Rodents of Ndola (Copperbelt Province, Zambia)

Inaugural-Dissertation

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Mathias Kawalika, MSc.

aus Chipata (Sambia)

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Die der vorliegenden Arbeit zugrundeliegenden Untersuchungen wurden unter direkter Betreuung von Herrn Prof. Dr. Hynek Burda, FB Bio- und Geowissenschaften, Landschaftsarchitektur der Universität Duisburg-Essen, im Freiland und in Laboratory Section von Ndola City Council sowie im Labor Kafubu Water and Sewerage Co. Ltd. in Ndola (Sambia) durchgeführt.

1. Gutachter: Prof. Dr. Hynek Burda (Univ. Duisburg-Essen)

2. Gutachter: Prof. Dr. Herwig Leirs (Univ. Antwerpen)

3. Gutachter: prof. Dr. Friedemann Schrenk (Univ. Frankfurt am Main)

Vorsitzender des Prüfungsausschusses: Prof. Dr. Guido Benno Feige
(Univ. Duisburg-Essen)

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I dedicate this thesis to my spiritual guide and mentor Sant Thakar Singh, my lovely wife Doyen, the children Enid, Clara, Jean, Henry, Margaret, Mirriam and Luwin and also my father Mr. Henry Chimpumba Kawalika. They all felt I deserved this one.

Abstract

The present thesis deals with rodents of Ndola, capital of the Copperbelt Province, Zambia, and its surroundings. The study area is located approximately 13 ° South and 28 ° 35 East, about 1,300 m above sea level, is characterised by average monthly rainfall of 1,198 mm (with a highly variable rain: monthly range 0-283 mm, with 5 to 7 virtually rainless months per year). The region exhibits a mosaic of built up areas, cultivated fields, forests and natural habitats of the original Zambezian savannah woodland.

The composition of the rodent fauna and its distribution across Zambia is analyzed and discussed here on the basis of a new-attitude analysis of the published data. My analysis reveals that Ndola can be denoted as a Zambian rodent diversity hotspot, as 46% (29 out of 63) rodent species known from Zambia were recorded also in the given area.

I analyzed more than 1,200 pellets of the Barn Owl from four different locations. Contents of about 850 owl pellets which could be attributed to particular months and were produced by two owl individuals was analyzed also quantitatively. Most of these pellets, representing a series encompassing 24 months, were collected from one owl nest in the Namboard Silo in a built-up and cultivated area. The rest originates from a nest in a forest habitat and covers four months. The pellet contents was analyzed from the taphonomical point of view, revealing that maxillary bones (either isolated or within the skull) with upper tooth rows, mandibles, femora and humeri were well preserved and gave information about numbers of preyed animals. The species identification and counting were based on maxillary bones.

Altogether 44% of pellets contained a single vertebrate prey specimen, 33% rests of two individuals, 16.5 % three specimens, 4% four specimens, up to 12 preyed individuals were represented in a single pellet.

Arthropods included in the diet of the Barn owl were mainly sunspiders, locusts and scarabeid beetles. Lizards and frogs/toads were only sporadically represented. Birds constituted up to 6% of vertebrate prey. Small mammals constituted about 93% of vertebrate prey, the most common prey being rodents (83%), mainly Multimammate rats (*Mastomys*, 54%), Pygmy Mice (*Mus minutoides*, 10%), Climbing Mice (*Dendromus*, 10%) and Gerbils (*Tatera*, 6%). The food composition in the forest was slightly different (*Mastomys* 38%, *Tatera* 23%, *Mus* 4%, birds 0.7%) but the difference may be due to a seasonal bias. The calculation reveals that the Barn Owl consumes about 1.6 kg vertebrates, mostly rodents, per month, about 19 kg per year. This makes an average daily consumption to be about 53 g (31-74 g), and an average weight of a single prey amounts to about 41 g. Changes in abundance of rodents in the course of the year(s) are analyzed. There appear two peaks of maxima of *Mastomys* rats during the year: in February and November.

The pellet analysis revealed at least 27 species of mammals belonging to four orders: 18 species of rodents, 1 species of elephant shrews, 4 species of shrews and 4 species of bats. Rodents *Aethomys chrysophilus*, *Dendromus mesomelas*, *Praomys jacksoni* and bats *Scotophilus leucogaster*, *Tadarida pumilla* represent new records for Ndola and surroundings.

Preliminary trapping study using traditional live traps is described. Altogether 581 rodents were trapped during 2181 trapnights (27% efficiency) in the course of three months at two localities. About 50 % of caught animals in both areas were *Mastomys natalensis*, about 20% (more in Mansansa, less in Namboard) were *Tatera* sp., about 10 % were *Mus minutoides*; about 10% were *Acomys spinosissimus* (Spine Mice), which were -apparently due to their diurnal habits - very rarely represented in owl pellets. Furthermore *Steatomys*, *Dasymys* and *Saccostomus* were identified in the sample. Some

further specimens were not identified so far. There were no shrews (apparently due to specific rodent bait) in traps. Generally, pellets reflect (apart from relative, but not absolute, absence of Spiny Mice) very well the composition of the small mammalian community in both, qualitative and quantitative aspects. Climbing Mice (*Dendromus*), which were quite common in pellets were not trapped.

This trapping study, though not yet completed, confirms the importance of the study of owl pellets. It is argued that analysis of owl pellets, as presented here, represents a cheap, relatively simple alternative, producing comparable comparative data on small mammal communities and their changes across space and time. Indeed, this is an excellent way of conducting surveys, especially in areas with few resources, and can potentially be used to monitor changes in biodiversity with little effort. It is surprising that thus far, this source of information has remained virtually untapped in Zambia in particular and in most of Africa in general. One problem is surely the lack of suitable identification keys for skulls (and bones in general) of African small mammals.

The next part of my thesis summarises results of more than eighteen years of my (more or less intensive) research on distribution, taxonomy, ecology, and the economic impact of the subterranean Giant Mole-Rat *Coetomys (Cryptomys) mechowi* (Bathyergidae, Rodentia) in Ndola. Much of the findings presented here have been published already in original research papers authored and co-authored by myself and published in international peer-reviewed scientific journals. I have priority in finding that giant mole-rats) are highly social and live in large families (with more than 20, probably with up to more than sixty members) where only one parental pair breeds. Further aspects of biology (like carnivorous habits) of this previously almost unknown species have been, for the first time, identified by myself. Of behaviour-ecological interest is the fact that giant mole-rats are relative generalists as far as their food choice and habitat (soil and vegetation type) selection are concerned. I have analyzed the sex ratio of giant mole-rats and shown that sex ratio among youngsters in male-biased but near to equality among adults. The fact that among pups born in captivity females prevail calls for an explanation. Some scenarios are suggested. I have contributed to description of the karyotype (2n=40) of *Coetomys mechowi*. My survey of the occurrence of mole-rats in different areas and my contribution to their karyological examination provided insight into the pattern of distribution and extensive diversification of mole-rats in Zambia. Based on the high proportion of biarmed chromosomes in the karyotype it is argued that *C. mechowi* represents an ancient lineage of mole-rats.

For the first time I have shown how important are the mole-rats as agricultural pests and as a source of animal proteins in many regions. I have demonstrated that locals are very well acquainted with these animals. Tapping their know-ledge is a good source of information and should not be underestimated.

Contents

Acknowledgement

I would like to give special tribute and thanks to my mentor Prof. Dr. Hynek Burda, for making it possible for me to finalise my research. He tirelessly supervised my studentship, objectively advising on every aspect of my research, suggesting and making me acquainted with the relevant literature, offering suggestions on research dimensions and mobilising financial support.

This research would not have been possible without the generous financial support of the "Freunde Verein von ZOO Basel". I am grateful to Prof. Dr. Heinz Durrer, Prof. Dr. Thierry A. Freyvogel, and Dr. Peter Studer as well as to the whole staff of the Zoological garden in Basel and to members of the "Freunde Verein" for their interest in mole-rats and in my research, their understanding and patient waiting for my report and for their very meaningful help.

Dr. Dieter Kock of the Senckenberg Museum in Frankfurt is also given special thanks for determining and checking species identification of the mammal remains from owl pellets. Without his great help I would not have learned a lot and much of the information contained in the pellets would not have been gained.

My thanks also go to the staff at Zambia Wildlife Authority especially Mr. Kampamba the Director of Research for facilitating export permission for me to send live specimens of mole-rats for further laboratory studies to University of Duisburg- Essen. My thanks also go to staff at Veterinary Department especially Dr. Mulenga the Provincial Agriculture Coordinating Officer and Dr. Muyaule the District Agriculture Coordinating Officer for taking keen interest in preparing sanitary certificates a prerequisite to obtaining export permits.

Mr. Nshingo, ZAFFICO Plantations Manager is acknowledged for giving me express permission to research in the plantations, whilst Mr. Chilemo ZAFFICO Plantation Superintendent and Mr. Banda retired ZAFFICO Plantation Superintendent for guiding and offering me information as regards to the plantations. Mr. John Mwape Regional Coordinator Food Reserve Agency for permission to collect owl pellets from Namboard. Mr. Boyd Katongo of Namboard for being a cooperating partner in collecting owl pellets from the silos, and also participating in the rodent trapping exercise within Namboard. Mr. Joseph Musonda, for being a cooperating partner in collecting owl pellets from Mansansa fire tower, and also participating in the rodent trapping exercise in Mansansa. Mr. T. Chupa Forestry Officer for historical information on the forestry reserves in Zambia. Mr. Kashinga for opening my world of mole rats by capturing the pioneer mole rat for my studies. The late Mr. Kalaka may his soul rest in eternal peace for his unmatched indigenous knowledge and expertness in fieldwork as regards to mole rats.

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My son Henry, his cousin Gilbert and their uncle Cholwe are also acknowledged for their assistance in sorting out owl pellets under my strict supervision.

Lastly very special thanks also go to Jana, whom I deprived the total attention of her husband Hynek Burda, whilst he dedicated most of his time attending to my studentship, instead of being with her, and also for her kind hospitality and good cooking the times I have been her guest.

Study area

Satellite map of Africa
prepared from a map published by EarthSat, National Geographic Society:
<http://plasma.nationalgeographic.com/mapmachine>

Zambia (cf., Ansell 1978; White 1983; Chikuma et al. 1985) is a land-locked country in south central Africa between 8° and 18° South latitude, and 22° and 34° East longitude (Fig. 1). Its area amounts to of 752,610 km^2 (Fig. 2).

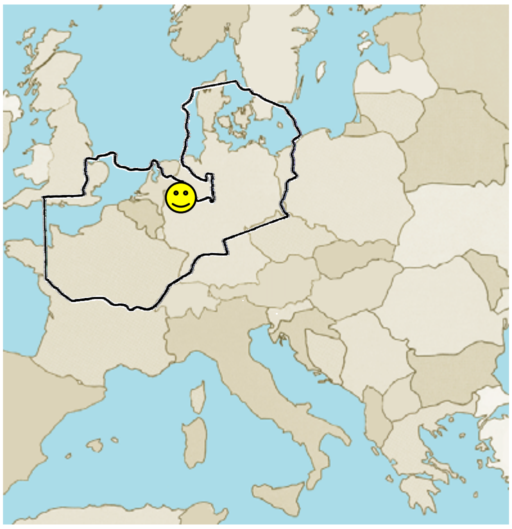

Fig. 1 (left): Zambia and Malawi (until 1964 known as Northern Rhodesia and Nyasaland, respectively) make up the central and main part of the Zambezian phytochorion. Mammalian fauna in both countries was studied principally by W.F.H. Ansell.
Fig. 2 (right): Contours of Zambia projected on the map of Central Europe (Ndola and Essen being centred) to illustrate area relations.

Topography

Zambia is largely occupied by undulating Great African Plateau varying from about 900 to 1,400 m above sea level. At some places, particularly at the northern-eastern rim it rises to over 2,000 m, reaching 2,320 m on the Mafingis, whereas it drops down to 329 m in the Zambezi valley. At the east, the Plateau is delimited by the Great Escarpment, the southern extension of the Great Rift Valley. The southern border of Zambia is made by the Zambezi River, on which the famous Victoria Falls (Mosi-o-Tunya) is located. Much of the land is drained by the Zambezi River (including its main tributaries, the Kafue and the Luangwa (Figs. 3, 4).

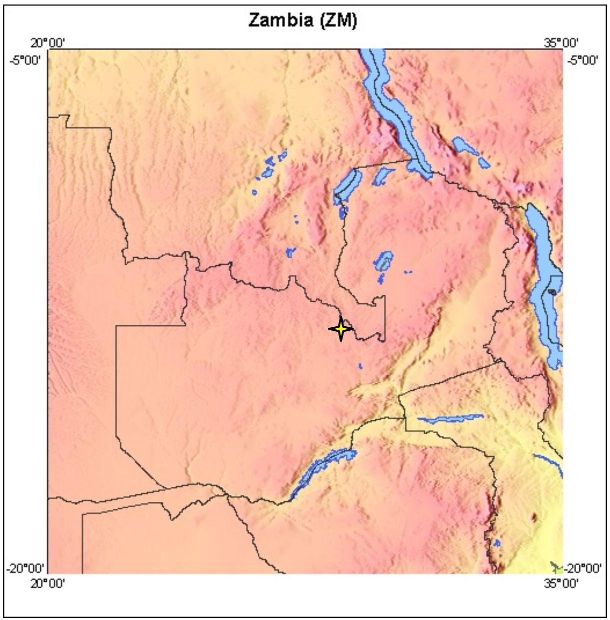

Fig. 3: Geomorphologic relief of Zambia. Ndola ✦
http://walrus.wr.usgs.gov/infobank/gazette/jpg/regions/fr zm.jpg

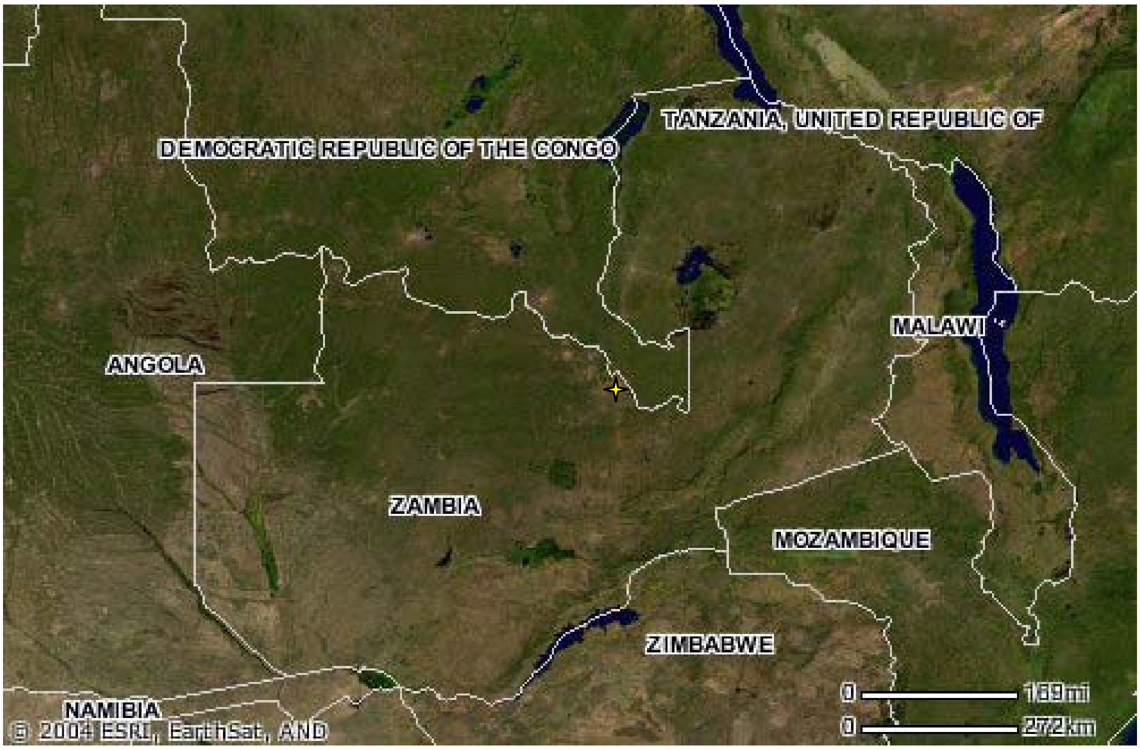

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Fig. 4: Satellite map of Zambia
(EarthSat, National Geographic Society: <http://plasma.nationalgeographic.com/mapmachine>).

Climate

In Zambia, there is a single rainy season from November to April, mean annual rainfall being between 600 mm in the South and 1,600 mm in the North (Copperbelt, Luapula and Northern province) (Fig. 5). Mean annual temperature varies between 18° to 24° C and is negatively correlated with altitude. The dry season (May - October) may be subdivided into a cool season (May - August) and hot season (September - November).

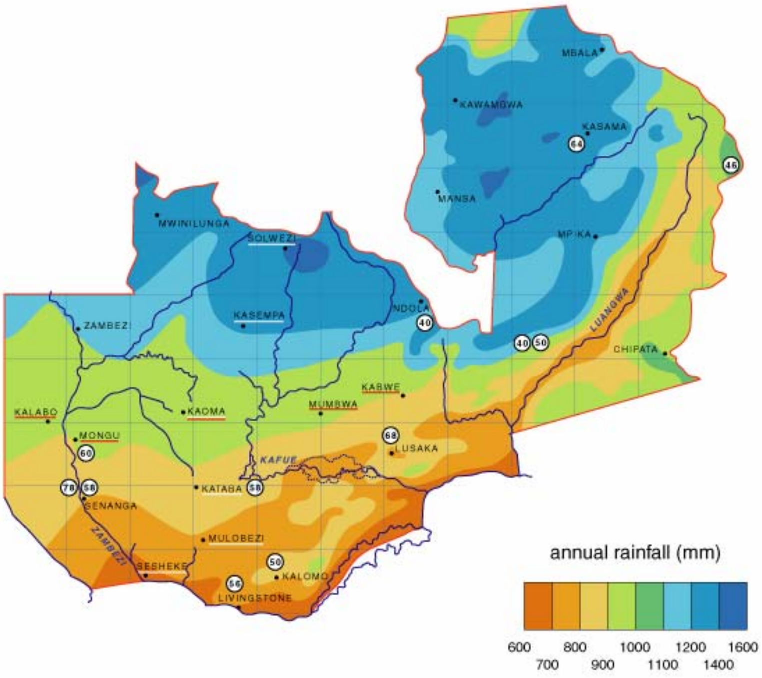

Fig. 5: Mean annual rainfall in Zambia (precipitation zones). (Jan Burda after Chikuma et al. 1985).

Vegetation

From the point of view of **phytochorial classification**, the whole of Zambia belongs (together with Malawi, Zimbabwe, large parts of Angola, Tanzania and Mozambique) to the so-called **Zambezian Region**. Most of the region is covered by savanna-woodland (see White 1983; Mayaux et al. 2004) for detailed information on vegetation types) (Figs. 6, 7).

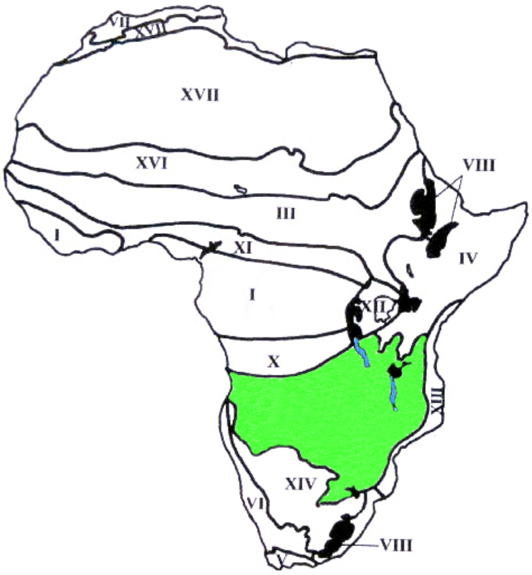

Fig. 6 (right): Phytochorial zonation of Africa. Zambezian region in green.
After White 1983.

Fig. 7 (below): Land cover of Africa.
After Mayaux et al. 2004.

