschlaggebend für die Erhaltung der einzigartigen Kleinsäugerfauna von Ruanda und seiner Nachbarländer. Eine vergleichende Analyse der Artenzahlen für die meisten afrikanischen Länder und der Arten-Areal-Beziehungen demonstriert, daß Ruanda, Uganda, Zaire und Kamerun einen hohen Anteil der gesamten Spitzmausfauna Afrikas beherbergen. Dieser Befund stützt die Hypothese von pleistozänen Refugialräumen im Gebiet der Kamerunberge und der Gebirge beiderseits des Albertinischen Grabens.

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Appendix. The areas of the African countries and islands and the numbers of shrew species recorded from each country or island that were used for the calculation of the regression curves shown in Figs. 3 & 4. Species numbers were compiled from all available literature sources and from unpublished file data.

Country, Island	Area (squ. km)	Number of species
Sudan	2 505 813	21
Algeria	2 381 741	5
Zaire	2 345 409	56
Libya	1 759 640	2
Chad	1 284 000	5
Niger	1 267 000	8
Angola	1 246 700	13
Ethiopia	1 221 900	20
South Africa	1 221 037	18
Mali	1 204 021	9
Mauretania	1 030 700	5
Egypt	997 667	5
Tanzania	945 087	27
Nigeria	923 768	24
Namibia	823 169	6
Mocambique	784 961	10
Zambia	752 614	13
Somalia	637 657	9
Botswana	600 372	8
Kenya	582 600	31
Cameroon	475 442	38
Morocco	458 730	6
Zimbabwe	390 272	11
Ivory Coast	322 463	18
Burkina Faso	274 200	11
Gabon	267 667	14
Western Sahara	266 000	3
Guinea	245 857	16
Ghana	238 537	16
Uganda	241 139	30
Senegal	196 772	8
Tunisia	164 150	3
Malawi	118 484	10
Liberia	111 369	10
Sierra Leone	71 740	16
Togo	56 000	13
Rwanda	26 338	15
Djibouti	21 783	2
Gambia	11 295	6
Bioko	2 018	7
Zanzibar	1 650	4
Pemba	1 014	2
Sao Tomé	964	1
Principe	128	1