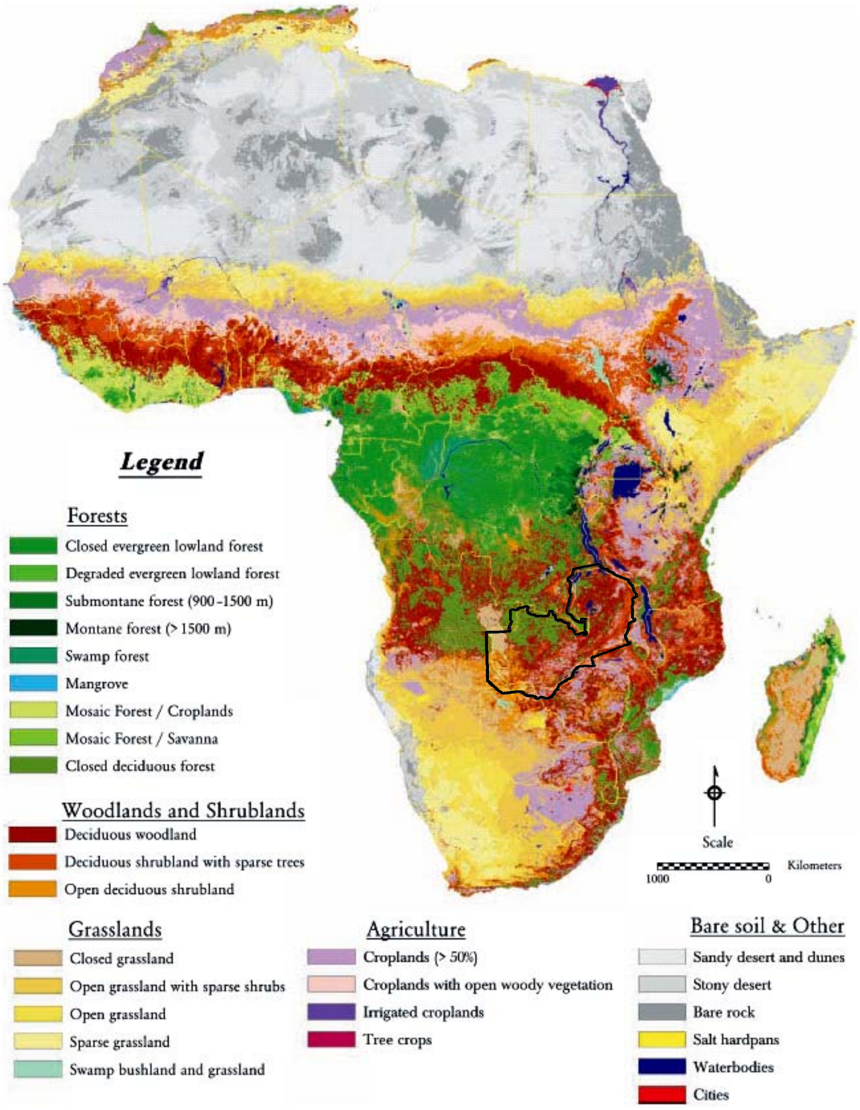

Figure 2 Global Land-Cover 2000 map of Africa.

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The study area is in the **Ndola District** as defined in the Provincial and District Boundaries Act, Cap. 286, of the laws of Zambia. Topographically, Ndola district lies on the gentle sloping Copperbelt peneplain at altitudes ranging between 1,200 m and 1,455 m above sea level, approximately 13 ^{o} South and 28 ^{o} 35 East (squares 1228 D-3 and 1328 B-1) (cf. Fig. 8, 9).

Fig. 8: Geopolitical map of Zambia. Arrow points on Ndola.
<http://www.expedia.com/pub/agent.dll?qscr=mgts>

Fig. 9: Geopolitical map of the Copperbelt province. Arrow points on Ndola.
<http//encarta.msn.com/map_701515007/Ndola.html>

Historical perspective

Ndola (Figs. 10, 11) is a rather young city, just 100 years old. Originally Ndola was a centre of African and Arab trade which was carried out in the shade of a fig tree, located near the railways goods shed. By reason of its geographical position, and the existence of mineral resources at Bwana Mkubwa, Ndolas' importance as a centre of the communications and transportation system of the region was established, a situation which was further consolidated by the completion of the Cape town to Congo (now Congo DR.) railway in 1910. The colonial government assumed control of the territory in 1924; administrative functions were based entirely on the Ndola Boma. Ndola developed rapidly as a result of favourable economic opportunities, it therefore attained municipal status in 1932, and city status was conferred upon it in 1967, at this time the boundary of this original district was also extended to cover 227,750 acres. Ndola's population amounts to almost 500,000 inhabitants.

Figs. 10, 11: Views of Ndola

Altitude

Ndola has an average elevation of approximately 1,300 m (1,200-1,450 m) above sea level. There are however isolated hilly outcrops such as Dola, Nakaputa and Kaloko Hills. These hills are not only strategic communication sites for radio masts and aerials but are also areas of outstanding natural beauty. Several views and vistas are offered from these hills. Higher elevation is reached north-west of Ndola, where mountains form the border with the Democratic Republic of Congo, whereas the elevation drops towards river valleys in the East and South (Figs. 12-14).

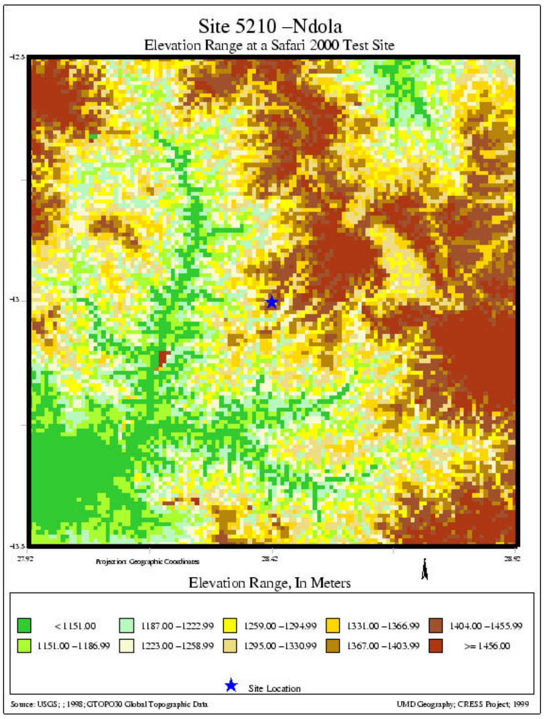


Fig. 12: (right) Elevation relief of Ndola (asterisk) and environs
<http://www.geog.umd.edu/landcover/cress>

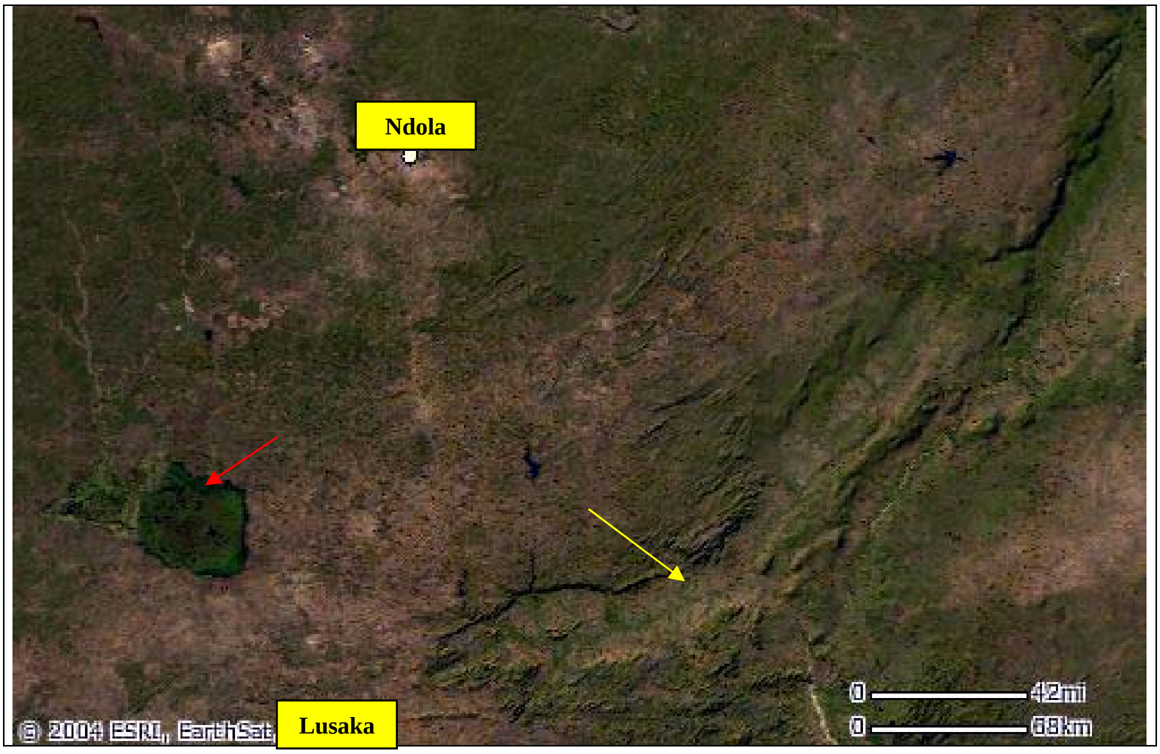


Fig. 13: Satellite map of Zambia. yellow arrow points to the Muchinga Escarpment, red arrow points to the Lukanga Swamp.
(EarthSat, National Geographic Society: <http://plasma.nationalgeographic.com/mapmachine>).

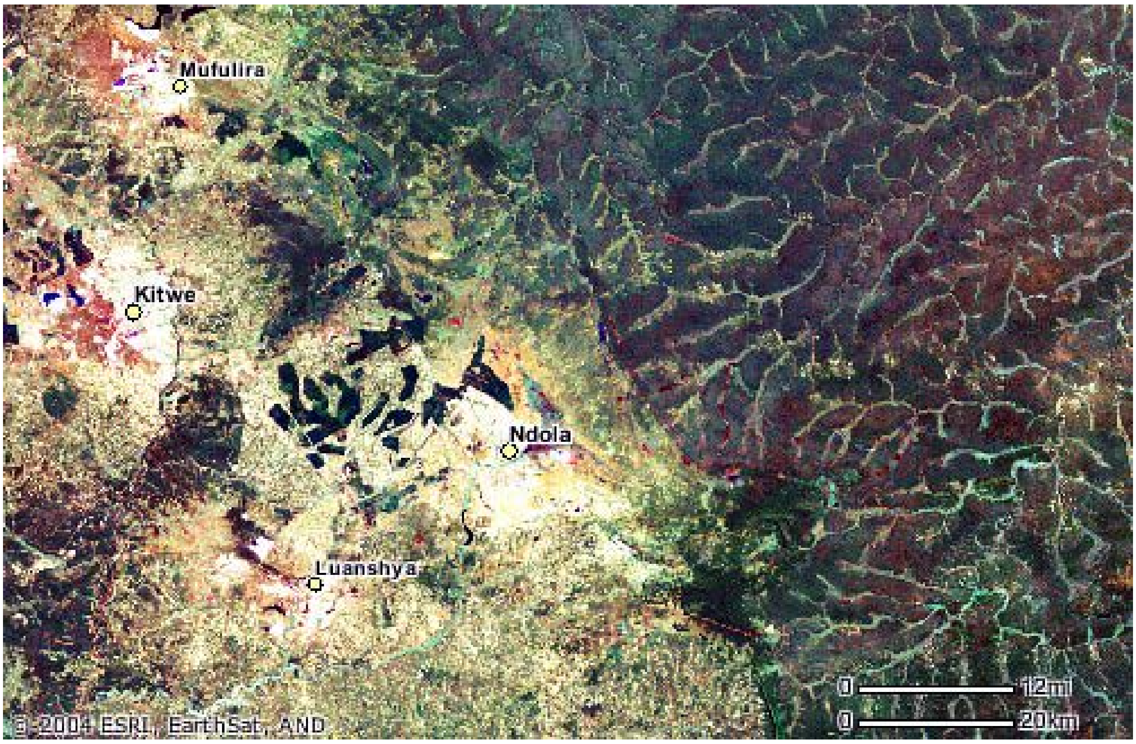


Fig. 14: Satellite map of the north-western part of the Copperbelt Province and across the border. The slopes on the west of Ndola belong to the D. R. Congo.
(EarthSat, National Geographic Society: <http://plasma.nationalgeographic.com/mapmachine>).

Climate

Ndola experiences three distinct seasons through out the year, and these are rainy (November through March), cool and dry (May through July) with the last being hot and dry (August through October). The average month temperature in Ndola falls from 21° C in February to 15° C in May/June and then rises again to the year's maximum of 23.5° C in September/October (cf., Chikuma et al. 1985). The study area is characterised by average monthly rainfall of 1,198 mm (with a highly variable rain: monthly range 0-283 mm, with 5 to 7 virtually rainless months per year (Table 1). Typically, the rainy season starts in November and goes to March.

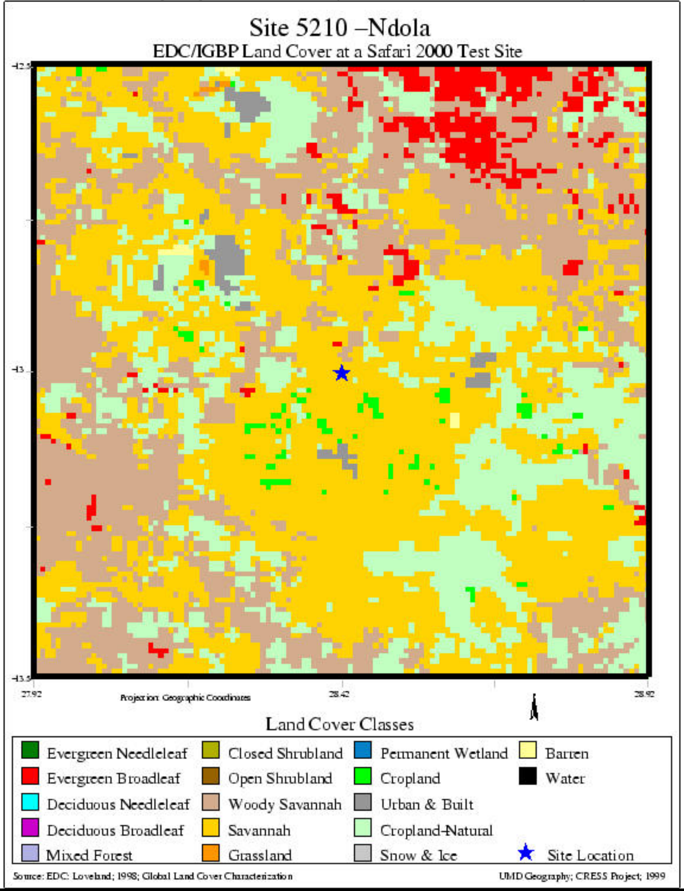
Table 1. Precipitation data for Ndola calculated from the Global Historical Climatological Network Database*.

	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**M**	**SD**	❹
M	283	245	180	37	5	0	0	0	2	24	132	277	**99**	**117**	**1,198**
SD	95	799	801	313	115	17	2	23	40	241	576	979			

The monthly means (M) and standard deviations (SD) are based on measurements of 76 years (1912-1989). The average annual rainfall (❹) is given. All values are in mm; I - XII = months of the year (January - December). Seasons are marked in colours: rainy, cool and dry, hot and dry.
*http://www.ncdc.noaa.gov/ol/climate/research/ghcn/ghcn.html

Vegetation type, land cover

The region belongs naturally to the savanna-woodland type (Figs. 15) with significant areas being agriculturally and horticulturally cultivated (Fig. 16).



Source: EDC: Loveland; 1998; Global Land Cover Characterization

UMD Geography; CRESS Project; 1999

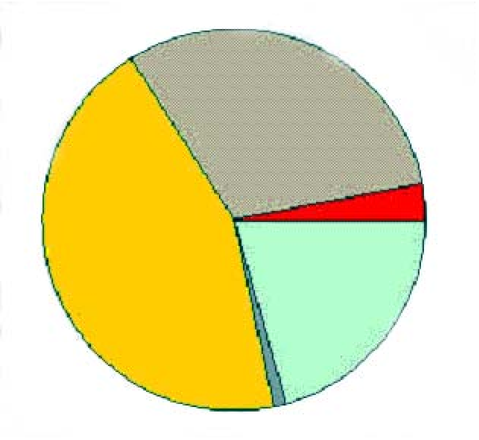
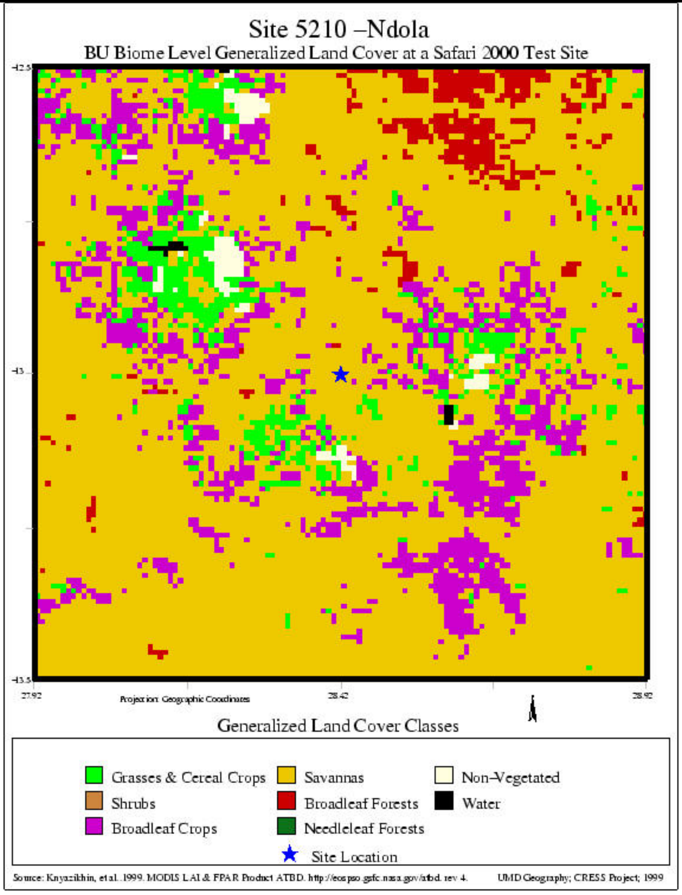


Fig. 15. Land cover around Ndola <http://www.geog.umd.edu/landcover/cress>



Source: Knyazikhin, et al. 1999. MODIS LAI & FPAR Product ATBD. http://eospso.gsfc.nasa.gov/atbd. rev 4.

UMD Geography; CRESS Project; 1999

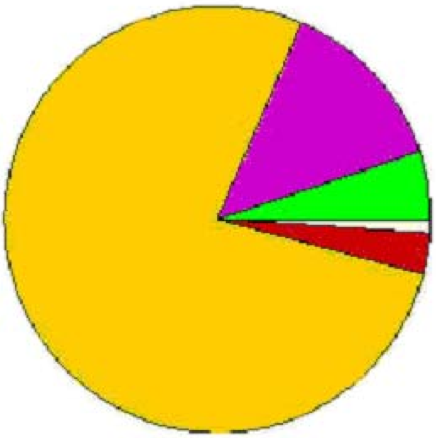


Fig. 16. Generalized land cover around Ndola <http://www.geog.umd.edu/landcover/cress>

Localities

My field research in Ndola surroundings (Fig. 17) was focused on several localities denoted here as: Namboard Silo and Mansansa Forest with respect to owl pellets, and Chichele, Dambo, Doyen’s Farm, Dumba, and Ndeke with respect to mole-rats.

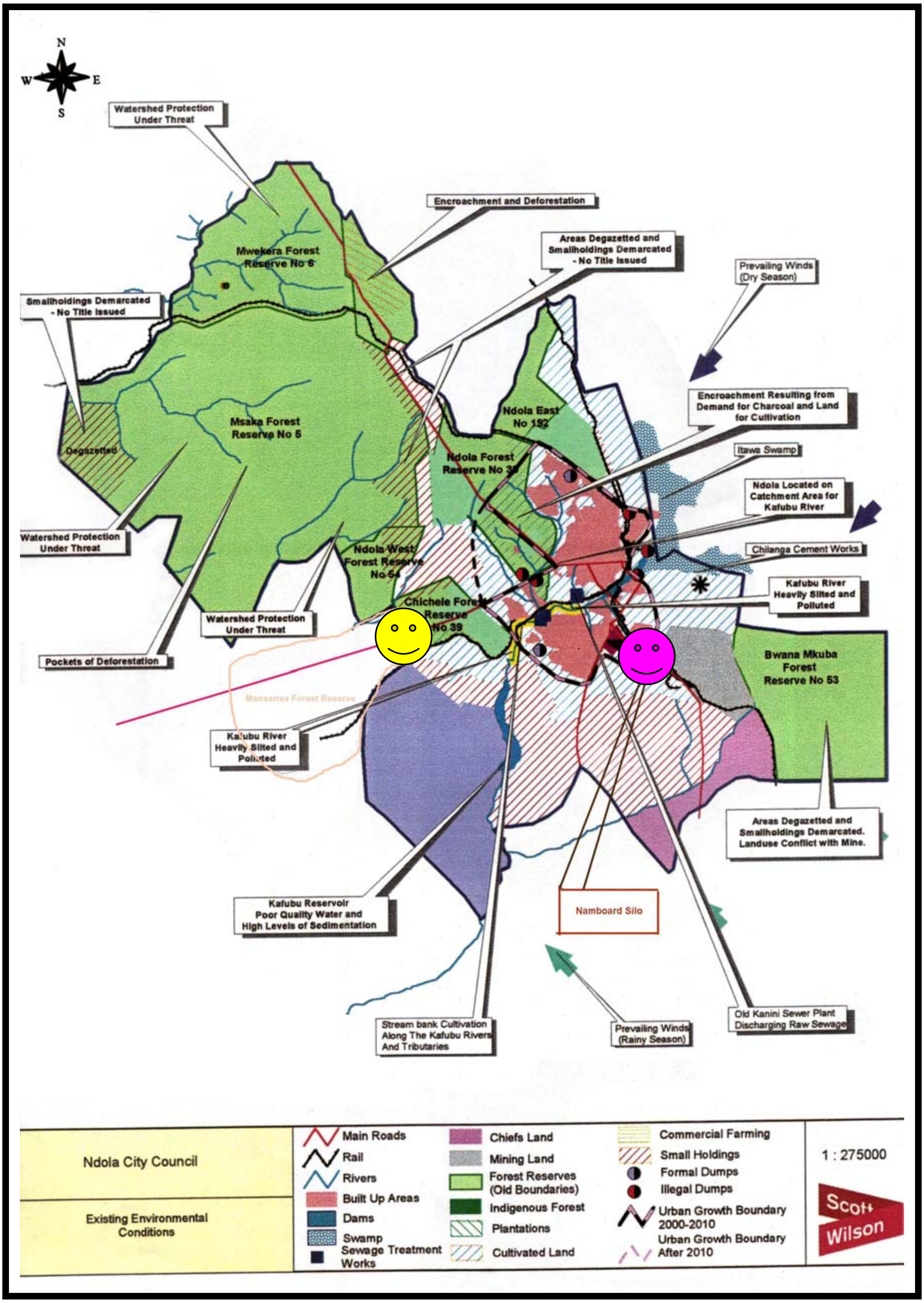


Fig. 17: Schematic map of Ndola environmental conditions. (Ndola City Council)

Mansansa/Chichele Forest ☺ Namboard silo ☺

Mansansa Forest Reserve is located westwards of the city roughly about 260 ^{0}, at the periphery of the district (Fig. 17) and was gazetted as forest reserve number 3 in 1946, under gazette number 72 of Cap 105 of the laws of Zambia. The whole forestry reserve covers an area of 9000 acres.

In 1967, part of this forest, which was a typical Miombo woodland was clear felled and cultivated to establish the forestry plantation for the timber industry. This plantation has two main plant species namely *Pinus oocarpa*, and *Eucalyptus cloeziana*. It has a ***fire observation tower***, which is situated in compartment number 228 (13° 01. 01S and 028° 29.62E) and which stands 25m high. This tower was used only during the dry hot season to be on the look out for possible fires. During the other seasons this tower was left unmanned. For the past close to ten years there has been very little or no activity at this tower because the trees have grown to almost mature status such that normal bush fire could not affect them in any way. (Fig. 18).

The Barn Owl is nesting in the cabin of the tower. Owl pellets from this locality offered a comparative study between the Barn Owls in a built up environment and those in a natural environment. The collection of pellets was not as systematic as that of Namboard (below), because this tower was not easily accessible, because the strange symbiotic relationship between the wild bees and owls occupying the same nesting area.

Fig. 18: Mansansa Forest. Pine plantation and observation tower.

Namboard Silo (Fig. 19) on the other hand is in the built up environment of the districts' heavy industrial area, and is located at the periphery of the industrial area southwards of the city roughly 160°. The GPS location is 13°01.38S and 28°39.80E (Fig. 17). This area is on the periphery of the heavy industrial area. Adjacent to Namboard is an open area where residents of Ndola practice seasonal cultivation (Fig. 20). These silos were operated by a company called National Agriculture Marketing Board (Namboard).

It was responsible for buying all grain from the various districts on behalf of the government. This company had a presence in all the districts of the country. This company was disbanded due to the privatization in the year 1988. From that year to date these silos through out the country have been out of use, no wonder the owls have taken refuge in most of these buildings. Activities around these silos in Ndola are basically grain storage and marketing in the storage sheds. The silos have remained in the same state since 1988. At the top floor of the silos there have been more than one family of owls resident. (See also the chapter Owl pellets).

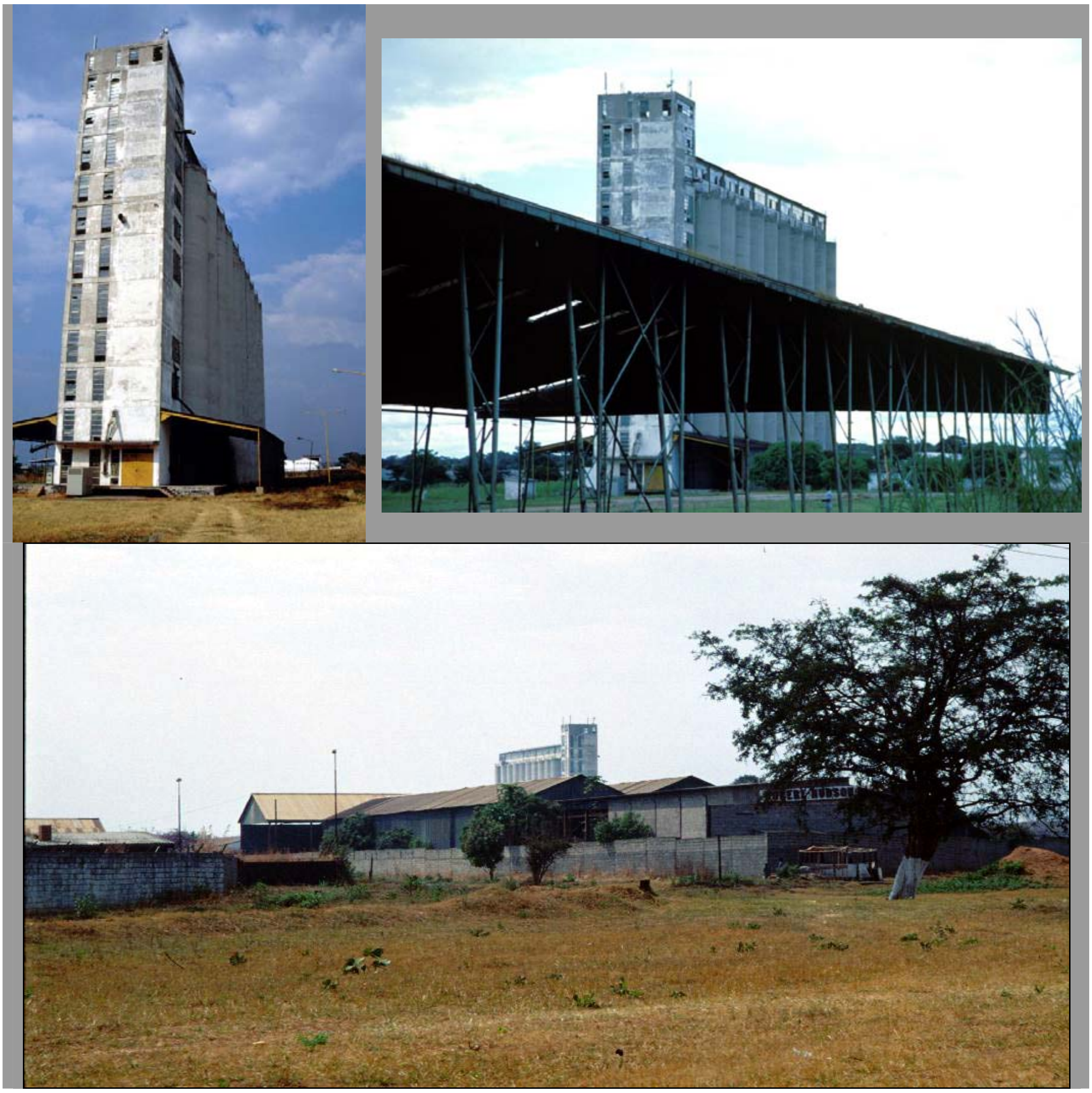


Fig. 19. Namboard Silo

Fig. 20: Surroundings of the Namboard Silo (hunting area of the barn owl). Pictures a the bottom show the landscape during the rainy and the dry seasons respectively.

Locality ***Chichele*** (Figs. 21, 22) is situated 8 km west of Ndola (Fig. 17). This is a forestry plantation attached to the Mansansa Forest Reserve Area (see above) under a private company. This plantation is subdivided into several sectors but of particular interest to me were sectors numbers 287, 290 and 291. These sectors on average are 36.4 ha in size. The whole of the plantation initially was a high grass woodland. This was knocked down by bulldozers and charcoaled in 1964-65. It was further deep ploughed and planting of exotic pine trees (basically *Pinus kesiyei*) was completed in 1968. Some sectors of the locality consist of a partly dense and wild acacia forest. In the acacia forest, the ground is covered with shrubs and herbs, whereas in the pine forest most of the ground is bare with interspersed grass. The only activities in the pine forest are harvesting of the logs and seasonal controlled burning to rid undesired weeds.

Mole-rats in this area have been undisturbed since thirty years (or at least since they recolonized this area after 1968).

Fig. 21: Chichele Forest - pine plantation

Fig. 22: Chichele Forest – acacia wood. Excavation of a soil profile. (Photo Andreas Scharff)

On the ***Dumba*** farmland, 5 km south of Ndola, at Kangonga Centre for Handicapped, both cultivated (with sweet potatoes) and uncultivated areas (covered with tall grass) were studied (Fig. 23).

Fig. 23: Farmland in Ndola during the rainy season.

Doyen`s farm is a nickname for a piece of land managed by my wife Doyen, where predominantly maize (and vegetables and other crops) are cultivated on a smaller scale (Fig. 24). It is located 18 kilometres on the Ndola Mufulira highway approximately 310^0 in the north-western direction.

Fig. 24: Family picnic on Doyen’s farm.

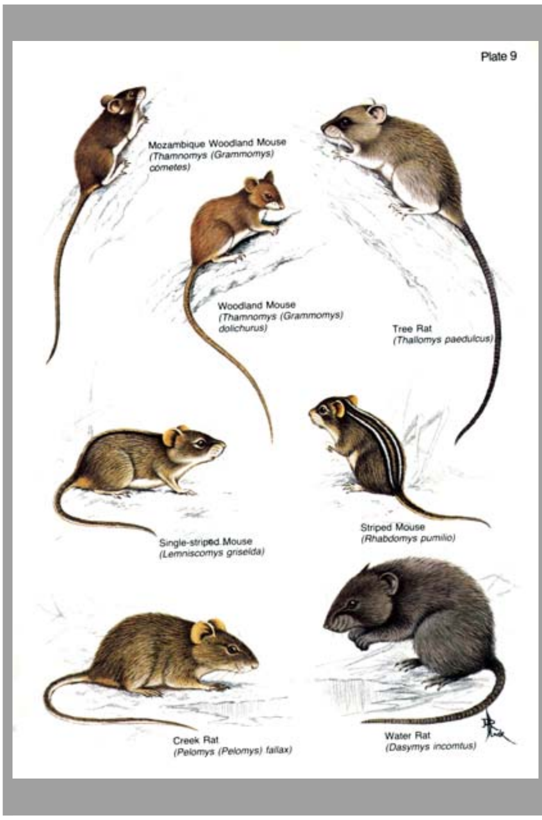
Locality ***Dambo*** is about 5 km south of Ndola. A *dambo* is a marshland that is seasonally inundated. Even during the peak dry season, groundwater was still high and only small parts of the *dambo* were passable.

Locality ***Ndeke*** is uncultivated farmland (abandoned for 8 years) close to a small stream 6 km south of Ndola. The sloped terrain is covered with grass and shrubs.

During dry seasons, all cultivated fields are partially burned.

Rodent diversity of Zambia

Wet (formol-preserved) specimens of "mice and rats" collected in January 2004 in Mansansa Forest



An illustration plate from De Graaff (1981)

Voucher specimens of mole-rats from collections of the National Museum in Bulawayo (Photo H. Burda)

Introduction and Methods

The earlier knowledge on the fauna of rodents of (what is now) Zambia has arisen from studies of W. H. C. Peters, R. C. Wroughton, O. Thomas, A. Smith which took place in 1880-1920. Later, in 1950-1980, the mammalian (including rodent) fauna has been systematically studied and reviewed by Ansell (1978) (with some addenda being brought by Ansell and Dowsett 1988). In his book, the author provided an annotated checklist with comments on taxonomy and distribution of particular species. Ansell lists altogether 63 species of rodents and provides maps with proved localities of their occurrence. Few new species have been added on the list since 1978. All those new records are achievements of field surveys I have been directly involved in. They all are actually results of the revision of the genus *Coetomys* (formerly *Cryptomys*), mole-rat, and splitting the genus into several new species (cf. Burda et al. 1999; Kawalika et al. 2001; Ingram et al. 2004; Van Daele et al. 2004).

Although Ansell (1978) provided very useful maps of distribution for each particular species (cf. Fig. 25-27), he did not pay attention to biodiversity (species richness) and did not quantify distribution of particular species. This information remained hidden.

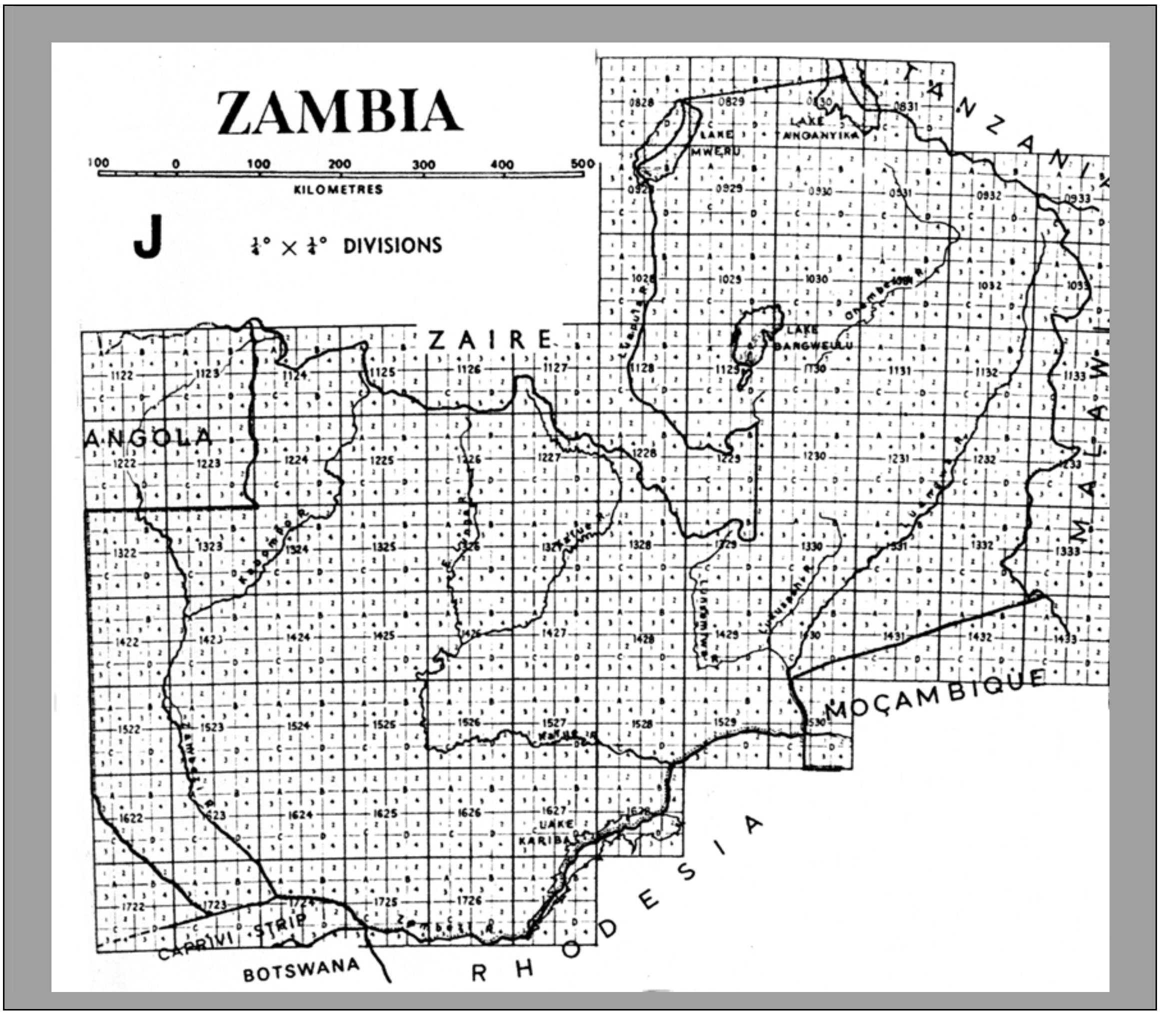


Fig. 25: Map of Zambia with a grid of degree squares (divided ¼ ° x ¼ °). Proven records of occurrence of every species are plotted into respective sub-squares. (Ansell 1978).

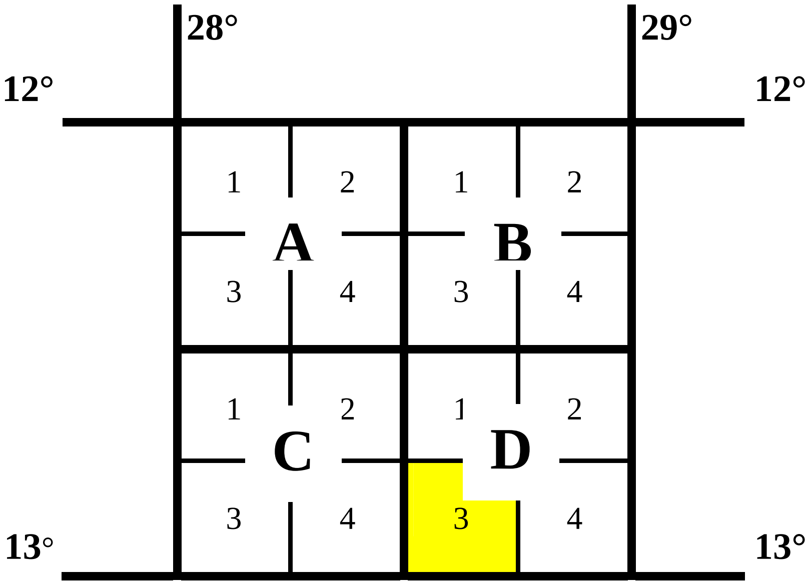


Fig. 26: An example of designation of plotting squares: the yellow marked square is designated as 1228 D-3. This is where Ndola is located its (coordinates being 12°58' S, 28°38' E).

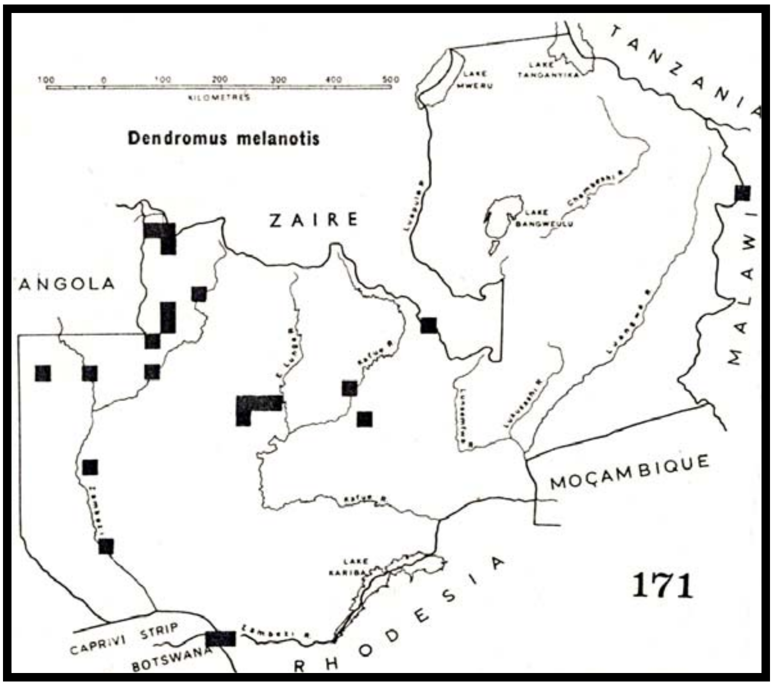


Fig. 27: An illustration example of a distribution map of the Grey Pygmy Climbing Mouse. (Ansell 1978).

In order to determine the distribution of particular species across the country, to identify possible rodent biodiversity hotspots, to assess the relative species richness of Ndola and surroundings (my study region), and to assess the commonness or rareness of particular species, I have extracted the available information from Ansell's book and plotted it against degree squares (as usual in faunistic surveys, cf. also Ansell 1978).

Results and Discussion

The results of the analysis are presented in the appendix Tables 1-8 (raw data) and in Table 2 and 3 and Fig. 28.

Table 2. Number of rodent species recorded in Zambia in particular degree squares.

Square	N species		Square	N species		Square	N species	
1033	33	🟥	1131	14	🟩	0932	6	🟦
1124	33	🟥	1233	14	🟩	1132	6	🟦
1228	29	🟧	1327	14	🟩	1422	6	🟦
1226	26	🟨	1523	14	🟩	1424	6	🟦
1323	26	🟨	1626	14	🟩	1723	6	🟦
1324	26	🟨	1623	13	🟩	1032	5	🟦
0933	25	🟨	1526	12	🟦	1227	5	🟦
1528	25	🟨	1628	12	🟦	1231	5	🟦
1224	24	🟨	1724	12	🟦	1329	5	🟦
1127	23	🟨	0829	11	🟦	1726	5	🟦
1331	23	🟨	1130	11	🟦	1030	4	🟦
1332	23	🟨	1232	11	🟦	1128	4	🟦
1525	23	🟨	1428	11	🟦	1133	4	🟦
1725	21	🟨	1529	11	🟦	1429	4	🟦
1325	20	🟨	0929	10	🟦	1029	3	🟦
1425	20	🟨	0930	10	🟦	1433	3	🟦
1427	20	🟨	1024	10	🟦	1624	3	🟦
1527	20	🟨	1225	10	🟦	1722	3	🟦
1431	18	🟩	1430	10	🟦	0928	2	🟦
0831	17	🟩	1530	10	🟦	0931	2	🟦
1230	17	🟩	1727	10	🟦	1222	1	🟦
1328	17	🟩	0830	9	🟦	1629	1	🟦
1330	17	🟩	1229	9	🟦	1728	1	🟦
1426	17	🟩	1326	9	🟦	1825	1	🟦
1031	16	🟩	1432	9	🟦	1028	0	🟪
1322	16	🟩	1522	9	🟦	1122	0	🟪
1625	16	🟩	1622	9	🟦	1123	0	🟪
1627	16	🟩	0828	8	🟦	1125	0	🟪
			1129	7	🟦	1126	0	🟪
			1423	7	🟦	1223	0	🟪
						1333	0	🟪
						1524	0	🟪

Degree squares are ranked according to their species richness, expressed also in the "rainbow colours". The yellow marked square (1228) encompasses Ndola and surroundings. The analysis is based on data provided by Ansell (1978).

The data are probably partly skewed due to the fact that some particular areas (degree squares) have not been surveyed in a comparable intensity and with comparable methods as others or only part of them was considered (the case of border squares). It is highly improbable that in some areas (squares 1028, 1122, 1123, 1125, 1126, 1223, 1333, 1524) there would be no rodents at all. In this way, the map (Fig. 28) identifies regions, "white spots" on the map, which should be studied to find out whether the poor biodiversity found is real or reflects just the lack of our knowledge. However there is no clear pattern which could be explained due to sampling artefacts. Thus, Lusaka and environs (square 1528), where Mr. Ansell lived and worked, exhibits lower species richness than e.g. Ndola. On the other hand, Ansell (1978) notes that Solwezi (1226) and Ndola (1228) were among his principal collecting localities. Squares 1725 (Livingstone) and 0831 (Mbala), where museums are located and intensive sampling took place formerly, exhibit just an average species richness. Interestingly, rodent species richness in large nationals parks like Lochinvar (1527), Kafue National Park (1526) or South Luangwa National Park (1331) seems to be lower (despite relatively intensive sampling) than in some other localities. The Nyika Plateau (1033), an afromontane region, was identified as a rodent "biodiversity hotspot" through my analysis. This is consistent with

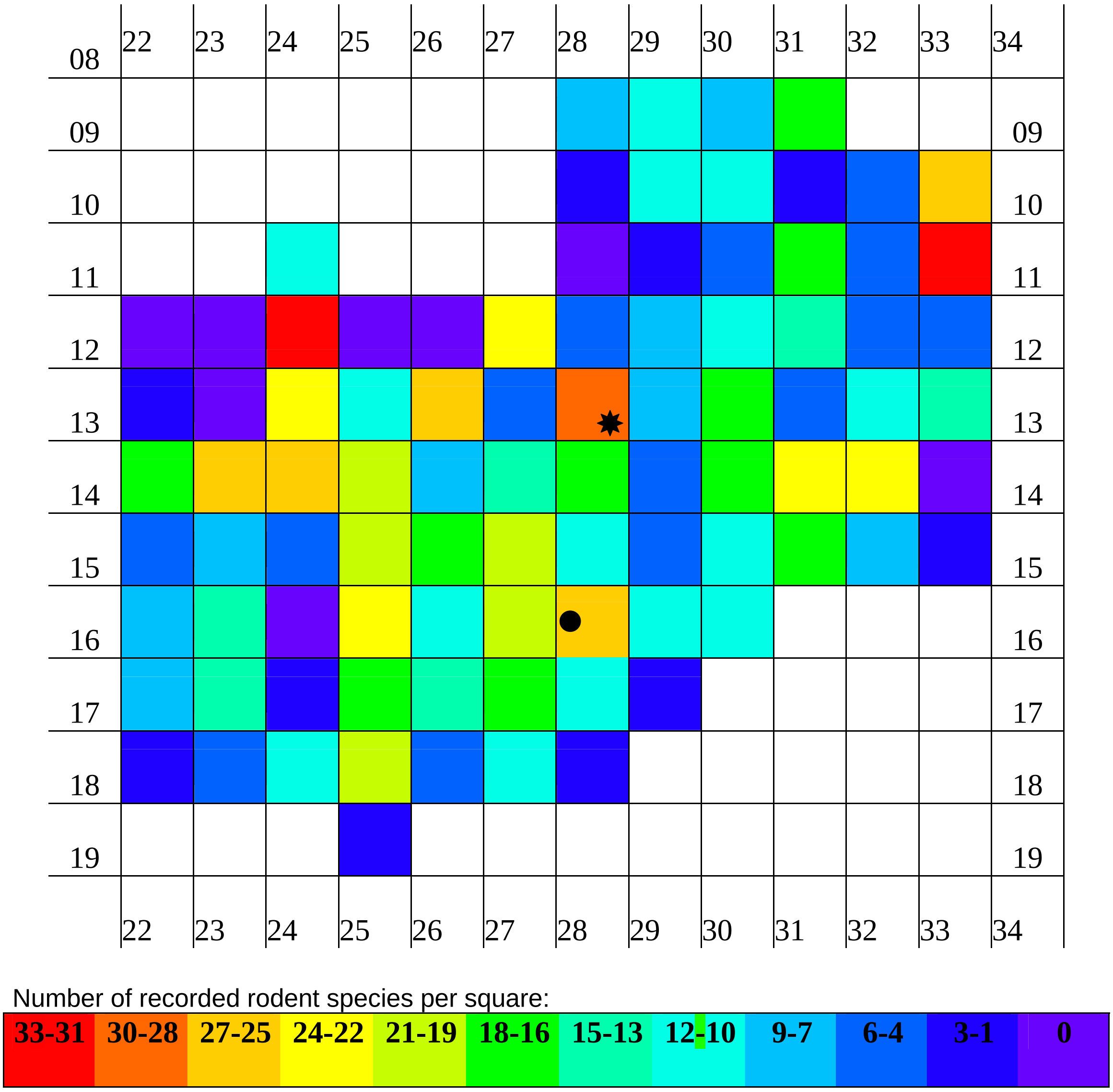


Fig. 28. Map of biodiversity of rodent fauna in Zambia. Numbers of species are plotted against degree squares. ✸ Ndola; ● Lusaka.

the expectation based on the knowledge of high biodiversity in Malawian Nyika, across the border (cf., Chitaukali et al. 2001 and Chitaukali 2002, and literature cited therein), although sampling on the Zambian site was rather incidental and punctual both in space and time. The second hotspot of a comparable magnitude appears in the square 1124. This result of my analysis is surprising although it could have been expected. The square encompasses isolated afromontane habitats in the Mwinilunga district where the Zambezi River springs. This region, recently afflicted by the influx of refugees from Angola and D. R. Congo, would surely deserve to be given more attention and support by nature conservation efforts. Two further hotspots appear in the square 1228 where industrial city of Ndola, is located. As mentioned above, the high number of species records may reflect, at least partly, intensive sampling efforts in these localities. Being species rich, relatively well surveyed (and not less importantly, being my home city), Ndola is a locality of interest to be revisited from the faunistic point of view after some 40 years, which have elapsed since Mr. Ansell collected here.

The rodent species in Zambia can be divided into several groups according to their geographical distribution (Fig. 29, Table 3):

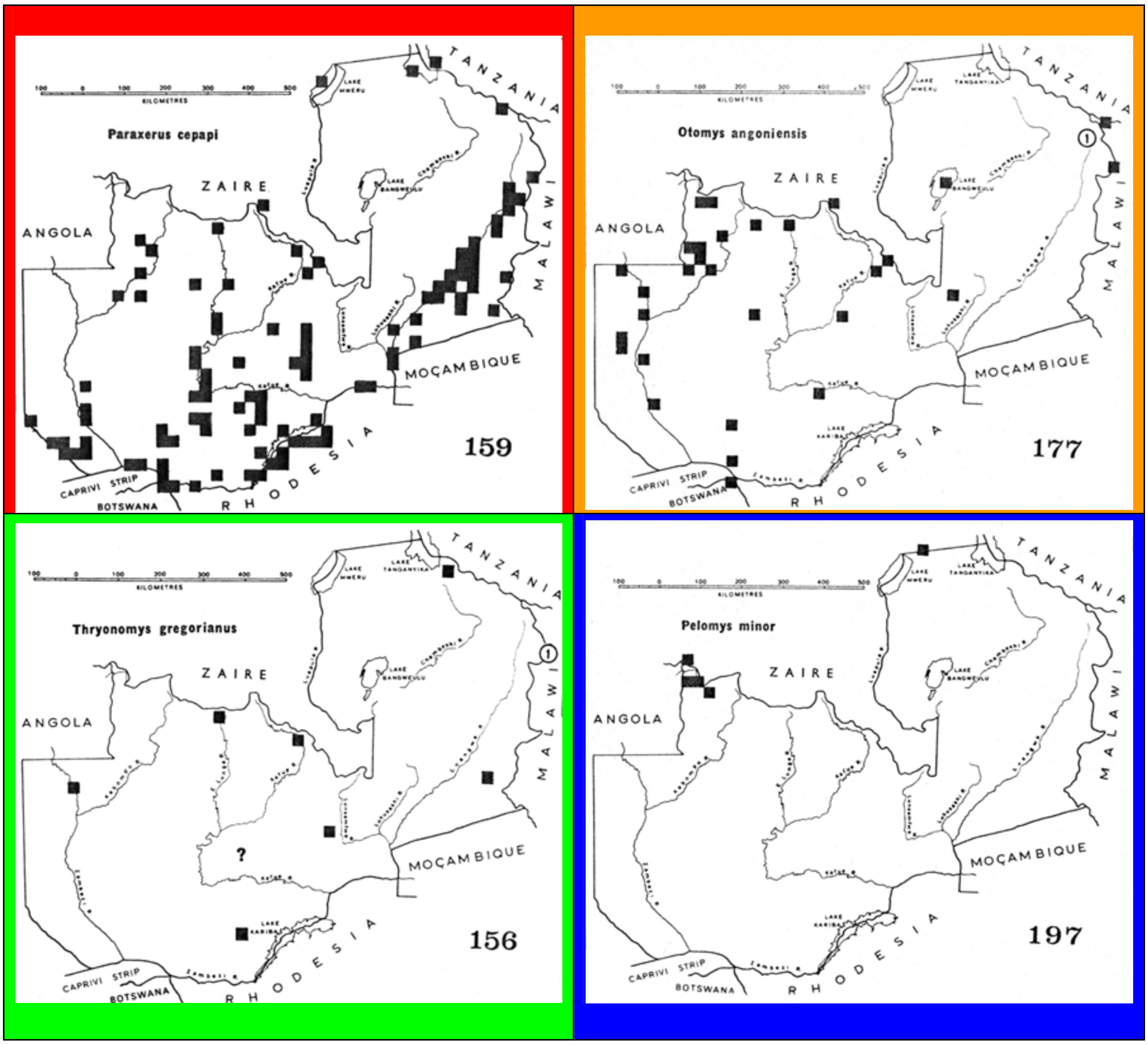


Fig. 29: Examples for species categorized as "broadly", "regionally", "limitedly", "locally" distributed.

The first group (about 1/3) includes species which are geographically "broadly" distributed in Zambia - each of this species was recorded in more than 30 % of the area of Zambia (i.e. > 30 degree squares of altogether 90 degree squares encompassing Zambia). Most broadly distributed are the Multimammate Rat (*Mastomys natalensis*) and the Bushveld Gerbil (*Tatera leucogaster*).

The second group (about 1/3) includes species with "regional" distribution (they can be encountered in more than 10% but in less than 30% of the Zambian area).

Species of the third group (1/6) have a limited distribution and were reported from 4-10% of the total area.

The fourth group (1/6) includes species exhibiting a "local" area of distribution (they can be considered "local endemites").

Table 3. Rodent species recorded in Zambia ranked according to the size of the area of their distribution (in per cent of the whole Zambian area).

broad		**regional**		**limited**		**local**	
Mastomys *natalensis*	**65**	***Heliosciurus*** *gambianus*	**29**	***Heliosciurus*** *rufobrachium*	**10**	***Graphiurus*** *monardi*	**3**
Tatera *leucogaster*	**50**	***Mus*** *minutoides*	**29**	***Steatomys*** *krebsi*	**10**	***Mus*** *sorella*	**3**
Hystrix *africaeaustralis*	**44**	***Pedetes*** *capensis*	**28**	***Praomys*** *denniae*	**9**	***Praomys*** *delectorum*	**3**
Paraxerus *cepapi*	**43**	***Otomys*** *angoniensis*	**25**	***Thryonomys*** *gregorianus*	**8**	***Pelomys*** *minor*	**3**
Saccostomus *campestris*	**43**	***Acomys*** *spinosissimus*	**24**	***Graphiurus*** *platyops*	**8**	***Paraxerus*** *boehmi*	**2**
Dasymys *incomtus*	**43**	***Coetomys*** *mechowi*	**22**	***Steatomys*** *minutus*	**8**	***Paraxerus*** *lucifer*	**2**
Coetomys spp.	**41**	***Mus*** *triton*	**22**	***Aethomys*** *namaquensis*	**8**	***Grammomys*** *cometes*	**2**
Pelomys *fallax*	**40**	***Lophuromys*** *flavopunctatus*	**22**	***Arvicanthis*** *niloticus*	**8**	***Otomys*** *typus*	**1**
Tatera *valida*	**39**	***Thryonomys*** *swinderianus*	**21**	***Dendromus*** *mesomelas*	**7**	***Otomys*** *denti*	**1**
Steatomys *pratensis*	**37**	***Dendromus*** *mystacalis*	**21**	***Dendromus*** *nyikae*	**7**	***Mus*** *musculus*	**1**
Lemniscomys *griselda*	**34**	***Tatera*** *boehmi*	**18**	***Zelotomys*** *hildegardae*	**7**	***Hybomys*** *univittatus*	**1**
Aethomys *chrysophilus*	**32**	***Dendromus*** *melanotis*	**15**	***Beamys*** *hindei*	**4**	***Rhabdomys*** *pumilio*	**1**
Graphiurus spp.	**31**	***Anomalurus*** *derbianus*	**14**	***Tatera*** *brantsi*	**4**	***Malacomys*** *longipes*	**1**
Rattus *rattus*	**31**	***Praomys*** *jacksoni*	**14**	***Lemniscomys*** *striatus*	**4**	***Colomys*** *goslingi*	**1**
Aethomys *kaiseri*	**31**	***Thalomys*** *paedulcus*	**13**				
Grammomys *dolichurus*	**31**	***Aethomys*** *nyikae*	**13**				
Cricetomys *gambianus*	**30**	***Heliophobius*** *argenteocinereus*	**12**				

Species occurring also in Ndola and environs (square 1228) are marked. The analysis is based on data provided by Ansell (1978). *Coetomys* sp. corresponds to the "*Cryptomys hottentotus*" of Ansell (1978) and includes seeveral species like *C. amatus*, *C. anselli*, *C. damarensis*, *C. micklemi*, *C. kafuensis*, *C.* "Kasama" and probably several more species. *Graphiurus* sp. includes *G. murinus* and *G. johnstoni*; *Coetomys mechowi* = *Cryptomys mechowi*; *Mastomys natalensis* = *Praomys natalensis*; *Grammomys* = *Thamomys*.

If we consider only squares (n=63) for which more than 5 species were recorded, than the average rodent species number per degree square is 15 (SD=7). The 63 species of rodents (and at least 7 species of recently identified mole-rat species should be added) listed by Ansell (1978) belong to 35 genera. It is of interest to compare this species richness with rodent biodiversity in Central Europe, where at a comparable area () 36 species in 21 genera can be counted (cf., Mitchel-Jones et al. 1999). The rodent biodiversity in Zambia is also comparatively higher than in the Southern African Region (cf., De Graaff 1981) (cf. Table 4). For sure, a more detailed analysis with regard to small-scale diversity (species numbers in degree squares), ecological factors, and species overlaps in Southern Africa and in central Europe would be needed to test applicability of rodents as a case for the species-area-relationships ecological theory (cf., Ricklefs 1997).

Table 4: Comparison of biodiversity of rodents in Zambia (cf. this thesis) with data on a comparable area size in Central Europe (based on Mitchel et al. 1999) and Southern African Subregion (based on De Graaff 1981).

region	**area (x1,000 km^2)**	**country**	**rodent genera**	**rodent species**
Zambia	750	Z	34	70
Central Europe	750	D, A, CZ, SK, DK, NL CH, B, SLO, L, FL	21	36
Southern Africa	3,310	ZA, NAM, ZW, RB southern half of MOC	40	76

The results of the recent revision of mole-rats (cf., Ingram et al. 2004 and the chapter on *C. mechowi*, this thesis) have been taken into account.

Among 63 species of rodents (sibling species of common mole-rats being considered a single species) reported from Zambia by Ansell (1978), 28 species (44%) were recorded also in Ndola and environs. Most of these species belong to the first two groups - i.e., they can be considered widely distributed. Only two species (*Thryonomys gregorianus* and *Zelotomys hildegardae*) occurring in Ndola have a limited distribution. There were no species reported by Ansell (1978) which would occur only there.

It should be pointed out that although the size of the area of distribution mostly correlates with local abundance of the species (its commonness or rarity) (e.g. the case of *Mastomys natalensis* or *Tatera leucogaster*), it does not need to be the case (e.g. the porcupine, *Hystrix africaeaustralis*) which is rather widely distributed but is nowhere common or abundant. Furthermore, the lower abundance and/or trappability of some species combined with less intensive or less extensive (in time and/or space) sampling may explain the lack of certain species in some squares.

Analysis of owl pellets

There are 12 species of owls (Strigiformes) recorded in Zambia (cf. Table 5). In my study, I have analyzed food of the Barn Owl (above, left).

Introduction

The avibase <http://www.bsc-eoc.org/avibase/avibase.jsp?region=zm&pg=checklist&list=clements> gives following species of owls to occur in Zambia:

Table 5: Checklist of Zambian owl species (Avibase)

Tytonidae	
African Grass-Owl	*Tyto capensis*
Barn Owl	*Tyto alba*
Strigidae	
African Scops-Owl	*Otus senegalensis*
European Scops-Owl	*Otus scops*
Southern White-faced Owl	*Ptilopsis granti*
Spotted Eagle-Owl	*Bubo africanus*
Verreaux's Eagle-Owl	*Bubo lacteus*
Pel's Fishing-Owl	*Scotopelia peli*
African Wood-Owl	*Strix woodfordii*
Pearl-spotted Owlet	*Glaucidium perlatum*
African Barred Owlet	*Glaucidium capense*
Marsh Owl	*Asio capensis*

The **Barn Owl** (*Tyto alba*) (subject of my study) (Fig. 30) is one of the most widespread of all land birds. It is cosmopolitan, on all continents except Antarctica, and on many islands (Fig. 31).

Fig. 30: A female African Barn Owl (*Tyto alba affinis*) from the Namboard Silo = supplier of owl pellets for my study.

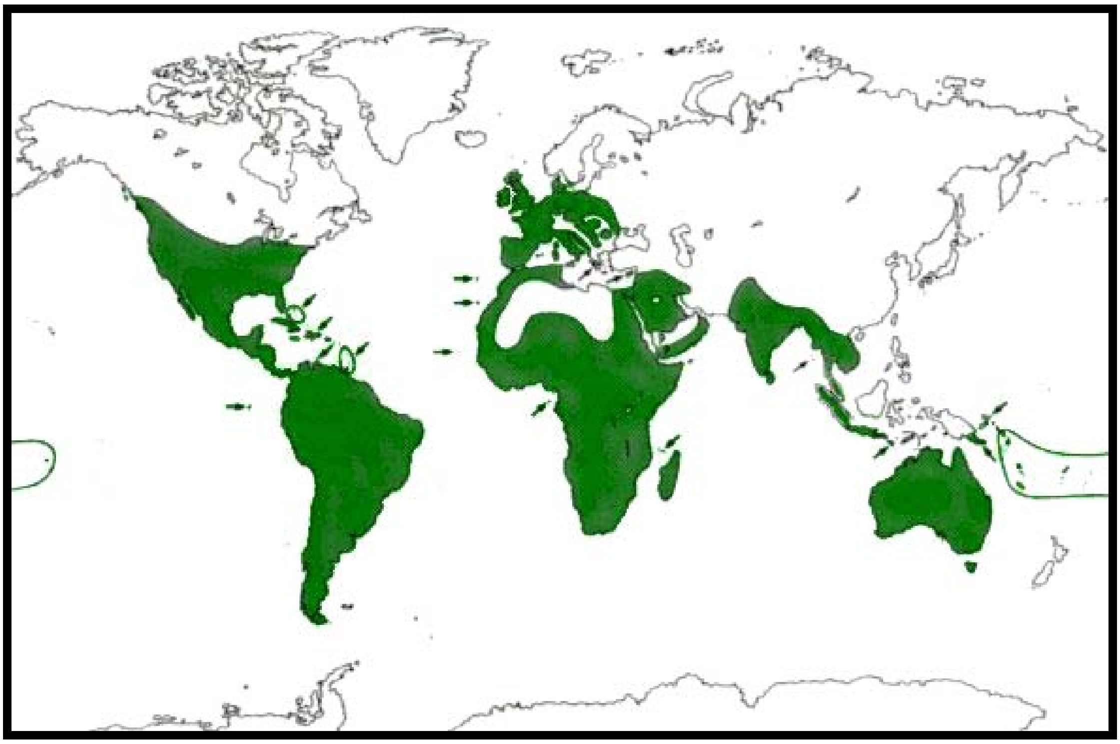


Fig. 31: Distribution of the Barn Owl (<http://www.owlpages.com>)

Given its wide distribution, there is plenty of information on the Barn owl in the literature. Much information can be found also in internet (quite informative are the websites of:
The Owl Pages: <http://www.owlpages.com>
and ***The World Owl Trust:*** <http://www.owls.org/Species/tyto/african_barn_owl.htm>
and the links provided there. It would be beyond the scope of my thesis to deal here with the Barn Owl in detail.

The Barn Owl in Zambia belongs to the subspecies *Tyto alba affinis* (African Barn Owl). Valuable specific information on the African Barn Owl is provided by ***Percy FitzPatrick Institute of African Orni*****thology** in Cape Town, South Africa. <http://web.uct.ac.za/depts/fitzpatrick/docs/r392.html>

I excerpted following information on the African Barn Owl (see Box, p. 36), relevant to the topic of my study, from the website of the Percy Fitzpatrick Institute of African Ornithology (see above), where also primary literature references are provided:

African Barn Owl – *Tyto alba affinis*

Body mass is 335 (220-470) g. **Habits:** Sedentary and resident in areas with stable food supply. Occupies any habitat, from desert to the border of evergreen forest, where there is abundant food and suitable roost and nest sites. Generally prefer more open habitats, such as lightly wooded savanna and grassland. Common in association with humans, urban, suburban and rural. Roosts by day, most often in a suitable cavity and close to a mate. Prefers secluded caves, crevices, tree holes, Sociable Weaver nest masses, or mineshafts and buildings, the floors of which accumulate numbers of regurgitated pellets. Emerges in the late dusk, only rarely diurnal. Hunts most intensely as soon as darkness falls, ranging at least 2-16km from nest or roost area. Pellets about 45x20mm, often dark and shiny with mucous, ejected 5.5-24hrs after meal (mean 12hrs). Hunts from succession of low perches or, most often, in silent flight, only rarely from the ground. Courses slowly over vegetation, flapping, gliding or rarely hovering, with face directed downwards to look and listen from prey. Drops feet-first on prey, but sometimes pursues birds in flight, snatches them from their roost or raids their nests. Kills prey by squeezing with the feet or nips of the bill. **Prey** size ranges from young francolin or hare down to termites. Eats mainly small rodents (7-110g in size, 75-97% of prey remains) but in urban areas small birds may predominate (40-95%) or, in deserts, geckos and scorpions. Overall, rodents comprise 75% of diet, shrews and birds an additional 23%, with mammals the main diet in winter augmented by birds and insects in summer. Eats about 42-82g/d (mean 55g/d). Also takes a few insectivores (shrews, elephant shrews), bats (van der Merwe 1980) frogs, lizards, or other arthropods. Monogamous and territorial, nests solitarily, but as close as 50m apart. **Breeding:** Recorded for all months but mainly Feb-May, generally earlier under winter rainfall of sw Cape (Aug-Dec) and later further north, in Zimbabwe Mar-Apr, Sept. May lay second and successive broods. ***Nest:*** In natural cavity, above or below ground, among rocks or in tree holes, large nest mass, mines or buildings, often same as roost site and used repeatedly over long periods.. ***Eggs:*** 2-13, mean 5.8 SD=1.9 (n=58 - D, 16-19 in ‘boom’ years. Variation in clutch size apparently related more to food availability rather than region or season. ***Incubation:*** Only by female, starts with laying of first egg, rest laid at intervals of 1-3d. Period: 29-34d. Female fed at nest by male, only rarely hunts for itself. Incubation shift lengths unknown. In larger and successive broods, chicks may inadvertently help in incubation. Later female assists in prey delivery, as chicks become noisy with wheezing and snoring begging calls, leaving them alone in the nest by about a month old. Nestling and fledging period 45-55d, related to abundance of food supply. Female and brood of 4 chicks require about 34kg of food (*ca.* 1700 small mammals), broods of 8-10 raised in good seasons. Juveniles begin to catch prey within a month of fledging. ***Breeding success:*** Highly variable from year to year, even for resident pairs.

The information on the diet of owls can be gained from the analysis of the owl pellets. **Owl pellets** are masses of bones, teeth, hair, feathers, scales, and arthropod skeletons. They are produced and regurgitated by owls (but also by hawks, eagles, and other raptors which swallow their prey whole or in large pieces). The soft parts of the prey are dissolved by proteolytic enzymes (protein digesters) and strong acids which occur in high concentrations in the stomachs of owls and raptors. The relatively weak stomach muscles of the bird form the undigested fur, bones, feathers, etc. into wet, slimy pellets. In this process, even the most fragile bones are usually preserved unbroken. Because the pyloric opening of the stomach into the intestine is narrow, only finely divided materials pass into the intestine. As a result, tiny bones only occasionally pass through the digestive system. Ideally, each whole owl pellet usually contains virtually complete skeletons of the animals which the owl ate the night before the pellet was formed. (cf., OWL

PELLET KIT. TEACHER'S GUIDE The South Carolina Department of Natural Resources: <http://www.dnred.com/owlkit.pdf>. However, pellets mostly contain remains of more than just one prey specimen and the remains of each specimen may be distributed in more pellets.

Study of the **diet of owls and** study of **rodent communities** may be closely intertwined. It is apparent that the manpower and resources which are devoted to the rodent research in South Africa or Europe on one hand side and Zambia on the other hand are not comparable.

However, the requirement of control sampling using comparable methods (covering comparable area, comparable time period, with the same trapping methods and intensity) remains, given the current economic and academic situation in Africa an utopia dream. For sure, also the research priorities nowadays lie elsewhere. Under these circumstances, the **analysis of owl pellets**, as presented here, represents a cheap, relatively simple alternative, producing comparable comparative data on small mammal communities and their changes across space and time. Indeed, this is an **excellent way of conducting surveys**, especially in areas with few resources, and can potentially be used to monitor changes in biodiversity with little effort. It is surprising that thus far, this source of information has remained virtually untapped in Zambia in particular and in most of Africa in general. One problem is surely the lack of suitable identification keys for skulls (and bones in general) of African small mammals.

Of course, even this source of information has its limitations - given e.g. by the occurrence and hunting habits of owls, habits of their potential prey, size factors etc. Bearing in mind that there may be sibling species, which can be recognised only on a base of morphometric analysis of large samples or karyologically or with methods of molecular genetics, the evaluation of materials has its own limitations. Nevertheless, the comparability of samples remains high due to comparable sampling and evaluation methods.

Material and Methods

My study of owl pellets has not been very easy because of the myth surrounding these creatures of the night. They are surrounded with a lot mysticism and are associated with the dark world. My attempt to find collaborators or let alone first find the locations of nesting sites of the owls was met with a lot of resistance. There were very few people who were willing to associate themselves with my study and therefore it took a lot of perseverance on my part especially that I had a lot of encouragement from my mentor Prof. Dr. Hynek Burda.

My study and collection of owl pellets started way back in the year 2000, where initially the first samples were from Fatima Girls Secondary School area and then more intensely from Namboard Silo (Fig 32). As a comparison other samples were collected from the Chichele forestry nursery and also more systematically from Mansansa forest reserve area (Fig. 33).

At the top floor of the silos there have been more than one family of owls. These have been observed since the year 2000, and during this period visitations were and are still limited to once per month, i.e. on the 21st of each and every month. This was primarily to ensure that the owls are not intimidated and forced out of this locality.

Since February 2002 (till January 2004 within the framework of this thesis) I have been collecting owl pellets from one nest in the silo on a regular monthly basis. Before starting the regular monthly collecting I had collected all the accumulated pellets

Fig. 32: Interiors of the silo: My way to the owl nest.

and debris to be sure that the next collection can be attributed to a particular one month period. Each month, some 30 complete pellets (some pellets were broken or disintegrated so that the exact number could not be determined) were collected and subsequently dissected and analyzed. Over two years (24 months) about 720 pellets from the Namboard Silo were examined and qualitatively and quantitatively assessed. From the Mansansa Forest, altogether about 120 pellets from four months (partly a discontinuous series) could be collected and attributed to one-month-periods. Besides that, many more pellets were collected prior to regular monthly sampling to be sure that the sample collected by the next visit would be that representing the last month. Besides that pellets were collected incidentally also in other sites (see above). All of them were examined and species were determined, yet they were not quantitatively analyzed. See also the chapter Study area for more general information on particular localities.

Fig. 33: The observation tower in the Chichele Forest. Roosting place of the owl is in the cabin on the top. Note the mound of giant mole-rats directly at the foot of the tower (arrow).

The pellets were disassembled and the bones of the animals were separated from the fur and/or feather using dissecting needles and forceps. In many cases, when pellets were too hard, they had to be placed into water (each pellet separate into a dish) where they disintegrated. The bones were cleaned of debris. Bones from pellets processed through the "wet method" were left to dry. Dry, clean bones (and other structures of interest like rests of arthropod exoskeletons) originating from one pellet were kept separately in small zipped plastic bags (bought in the pharmacy) or in plastic film containers. Later for examination bones were sorted, identified and recorded according to type (e.g., skulls, maxillae, mandibles, particular long bones of the postcranial skeleton, vertebrae, etc.) and according to the size (Fig. 34).

Fig. 34: Example of contents of one pellet of the Barn Owl from Namboard.

The species determination turned to be a rather difficult task for me, since there are no determination keys for skulls (and definitely not for postcranial bones) of small rodents of the Zambezian region. There are some pictures and more or less general descriptions (which turned mostly to be of little use) on East African rodents in Kingdon (1974) and on South African rodents in De Graaff (1981) and Smithers (1983). Last year I got an interactive PC software - a determination key of mammals of Tanzania. "Tanzanian Mammal Key" produced in 2001 by Bill Stanley of the Field Museum in Chicago (<tanzaniakey@fmnh.org>), yet even apart from geographical limitations, the use of this key is rather limited, as it is only a one-way determination key, which does not enable any more direct search or checking. There are only few experts worldwide who are able to determine skulls and its parts thanks to their immense experience, and - not unimportant - access to comparative museum collections and knowledge of and access to information scattered in the (mostly older) literature. One of such renowned experts is Dr. Dieter Kock of the Senckenberg Museum in Frankfurt am Main, Germany. I have been lucky to have gained Dr. Kock for my project. He has checked the determination of all the specimens and determined those I could not identify. So he is responsible for and at the same time he is a guarantee of correct species identification of all the specimens found in pellets. In the course of my study I have learned to determine all the bones and their laterality, and I learned to recognize the major types (rodents, shrews, macroscelids, bats, birds, frogs, reptiles, solifugae, termites, scarabeids, orthopterans), and, in the case of rodents, the most frequent genera: *Mastomys*, *Tatera*, *Mus*, *Dendromus*. The paired bones were counted within each pellet and the sum for each month was counted. The species determination was done on the base of the cranium and, particularly on the base of upper tooth rows. In the case that the skull was fragmented and the right and left maxillae were separated, care was taken to avoid double counting. A slight double counting error may have arisen with respect to overlap between two subsequent months. (This error is considered to be negligible within the context of the whole analysis).

Results and Discussion

Owls

In both localities, Namboard and Mansansa, I could observe the owls from close vicinity and thus I could confirm that in both cases these were Barn Owls (*Tyto alba*). Since in both cases, the roosting place served also as the nest place I assume that both my suppliers of pellets were females.

During the observations made it was found that eggs were always discovered towards the end of March, and, the latest month in which eggs were still observed was in late May. In all other months no eggs were seen from the nesting places. These findings have been consistent throughout the observation period. The maximum number of eggs observed per nest was four with a minimum of one. Three breeding nests have been observed at any one time during the breeding season.

Given the fact that the Barn Owl is said to avoid forests, finding it in the given locality is of interest. Breeding season being from March till April, i.e. at the end of the rainy season and beginning of the dry season, is consistent with observations from Zimbabwe (cf., the box above). Clutch size seems to be a bit smaller than that reported from South Africa. (see the box above).

Pellets

Pellets were blackish, mostly cylindrical (Fig. 35): 39.6 (SD=5.7) x 21.0 (SD=3.2) mm (range 24-63 mm x 15-31 mm) in size (n=120 pellets from Namboard: 10 randomly chosen complete pellets from each month in the year 2002). Some pellets were rather spherical (in one case: 28x31x39 mm). There was no apparent correlation between the size or shape of a pellet and its contents. Owl pellets from Mansansa were not systematically measured, yet they were apparently not different from pellets from Namboard. About 30 (18-34) more or less complete pellets were collected from each site each month. Sometimes, some pellets were rather disintegrated or get crumbled during the transport, so that exact counts cannot be stated. In June 2003 also four mummified cadavers of mice were found among pellets.

Fig. 35: Pellets of the Barn Owl from Namboard (Photo: Marie-Therese Bappert)

Pellets were within the size range given for South African barn owls (cf., Box above). The number of pellets is consistent with the idea that one pellet is produced per day (cf. Box above).

Pellet contents

Remarks on taphonomy*

(***Taphonomy** is the study of the fate of the bodies of organisms after they die. It studies such phenomena as decomposition and formation of fossils. In this context it deals with preservation of particular bones in owl pellets.) Many older pellets (if not disintegrated) were infested with moths. The bones from older pellets were darker - apparently as a consequence of longer effect of stomach acid.

It was observed that rests of many specimens were distributed over several pellets. Thus, the remnants of one specimen of the elephant shrew, a rare prey of the Barn Owl in the studied sample, which could be unambiguously distinguished from other species, were found in at least three pellets. On the other hand, a single pellet can contain rests of several specimens. An analysis of complete pellets from Namboard (n=500) shows that 44% of pellets contained a single vertebrate prey specimen, 33% rests of two individuals, 16.5 % three specimens, 4% four specimens, up to 12 preyed individuals were represented in a single pellet. Thus in one pellet from the Mansansa Forest (July) rests of 9 different rodent individuals, 2 shrews and one bat were found together. (The number of individuals was assessed on the base of representation of bones of different types and sizes, respecting their laterality.)

It was noticed that rests of shrews hold mostly together and the complete skeleton of an individual is usually expelled in one pellet. Most skulls (independently of the size) have a damaged parietal and occipital region. This finding relates to the habit of the Barn Owl to kill its prey by striking the rear of its head with beak (D. Kock, personal communication). A great proportion of skulls of gerbils (*Tatera*) were complete and nicely preserved (though being rather big) -an indication of exceptional stability of these skulls. Some few pellets consisted only of debris (hairs, feathers, small bones or chitin rests).

Analysis of 300 complete pellets from Namboard (Table 6) revealed consistence in the number of individual vertebrate prey items as estimated from the number of paired long bones (femur and humerus), dental bones (mandibles), and maxillae with upper tooth rows. However, particularly in small or young rodents maxillae may rapidly disintegrate and isolated tooth rows (if present at all) may be overlooked. Therefore it would be meaningful to have a determination key based on mandibles or long bones.

Table 6: Absolute numbers of selected paired bones and estimated numbers of preyed items (only mammals and birds are considered) found in 300 complete pellets of the Barn Owl from Namboard 2003.

bone elements	**counts**	**assessed number of specimens**	
mandible	636	318	
femur	633	317	
humerus	630	315	
os coxae	510	255	
tibia	542	271	
ulna	425	213	
rather complete skull	229	229	315
isolated maxilla with teeth	171	86	

Species analysis

The results with respect to species identification and their respective numbers as found in pellets collected in one-month-periods in Namboard and Mansansa are provided in Tables 7-10.

Plant items were apparently some seeds and in one case a peanut shell, or some items could not be determined. They may have get into owl's stomach with preyed birds.

Arthropods (Fig. 36) were represented by locusts, scarabeid beetles, sunspiders and termites or ants. Some items could not be identified. Of interest were large amounts of chelicerae of ***sunspiders*** (solifugae) in some pellets (up to 33 chelicerae were counted in one pellet). Conspicuous was the coincident presence of sunspiders and termite (or ant) (?) heads found in the same pellets. I assume that termites were actually undigested food remains of sunspiders taken together with these items. Sunspiders were found also in the food of some other owl species, like *Athene noctua* (Obuch and Kristin 2004) or *Otus senegalensis* (<http://web.uct.ac.za/depts/fitzpatrick/docs/r396.html>). In these cases, however, these species represent smaller owls, known to feed predominantly on invertebrates, and inhabiting arid zones. Sunspiders generally are characterized as inhabitants of arid regions (<http://www.museums.org.za/bio/arachnids/solifugae.htm>). Finding them therefore in high proportion the food of the Barn Owl from relatively mesic regions, and predominantly during the rainy season (Tables 4, 5) is surely of interest.

The ***frogs, lizards and birds*** belonged apparently to different species and body sizes; yet they could not be determined.

Pellets of two Barn Owls from Ndola (Namboard and Mansansa) contained at least 27 species of ***mammals*** (Table 7). Note that shrews and one bat (*Pipistrellus*) could be identified only on the generic level. The skull of the dormouse (*Graphiurus*) resembles closely *G. surdus*, yet this species is known only from Western Africa. There were at least three species of *Crocidura* and three species of *Dendromus* (most probably *D. melanotis*, *mystacalis and mesomelas/nyikae*). At least three species of rodents and two species of bats are new records for Ndola and should be added to the list (cf., Tables 7 and 3).

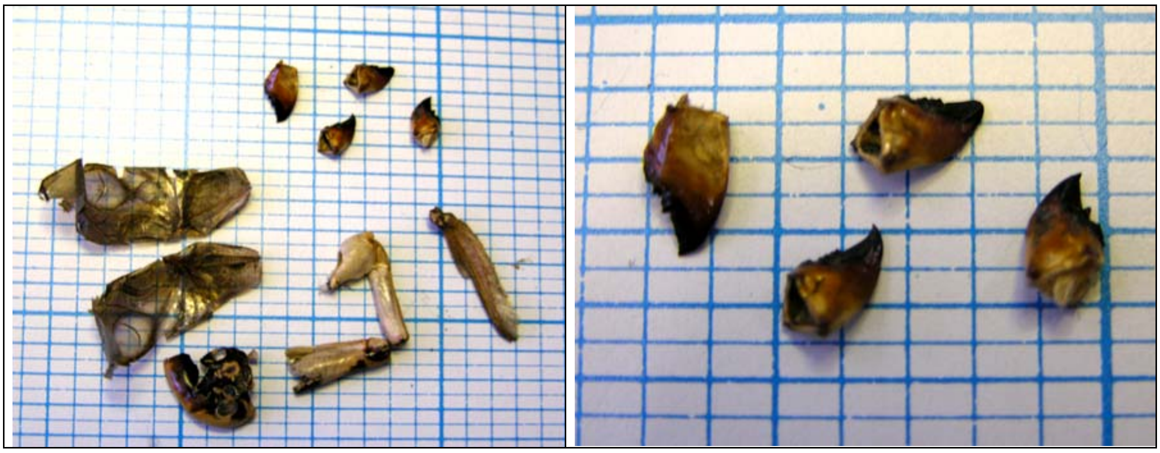


Fig. 36: Arthropod remains from an owl pellet (wings and legs of locusts and chelicerae of sunspiders, magnified in the right picture.

Table 7: List of mammal species found in pellets of two barn owls from Ndola.

Rodentia	
1	*Acomys spinosissimus*
2	*Aethomys nyikae*
✳3	*Aethomys chrysophilus*
4	*Dasymys incomtus*
5	*Dendromus* S (*melanotis*)
6	*Dendromus* M (*mystacalis*)
✳7	*Dendromus* L (*mesomelas*)
8	*Grammomys dolichurus*
9	*Graphiurus* sp.
10	*Mastomys natalensis*
11	*Mus minutoides*
12	*Pelomys falax*
✳13	*Praomys jacksoni*
14	*Rattus rattus*
15	*Saccostomus campestris*
16	*Steatomys pratensis*
17	*Tatera boehmi*
18	*Tatera valida*

Macroscelidea	
19	*Elephantulus brachyrhynchus*
Insectivora	
20	*Suncus* sp.
21	*Crocidura* (small form)
22	*Crocidura* (medium form)
23	*Crocidura* (large form)
Chiroptera	
24	*Pipistrellus* sp.
25	*Scotophilus dinganii*
✳26	*Scotophilus leucogaster*
✳27	*Tadarida pumilla*

Species are marked with respect to their distribution in Zambia: broad, regional, limited, new records for Ndola are marked ✳ (cf., Table 3).

Fig. 37: Skulls of the most frequented rodents predated by the Barn Owl (from left): *Mus minutoides*, *Mastomys natalensis*, *Tatera vallida*

Table 8 Numbers of individuals of particular species/genera found in owl pellets in respective months (pellets were collected always on the 21st day of the month) from February 2002 through January 2003.

Namboard (February 2002 - January 2003)													
month	**Feb 02**	**Mar 02**	**Apr 02**	**May 02**	**Jun 02**	**Jul 02**	**Aug 02**	**Sep 02**	**Oct 02**	**Nov 02**	**Dec 02**	**Jan 03**	**Σ**
plant items													
seed, peanut shell etc.	0	0	0	0	0	0	1	3	1	0	0	0	**5**
arthropods													
arthropoda (indet.)	0	0	0	0	0	0	0	1	0	0	0	1	**2**
solifugae	1	0	0	0	0	0	2	0	2	6	0	13	**24**
Orthoptera	0	4	0	2	0	0	1	0	3	3	2	0	**15**
Coleoptera	0	0	0	0	0	0	0	0	0	1	1	0	**2**
vertebrates													
Frog/toad	0	0	0	0	0	0	0	0	1	1	0	0	**2**
reptile	0	0	0	0	0	0	0	0	1	0	0	0	**1**
bird	2	0	2	0	2	1	1	4	2	3	4	4	**25**
Tadarida pumilla	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Crocidura	6	7	0	12	8	1	2	1	2	3	3	1	**46**
***Crocidura* L**	0	0	0	0	0	0	0	0	0	0	1	1	**2**
***Crocidura* M**	0	0	0	0	0	0	0	3	0	0	0	2	**5**
***Crocidura* S**	0	1	0	0	0	0	0	0	0	0	0	0	**1**
Suncus	1	1	0	1	1	0	0	0	0	0	0	0	**4**
Elephantulus	0	1	0	0	0	0	1	0	0	0	0	0	**2**
Acomys	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Aethomys chrysophilus	0	1	0	0	0	0	0	0	0	0	0	0	**1**
Aethomys nyikae	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Dasymys	0	0	0	1	0	0	0	0	0	0	1	0	**2**
Dendromus	1	3	2	0	0	1	3	1	2	1	2	4	**20**
***Dendromus* L**	0	0	0	3	0	0	0	0	0	0	0	0	**3**
***Dendromus* M**	0	0	0	0	0	0	1	0	0	0	0	0	**1**
***Dendromus* S**	0	0	1	2	2	0	1	0	0	0	0	0	**6**
***Graphiurus* sp.**	0	0	0	0	0	0	0	0	1	0	0	0	**1**
***Mastomys* adult**	30	21	20	24	12	17	16	13	27	14	17	12	**223**
***Mastomys* juvenile**	2	0	0	1	0	0	5	2	3	2	0	0	**15**
Mus	5	4	6	0	1	6	10	12	14	0	2	2	**62**
Pelomys	0	0	0	0	1	1	0	0	1	1	0	0	**4**
Praomys	0	0	1	1	0	1	0	1	1	0	0	0	**5**
Rattus rattus	0	0	0	0	0	1	1	0	0	0	0	0	**2**
Saccostomus	0	1	1	0	0	0	1	1	0	0	0	1	**5**
Steatomys	0	2	4	0	1	3	0	0	0	1	0	0	**11**
***Tatera* adult**	2	1	4	1	2	2	3	3	1	1	0	3	**23**
***Tatera* juvenile**	0	0	2	0	0	1	0	2	0	0	0	0	**5**
sum (vertebrates)	**50**	**43**	**43**	**46**	**30**	**35**	**45**	**43**	**57**	**27**	**30**	**30**	**479**

The numbers given for seed and arthropods refer to the number of pellets in which these items were found. L, M, S = large, medium, small type

Table 9: Numbers of individuals of particular species/genera found in owl pellets in respective months (pellets were collected always on the 21st day of the month) from February 2003 through January 2004.

Namboard (February 2003 - January 2004)													
month	**Feb 03**	**Mar 03**	**Apr 03**	**May 03**	**Jun 03**	**Jul 03**	**Aug 03**	**Sep 03**	**Oct 03**	**Nov 03**	**Dec 03**	**Jan 04**	**Σ**
plant items													
seed, peanut shell etc.	0	0	0	1	0	0	0	0	0	0	0	0	**1**
arthropods													
arthropoda	1	1	1	0	0	0	0	0	2	0	0	0	**5**
solifugae	1	0	0	0	0	0	1	0	0	2	2	2	**8**
Orthoptera	1	2	0	0	1	0	0	0	0	1	0	0	**5**
Coleoptera	0	3	2	0	0	0	0	2	0	0	0	0	**7**
vertebrates													
Frog/toad	0	0	2	0	0	0	0	0	0	0	0	0	**2**
reptile	0	0	2	0	1	0	0	0	0	0	0	0	**3**
bird	5	5	11	3	1	1	1	4	4	0	0	0	**35**
Tadarida pumilla	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Crocidura	8	1	0	2	0	0	2	0	2	3	0	3	**21**
***Crocidura* L**	0	0	1	0	0	0	0	0	1	0	0	0	**2**
***Crocidura* M**	0	0	1	0	0	0	0	0	0	0	0	3	**4**
***Crocidura* S**	0	0	0	1	2	0	0	0	1	0	0	0	**4**
Suncus	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Elephantulus	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Acomys	0	0	0	0	0	0	0	0	0	0	1	0	**1**
Aethomys chrysophilus	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Aethomys nyikae	0	0	0	0	0	0	1	0	0	0	0	0	**1**
Dasymys	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Dendromus	4	6	7	3	3	1	3	0	0	4	1	2	**34**
***Dendromus* L**	0	0	0	0	0	0	0	0	0	0	0	0	**0**
***Dendromus* M**	0	0	0	0	0	1	0	0	0	0	2	0	**3**
***Dendromus* S**	0	0	0	1	0	0	0	0	0	0	0	0	**1**
***Graphiurus* sp.**	0	0	0	0	0	0	0	0	0	0	0	0	**0**
***Mastomys* adult**	20	25	14	19	14	24	22	25	28	20	13	22	**246**
***Mastomys* juvenile**	0	1	2	0	2	6	3	0	0	0	0	0	**14**
Mus	3	3	0	2	6	8	5	1	0	1	2	0	**31**
Pelomys	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Praomys	0	0	0	0	1	1	0	2	0	0	0	0	**4**
Rattus rattus	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Saccostomus	0	0	0	1	0	3	1	2	0	2	3	2	**14**
Steatomys	0	0	0	1	0	0	0	0	0	0	0	0	**1**
***Tatera* adult**	0	2	1	0	2	1	5	5	2	1	7	3	**29**
***Tatera* juvenile**	0	0	1	0	0	1	0	0	0	0	0	0	**2**
sum (vertebrates)	**40**	**43**	**42**	**34**	**32**	**47**	**43**	**39**	**38**	**31**	**29**	**35**	**453**

The numbers given for seed and arthropods refer to the number of pellets in which these items were found. L, M, S = large, medium, small type.

Table 10: Numbers of individuals of vertebrates found in owl pellets in four months in the Mansansa Forest Reserve Area.

Mansansa Forest 2003-2004					
	Jun 03	**Jul 03**	**Aug 03**	**Jan 04**	**Σ**
bird	1	0	0	0	1
Crocidura sp.	1	9	8	2	20
Scotophilus dinganii	1	0	0	0	1
Scotophillus leucogaster	1	0	0	0	1
Pipistrellus sp.	0	0	0	1	1
Acomys spinossisimus	0	0	0	0	0
Aethomys sp.	0	2	0	2	4
Aethomys chrysophilus	0	0	0	3	3
Aethomys nyikae	0	0	0	1	1
Dendromus sp.	5	1	1	1	8
Grammomys dolichurus	0	1	0	0	1
Mastomys natal. adult	16	10	12	12	50
Mastomys juvenile	0	1	0	0	1
Mus minutoides	1	1	2	1	5
Pelomysfallax	1	0	0	0	1
Praomys jacksonii	0	1	0	0	1
Rattus rattus	0	1	0	0	1
Saccostomus campestris	0	0	1	0	1
Steatomys pratensis	1	2	0	0	3
Tatera sp. adult	2	8	9	10	29
Tatera sp. juvenile	1	1	0	0	2
sum (vertebrates)	**31**	**38**	**33**	**33**	**135**

(In May 2003 and in December 2003, the accumulated pellets were collected and examined, yet not included in this analysis.)

Altogether 1,034 vertebrates were identified in the studied sample (Table 11) which gives an average of 38 (SD=7) vertebrates caught by an owl per month.

Table 11: Numbers of individuals of vertebrates found in owl pellets in respective months.

sample	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Σ**
NM2002	50	43	43	46	30	35	45	43	57	27	30	30	**479**
NM2003	40	43	42	34	32	47	43	39	38	31	29	35	**453**
Mansansa					**31**	**38**	**33**					**33**	**135**
sum	**90**	**86**	**85**	**80**	**93**	**120**	**121**	**82**	**95**	**58**	**59**	**65**	**1034**
mean	**45**	**43**	**42**	**40**	**31**	**40**	**40**	**41**	**48**	**29**	**29**	**22**	

(Pellets were collected always on the 21st day of the month from February 2002 through January 2004.)

These numbers vary in the course of the year (Table 11, Fig. 38), with a minimum being in June (middle of the cold dry season) and at the beginning of the rainy season (November - December). For the owl is surely more important the weight of the captured animals. This aspect will be analyzed further below.

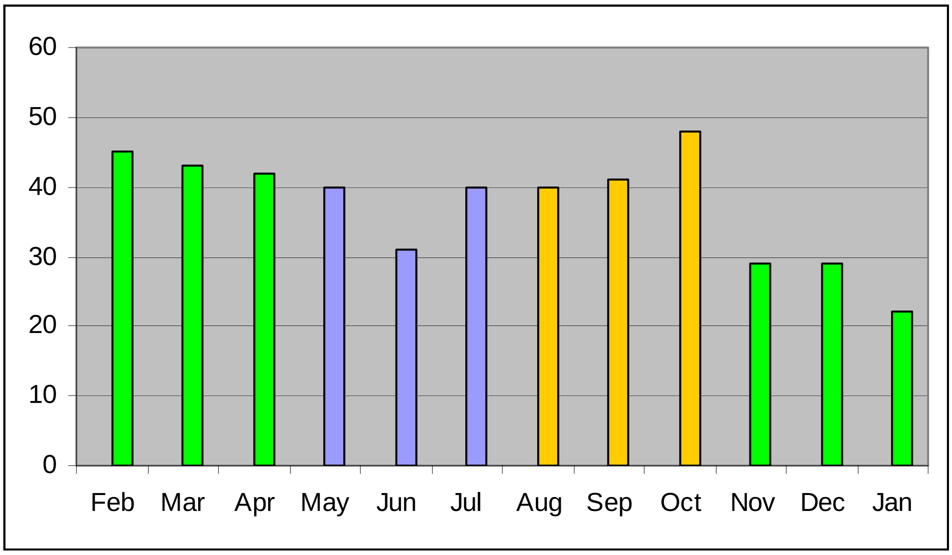


Fig. 38: Average number of vertebrate specimens found in Barn Owl pellets per month. Seasons are marked in colour: rainy, cold dry, hot dry.

Table 12 and Figures 38-47 demonstrate that different vertebrate species contribute differently and at different times to the diet of the Barn Owl. Thus more than 90% of the captured vertebrates in Namboard were Multimammate Rats (54%), Pygmy Mice (10%), shrews (9%), Climbing Mice (8%), gerbils (6%), and birds (6%). The food composition of the owl in Mansansa was similar, though slightly different: Multimammate rats (38%), gerbils (23%) shrews (15%), Climbing Mice (6%), Pygmy Mice (4%) contributed together to 86% of the prey. This may reflect different habitat or different habits of the particular owl individual but it may be also the effect of the season, since the analyzed sample from Mansansa Forest was smaller.

Whereas there was surely a difference in the proportion of particular species according to the period of the year (Figs. 39, 42-47) there was no apparent difference (at least not in more frequently represented species, *Mastomys*, *Dendromus*, *Tatera* and birds) between two subsequent years (Fig. 39). On the other hand, the difference between both years with respect to proportion of *Mus*, *Saccostomus* and *Steatomys* in the food was conspicuous.

The proportion of birds in the diet was smaller than that found in South Africa (cf. Box). However, there may be also local individual habits of owls. This could explain quite a high proportion of bats in the diet the barn owl from Mansansa, or high numbers of sunspiders found in pellets of the owl from Namboard.

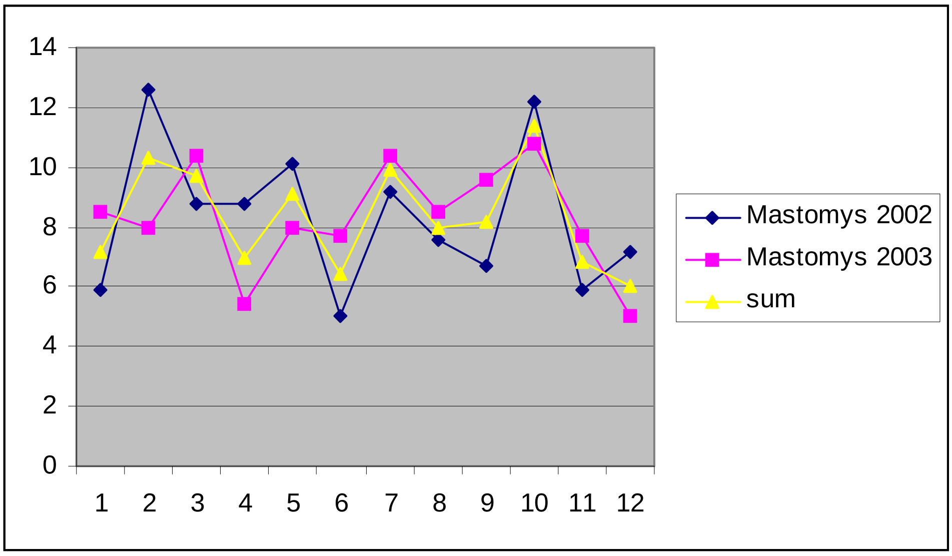


Fig 39: Changes in abundance of the Multimammate rat (or in the preference of the Barn Owl for it) in the course of two subsequent years. x- axis = months, y-axis proportion of rats in pellets (in per cent), the whole year's capture of rats being 100%.

Table 12: Numbers of individuals of representatives of diverse vertebrate taxa found in owl pellets in Namboard (NM in two years) and in the Mansansa Forest Reserve Area (MF in the course of four months).

genus/type	**numbers**				**per cent**			
	NM 02	**NM 03**	**NM sum**	**MF**	**NM 02**	**NM 03**	**NM sum**	**MF**
Mastomys	238	260	**498**	51	50.1	58.0	**54.0**	37.8
Mus	62	31	**93**	5	13.0	6.8	**10.0**	3.7
Crocidura	54	31	**85**	20	11.3	6.8	**9.1**	14.8
Dendromus	30	38	**68**	8	6.3	8.4	**7.4**	5.9
bird	25	35	**60**	1	5.0	7.7	**6.4**	0.7
Tatera	28	31	**59**	31	6.0	6.8	**6.3**	23.0
Saccostomus	5	14	**19**	1	1.0	3.1	**2.1**	0.7
Steatomys	11	1	**12**	3	2.3	0.2	**1.2**	2.3
Praomys	5	4	**9**	1	1.0	0.9	**1.0**	0.7
Pelomys	4	1	**5**	1	0.8	0.2	**0.5**	0.7
reptile	1	3	**4**	0	0.2	0.7	**0.4**	0
Suncus	4	0	**4**	0	0.8	0	**0.4**	0
frog/toad	2	2	**4**	0	0.4	0.4	**0.4**	0
Elephantulus	2	0	**2**	0	0.4	0	**0.2**	0
Acomys	1	1	**2**	0	0.2	0.2	**0.2**	0
Dasymys	2	0	**2**	0	0.4	0	**0.2**	0
Rattus	2	0	**2**	1	0.4	0	**0.2**	0.7
Aethomys	1	1	**2**	8	0.2	0.2	**0.2**	5.9
bat	1	0	**1**	3	0.2	0	**0.1**	2.3
Graphiurus	1	0	**1**	0	0.2	0	**0.1**	0
Grammomys	0	0	**0**	1	0.2	0	**0**	0.7
sum (vertebrates)	**479**	**453**	**932**	**135**	**100**	**100**	**100**	**100**

Interesting are two findings of the Spiny Mouse (*Acomys spinosissimus*), which is a clearly diurnal species, in pellets from October 2002 and December 2003. It should be noted that, otherwise, Spiny Mice are quite frequent species in the area (own observation). The absence of mole-rats from pellets is of interest per se and will be discussed in the chapter on mole-rats.

The main prey animals show distinct changes in their abundance in the course of the year (as reflected in their proportion in the diet of the owl; alternatively the changes reflect changes in the owl's preferences or in accessibility of those animals for the owl) (cf., Figs 42-47). Some of these changes can be explained by seasonal changes of the habitat: thus, Pygmy Mice and gerbils may be more easily localizable during the top dry season when the vegetation is burnt or sparse. However, the Climbing Mouse and Shrews show during this period their minima. Apparently much more has still to learnt about ecology and habits of these particular species to provide an explanation.

Daily food consumption of the owl

As argued above, for the hunting success of the owl is of relevance the weight of particular prey items rather than the number of captured animals. I have tried to assess the food intake of the owl per month (and per day in different months) by multiplying an average weight of particular prey species by their numbers in given periods. The average weights were taken from following sources: Kingdon 1974, De Graaff 1981, Skinner and Smithers (1990), Chitaukali 2002). These weights are given and food intake for particular species is calculated in tables in Appendix. The results are summarized below in Table 13 and Fig 48. The calculation reveals that the Barn Owl consumes about 1.6 kg vertebrates, mostly rodents, per month, about 19 kg per year. This makes an average daily consumption to be about 53 g (31-74 g), and an average weight of a single prey to be about 41 g.

These data are in very good agreement with the data for the Barn Owl from South Africa, estimating the daily food consumption to be 55 (42-82) g/day (see the Box above). It should be noted at this point that

1) I have not considered the weight of arthropods which may be also considerable (locusts and sunspiders);

2) the data on body weight of rodents as given in the literature are subject of great variation, and thus may be a source of some mistakes. Thus, for instance, Skinner and Smithers (1990) give the body mass of *Pelomys fallax* to be 141.5 g in males and 117.9 in females, whereas Kingdon (1974) states the body mass for this species to be 50 g. In most cases, however, the data are somewhat comparable.

3) I had no possibility to weigh the owl. It may be, however, that "my" animals are smaller than those from South Africa (consistently with the prediction of the Bergman's rule) and thus a lower consumption could be expected.

The data show that the average daily food intake changes throughout the year (Fig. 48). interestingly the number of catches/day changes in the same way (Fig. 49) indicating that the changes are not due to changing prey size (Fig. 50). Although the latter factor also changes slightly throughout the year, its changes are less prominent. The lower food intake in June can be explain by the fact that in that time fledging chicks in that time start to leave the nest and have great requirements and the parents themselves eat less. The second minimum in November through January cannot be, however explained in this way. Although it is theoretically possible that owls breed in September again (see the Box) I have not observed second breeding attempts.

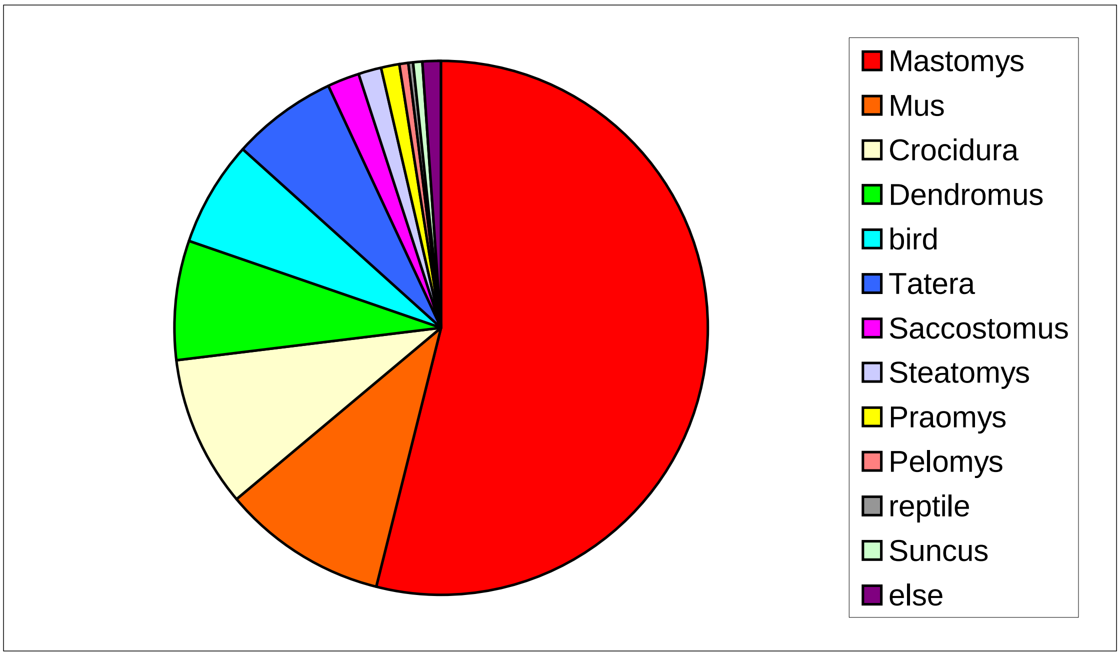


Fig. 40: Proportion of the vertebrates in the diet of the Barn Owl in Namboard over two years.

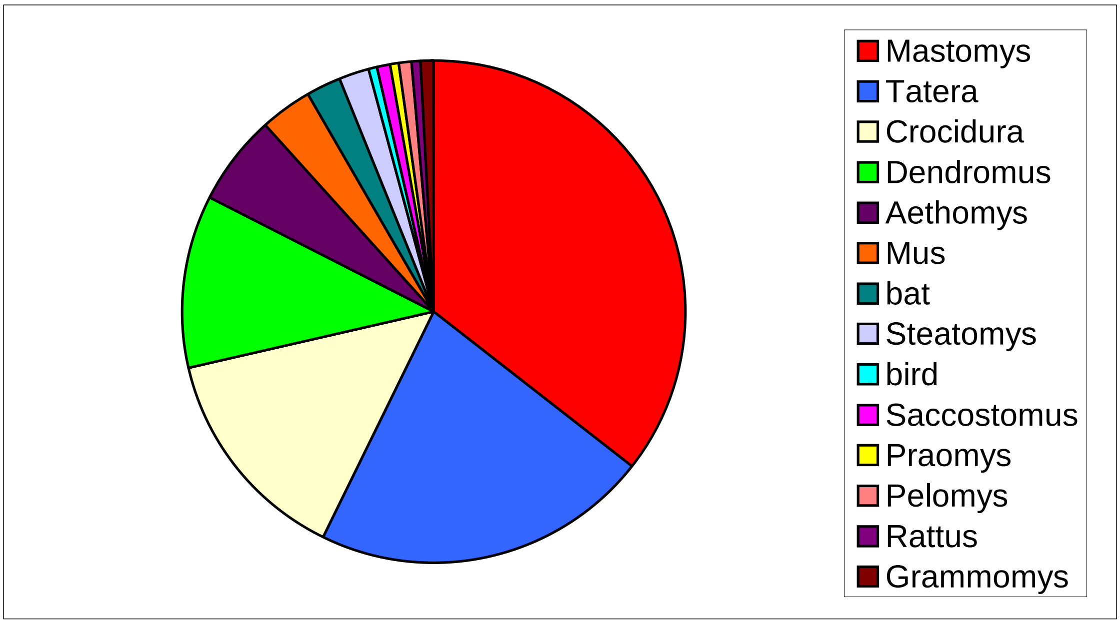


Fig. 41: Proportion of the vertebrates in the diet of the Barn Owl in Mansansa Forest in the course of four months.

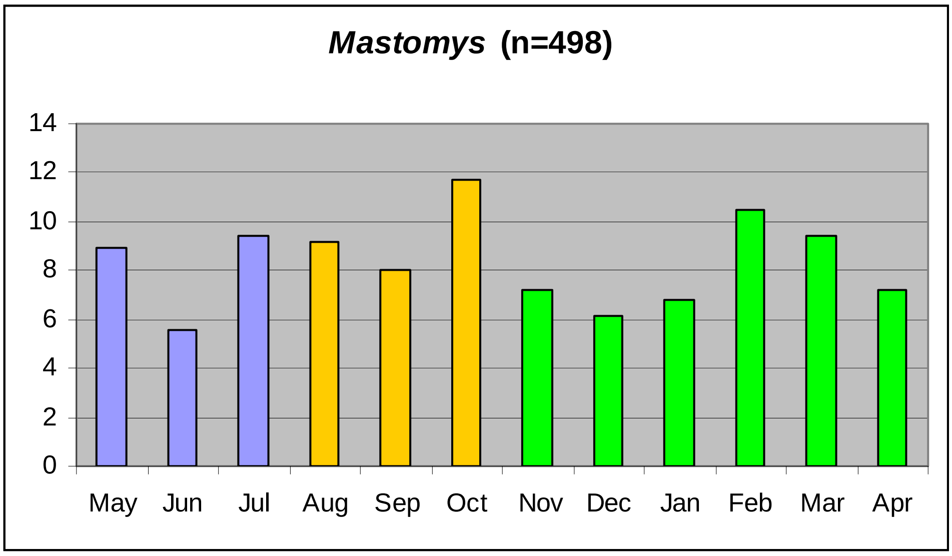


Fig. 42: Changes in abundance of the Multimammate rat (or in the preference of the Barn Owl for it) in the two years study period. x-axis = months, y-axis proportion of rats in pellets (in per cent), the whole year's capture of rats being 100%. Seasons are marked in colour: rainy, cold dry, hot dry.

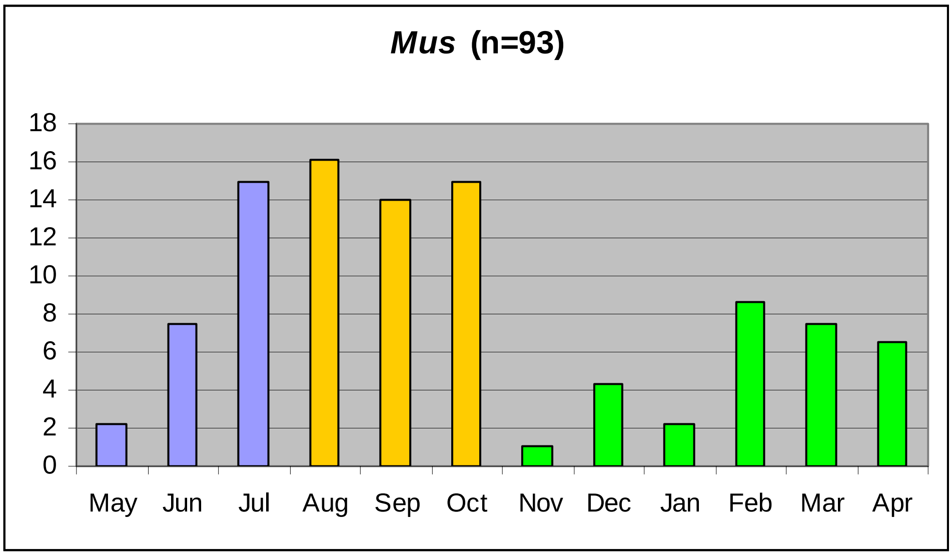


Fig. 43: Changes in abundance of the Pygmy Mouse (or in the preference of the Barn Owl for it) in the two years study period. x-axis = months, y-axis proportion of mice in pellets (in per cent), the whole year's capture of rats being 100%. Seasons are marked in colour: rainy, cold dry, hot dry.

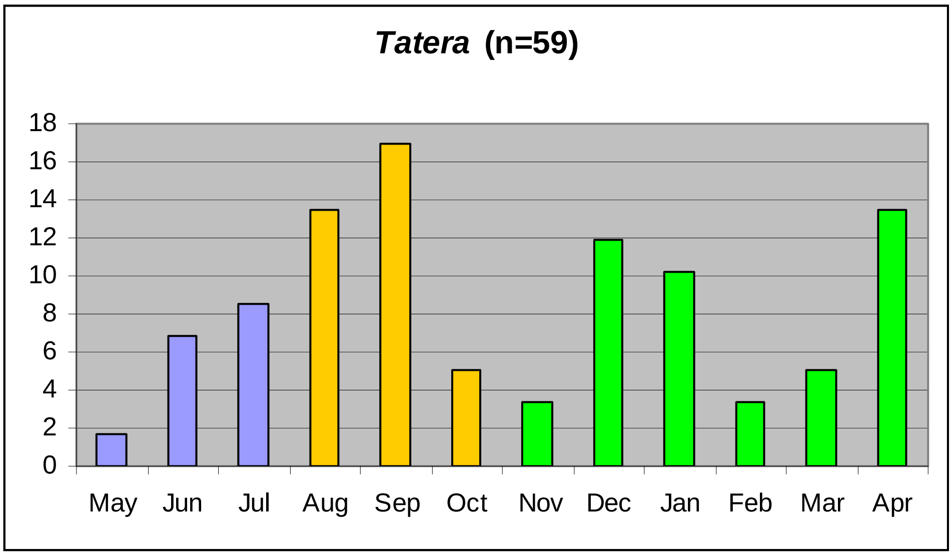


Fig. 44: Changes in abundance of the gerbils (or in the preference of the Barn Owl for it) in the two years study period. x-axis = months, y-axis proportion of gerbils in pellets (in per cent), the whole year's capture of rats being 100%. Seasons are marked in colour: rainy, cold dry, hot dry.

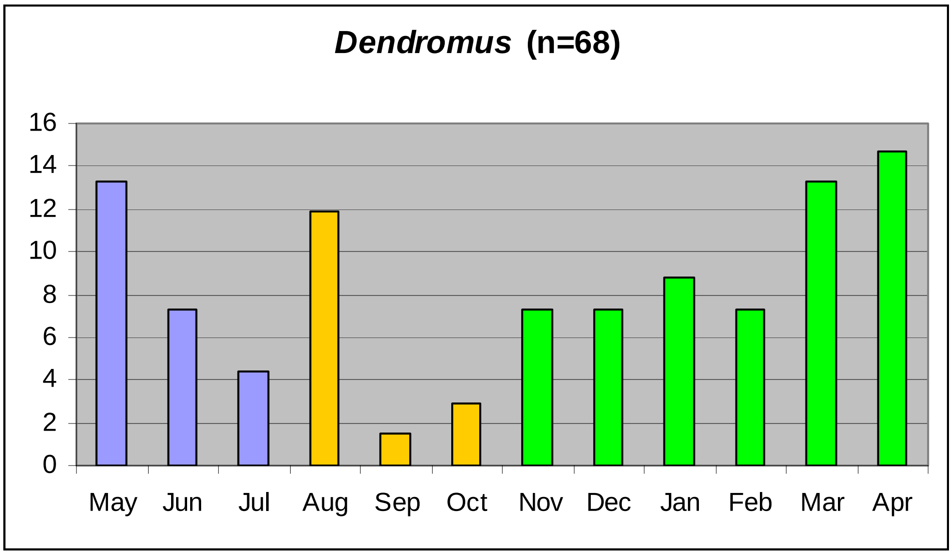


Fig. 45: Changes in abundance of the Climbing Mouse (or in the preference of the Barn Owl for it) in the two years study period. x-axis = months, y-axis proportion of mice in pellets (in per cent), the whole year's capture of rats being 100%. Seasons are marked in colour: rainy, cold dry, hot dry.

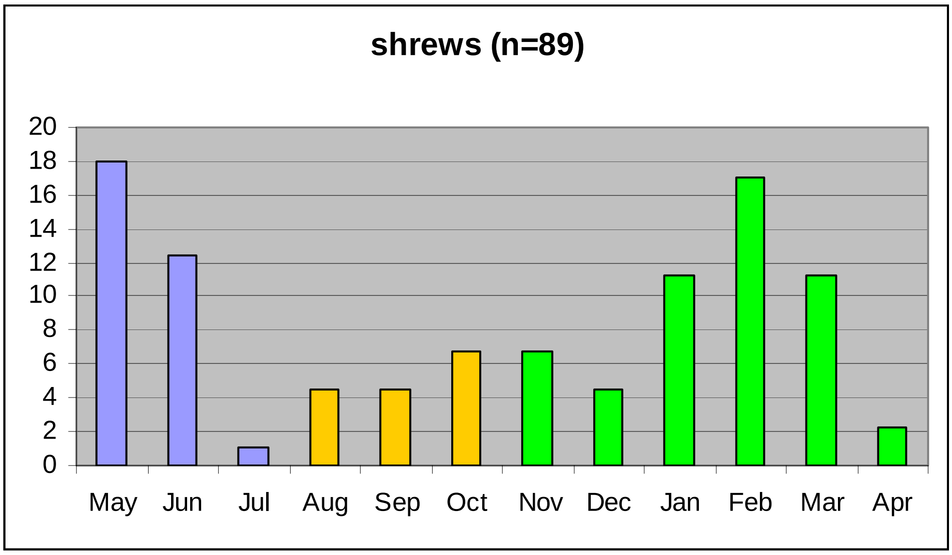


Fig. 46: Changes in abundance of the shrews (or in the preference of the Barn Owl for it) in the two years study period. x-axis = months, y-axis proportion of shrews in pellets (in per cent), the whole year's capture of rats being 100%. Seasons are marked in colour: rainy, cold dry, hot dry.

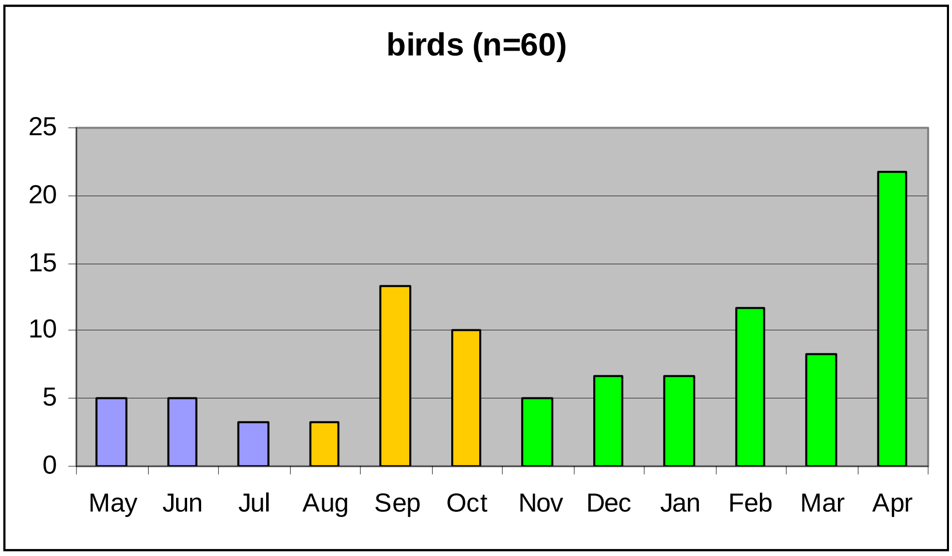


Fig. 47: Changes in abundance of the Pygmy Mouse (or in the preference of the Barn Owl for it) in the two years study period. x-axis = months, y-axis proportion of mice in pellets (in per cent), the whole year's capture of rats being 100%. Seasons are marked in colour: rainy, cold dry, hot dry.

Table 13: Summarized data on food consumption of two Barn Owls gained from the pellet analysis from two localities and in the course of two years: Namboard 2002, Namboard 2003, Namboard summarized, and Mansansa Forest.

	Feb	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Mean**	**SD**
food intake /month (g)	2060	1634	1881	1803	1162	1666	1651	1430	2047	1195	1267	1208	1,584	328
	1388	1823	1447	1390	1172	1037	2147	2120	1903	1335	1547	1645	1,579	356
	1724	**1728**	**1664**	**1596**	**1167**	**1351**	**1899**	**1775**	**1975**	**1265**	**1407**	**1426**	**1.582**	**335**
					1416	1865	1651					2052		
food intake /day (g)	74	53	63	58	39	54	53	48	66	68	41	39	55	12
	50	59	48	45	39	33	53	71	61	44	50	53	51	10
	62	**56**	**55**	**51**	**39**	**43**	**53**	**59**	**63**	**56**	**45**	**46**	**53**	**11**
					47	60	53					66		
number of catches /month	50	43	43	46	30	35	45	43	57	27	30	30	40	9
	40	43	42	34	32	47	43	39	38	31	29	35	38	6
	45	**43**	**43**	**40**	**31**	**41**	**44**	**41**	**48**	**29**	**30**	**33**	**39**	**8**
					31	38	33					33		
prey mass /catch (g)	41	38	44	39	39	48	37	33	36	44	42	40	40	4
	35	42	34	41	37	22	50	54	50	43	53	47	42	9
	38	**40**	**39**	**40**	**38**	**35**	**43**	**43**	**43**	**43**	**47**	**43**	**41**	**7**
					46	49	38					62		

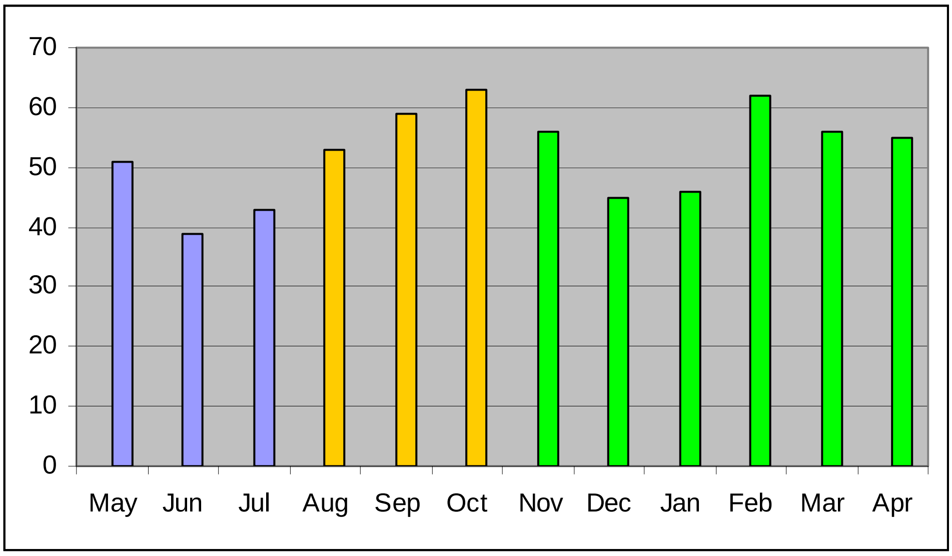


Fig. 48: Food intake (g) per day (vertebrate prey, mean for two years) of one Barn Owl from Namboard. Seasons are marked in colour: rainy, cold dry, hot dry.

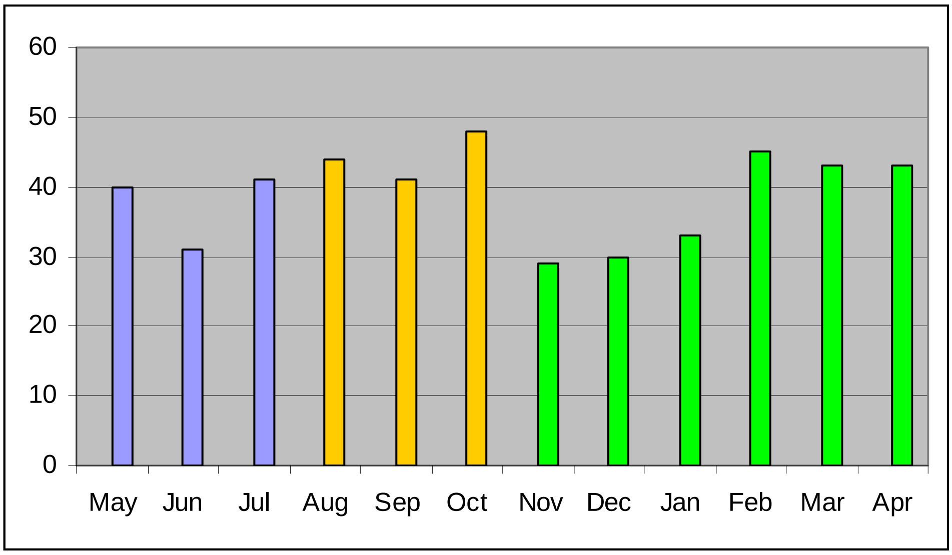


Fig. 49: Number of catches per day (vertebrate prey, mean for two years) of one Barn Owl from Namboard. Seasons are marked in colour: rainy, cold dry, hot dry.

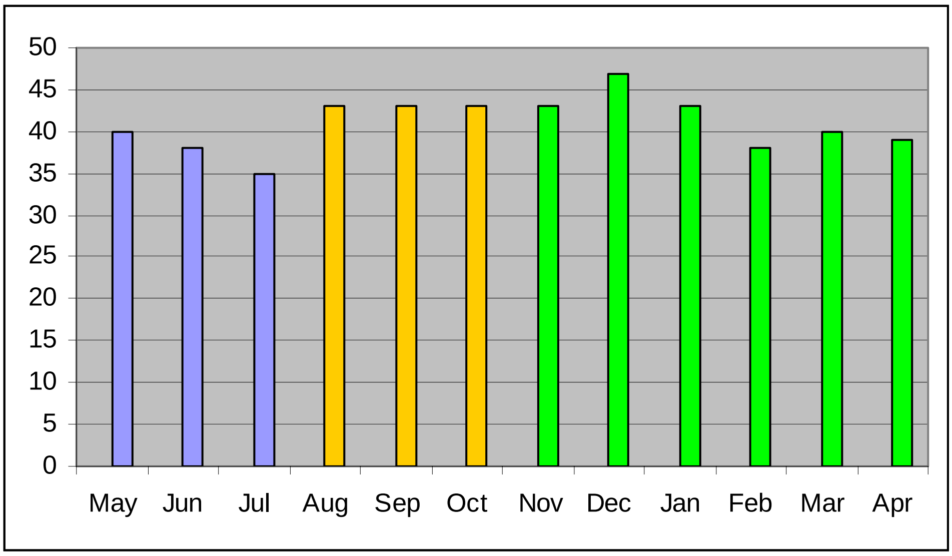


Fig. 50: Average body mass of a single vertebrate prey (mean for two years) of one Barn Owl from Namboard. Seasons are marked in colour: rainy, cold dry, hot dry.

Rodent Trapping

Trapping action

Introduction

To get specimens for comparative quantitative and qualitative data on rodents in the study area, composition of the rodent community, the abundance of particular species, population structure and dynamics , and last but not least to obtain voucher specimens for rodent species, a trapping study was started recently. This study is in progress and in process of standardisation. Also, not all the specimens could be identified so far. Therefore the study is only shortly and preliminarily presented here.

Methods

Trapping took place at the localities Namboard and Mansansa Forest Reserve described above, in December 2003, January and February 2004.

For trapping traditional live trap was used. This is a very common trap, which even me as a small boy used to make when going mice hunting in cultivated fields. I tried to check with our local museum to find out about the inventor of this trap and found that there was nothing mentioned and to date there is nothing to stake who invented this trap. It can therefore only be attributed as appropriate technology employed by field rodent hunters.

Fig. 51: Traditional can live trap

MATERIALS

1. Cans (completely open on one end)
2. String
3. Stick
4. Soft wire
5. Bait (usually grain or nuts)
6. Lids (slightly larger to cover open end of can)

Fig. 52: Making the trap.

The size of the can and the choice of bait will usually determine the size and type of rodent that can be trapped.

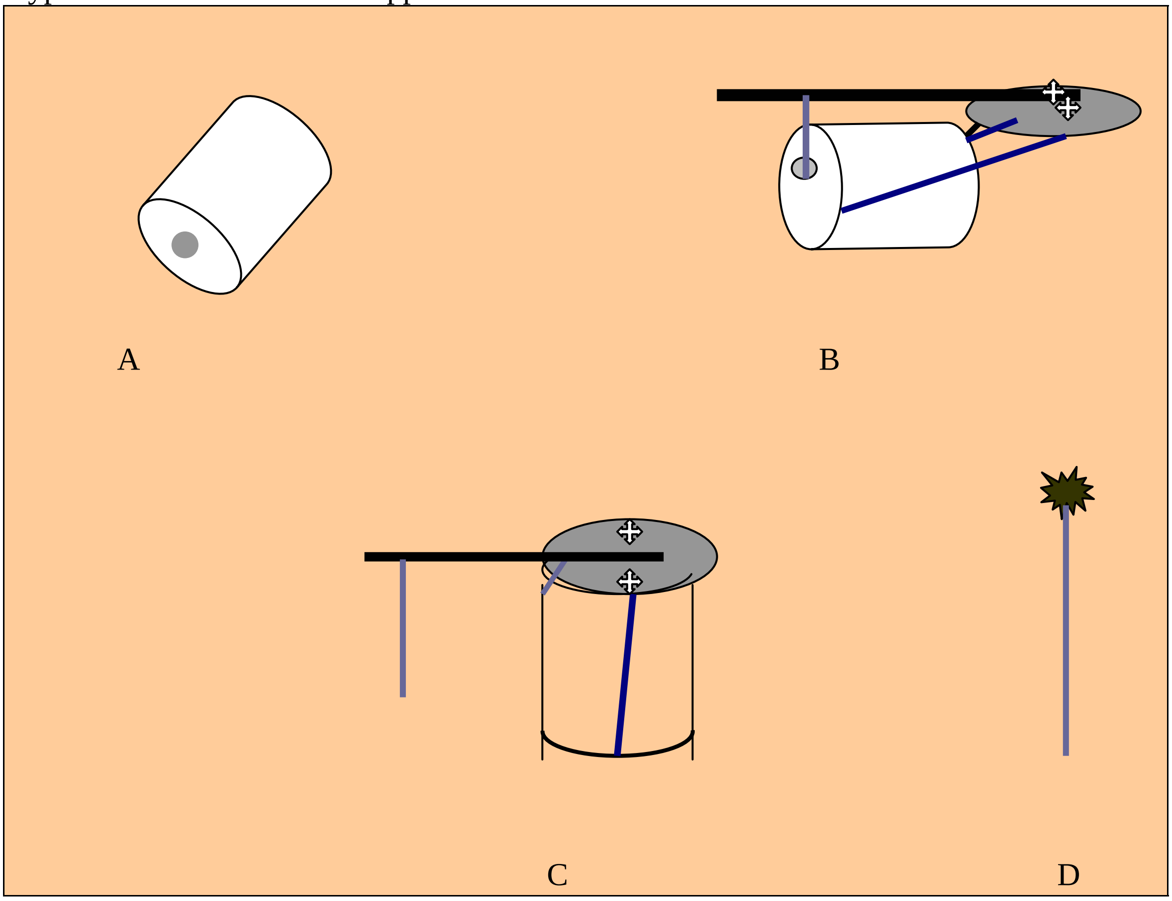


Fig. 53: Making the trap
A: a can with a hole made at the bottom; B: a complete assembled trap ready with bait for setting in the field; C: a triggered trap; D: a bait with string ready for inserting in the trap.

The following is a description of the principle of how the rodent trap works.

The mechanism is such that the string and bait form the trigger of the trap. The stick serves as the lever to hold the lid open and the rubber bands under tension, so that when the trap is triggered, the rubber bands lose their tension and there by shut the lid. The trapped animals remain in the can because a lot of energy is required to open the lid since any action to try to open means putting the rubber bands to tension.

The string with the bait is passed from the inside of the can through the hole. The lip is then opened as in fig. 2, and the string tied around the stick so as to hold the rubber bands under tension, as well as keeping the lid to the trap open. The prey would then walk into the can, during the process of eating on the bait; the string is loosed or cut. The stick that was held in the open position of the lid will snap and voila the prey is trapped in the can.

As bait I used corn (maize) grains. The first trials with roasted groundnuts were not successful.

The animals were sacrificed with ether overdosis and preserved in 70% ethanol.

Results and Discussion

Results are summarized in the Table 14.

Namboard	**Dec. 03**	**Jan. 04**	**Feb. 04**	**sum**
trapnights	371	395	229	**995**
traps triggered	97	169	77	**343**
animals caught	46	96	44	**186**

Mansansa	**Dec. 03**	**Jan. 04**	**Feb. 04**	**sum**
trapnights	326	640	220	**1186**
traps triggered	183	401	36	**620**
animals caught	176	191	28	**395**

It is evident that trapping efficiency in the forest (33.3%) was much higher than in the Namboard area (18.7%). This can be attributed to many cats in the area. High rains have reduced the trapping success in Mansansa in February. Generally, the reliability and efficacy of traps seems quite high and is satisfying. The caught animals involved many pygmy mice as well as large gerbils.

About 50 % of caught animals in both areas were *Mastomys natalensis*, about 20% (more in Mansansa, less in Namboard) were *Tatera* sp., about 10 % were *Mus minutoides*; about 10% were *Acomys spinosissimus* (Spine Mice), which were - apparently due to their diurnal habits - very rarely represented in owl pellets. Furthermore *Dasymys*, *Saccostomus* and *Steatomys* were identified in the sample. Some further specimens were not identified so far. There were no shrews (apparently due to specific rodent bait) in traps. Generally, pellets reflect (apart from relative, but not absolute, absence of Spiny Mice) very well the composition of the small mammalian community in both, qualitative and quantitative aspects. Climbing Mice (*Dendromus*), which were quite common in pellets were not trapped.

This trapping study, though not yet completed, confirms the importance of the study of owl pellets

Giant mole-rat (*Coetomys mechowi*)

The late Mr. Kalaka (Ndola), one of the most experienced mole-rat hunters
(here with his giant mole-rats)
whom I am obliged for much of the information and help in the field
may his soul rest in peace.

Introduction

The endemic African rodent family Bathyergidae (African mole-rats) represents an ancient (earliest Miocene) radiation of truly subterranean mammals. These mole-rats are confined to self-constructed underground burrow systems where they live, reproduce and find their food. They are morphologically, physiologically and behaviourally highly specialised and adapted for their subterranean way of life. They have cylindrical body with short limbs and short tails, prominent incisors which are used for digging (biting off soil). They tend to heterothermy, have relatively low metabolic rates and are unable to synthesise vitamin D. They have miniaturised eyes and are blind, they have no ear pinna and cannot localise sounds and their hearing is restricted to a low frequency range. They have well developed spatial memory and use magnetic compass for orientation. The family includes six genera of mole-rats exhibiting different social behaviour: three genera (*Bathyergus*, *Georychus* and *Heliophobius*) comprise animals of solitary habits, three genera, *Heterocephalus*, ***Coetomys**** and *Cryptomys* are highly social. Particularly the unique social biology (eusociality) of the naked mole-rat (*Heterocephalus glaber*) and the social mole-rat (*Coetomys* spp.) has triggered the interest in the family, with the consequence that the three named genera rank currently to the most thoroughly studied and best known African rodents. Various aspects of morphology, physiology, biology and evolution of African mole-rats (and other subterranean mammals) were reviewed in five book monographs published within the last decade (Nevo and Reig 1990; Sherman et al. 1991; Nevo 1999; Bennett and Faulkes 2000; Lacey et al. 2000).

Shortly after H. Burda and me became interested in mole-rats in Zambia and had initiated taxonomic studies of these subjects (Macholan et al. 1993; Filippucci et al. 1994, 1997) it became apparent that there was high species diversity in Zambia. These studies resulted in description of several new species or reconfirmation of the species status (Macholan et al. 1998; Burda et al. 1999; Kawalika et al. 2001; Burda et al. submitted). The research has culminated with three recent papers on genetic (Faulkes et al. 2004; Ingram et al. 2004) and karyotypic (Van Daele 2004) diversification of mole-rats. Particularly the papers by Ingram et al. (2004) and Van Daele et al. (2004) demonstrated and discussed extraordinary speciation rate of mole-rats in the Zambezian region, and especially in Zambia. It would be redundant to recapitulate here what has been written in these papers.

Coetomys mole-rats are remarkably polymorphic (Rosevear 1969, Ansell 1978; Honeycutt et al. 1991; Burda et al. 1999), so that it is not possible to provide unambiguous diagnostic morphological traits or measurements. Whereas most of the mole-rat species are morphologically rather similar, and can be diagnosed on the base of their karyotypes, genetic and allozyme differences, and only subtle morphological differences are apparent, one species is markedly different: the giant mole-rat, *Coetomys mechowi.*

When I moved from Lusaka to Ndola in 1988, my attention was drawn to big mole-hills (Fig. 54) and street vendors selling giant mole-rats for food (cf., Fig. 55). These mole-rats, common in Copperbelt Province, but unknown in Lusaka and South eastern Zambia, where I came from, are guinea-pig-sized and hence much bigger than laboratory hamster-sized Ansell's mole-rats from Lusaka I used to know.

***Coetomys** is a new genus recently emancipated from the genus *Cryptomys* and comprising species of "*Cryptomys*" from out of South Africa (Ingram et al. 2004).

Fig. 54: Mounds done by giant mole-rats in (what used to be) a sweet potato field

Fig. 55: Street vendors selling live giant mole-rats. (On the picture my wife Doyen, Simone Lange, and myself.) (Photo: Regina Wegner)

In the present thesis I summarise the studies on the giant mole-rat performed by myself and in co-operation during the last 15 years, and partly already published as original research peer-reviewed papers in international scientific journals. It should be pointed out that until the publication of our first report (Burda and Kawalika 1993) the biology of giant mole-rats was virtually unknown. Kingdon (1974) encompassed all the available knowledge in one sentence: "*Cryptomys mechowi* is a little known form of reportedly solitary habits". As we have shown the assumption about solitariness of giant mole-rats was fully wrong…

Among numerous *Coetomys* species, the giant mole-rat (*C. mechowi*) is distinguished because of large body size, social living, and distribution in mesic areas of the subequatorial central Africa (Democratic Republic of Congo, Angola and Zambia; Honeycutt et al. 1991). This species may help to elucidate the evolution and adaptive significance of eusociality in African mole-rats (Burda and Kawalika 1993), a question which is not yet solved (Burda et al. 2000).

Whereas the taxonomy (Faulkes et al. 1997; Filippucci et al. 1997; Macholan et al. 1993; Faulkes et al. 2004; Ingram et al. 2004), parasitology (Scharff et al. 1996, 1997), reproduction (Bennett and Aguilar 1995; Bennett et al. 2000; Burda and Kawalika 1993; Scharff et al. 1999), ethology in captive animals (Credner et al., 1997; Wallace and Bennett, 1998; Heth et al. 2002), neuroanatomy (Lindenlaub and Burda 1994; Peichl et al. 2004) and physiology (Bennett et al. 1994) of *C. mechowi*, have been studied; information on free living colonies is still meagre and anecdotal (Burda and Kawalika 1993; Hill 1941, Scharff et al. 2001).

Taxonomy of the giant mole-rat

Giant mole-rats are not only morphologically (body size) but also karyologically (Macholan et al. 1993), though less allozymatically (Filippucci et al. 1997), distinct from the smaller forms of *Coetomys*.

Karyotyping technique

I have delivered specimens for the karyological study (Macholan et al. 1993) and for molecular-genetic analyses (Ingram et al. 2004). I myself have prepared standard chromosome specimens from three giant mole-rats (Ndola- Chichele). I myself have not directly participated in banding of chromosomes or in genetic studies.

Protocol for preparing karyotypes from bone marrow

(modified after Ford and Hamerton 1956)

1. Intraperitoneal injection of 0.03 % colchicine (0.3 g in 1 l of distilled water) solution in dose 1ml /100g body weight.
2. After 30 min. the animal is sacrificed under final ether narcosis, decapitated and long bones (femur and tibia) are removed. Epiphyses are cut off and bone marrow is rinsed out with a syringe with 2 x 1 ml of 0.075 % KCl (5.59 g KCl: 1 l H_2O). Bone marrow is mixed with the Pasteur pipette into the solution.
3. Hypotonisation for 10 minutes in KCl solution at a body temperature (37° C).
4. Centrifugation for 4 min. in 800-1,000 rpm (using a hand centrifuge, this means some 80 cycles per minute)
5. Discard the supernatant and add carefully approximately 2 ml of Carnoy's fixative
   (= methanol : glacial acetic acid = 3 : 1). Also rinse the rim.
6. After 5 min. change carefully the fixative, leaving the cell sediment. The fixative is changed again after 20 min., and then again after 5 min.
7. in the last fixative, resuspend the pellet with Pasteur pipette and drop onto slides from the height of 20-50 cm. Draw the slide immediately through the flame of sootless dry-spirit and leave to dry over night.
8. Staining in 2% Giemsa solution for 30 min.

We have published the results of our study of two giant mole-rats from Ndola already several years ago (Macholan et al. 1993). Our subsequent studies (unpublished) of animals from Ndola-Chichele and from Chibale as well as the study of Aguilar (personal communication) of animals from Chingola have been fully consistent with the earlier findings. The diploid chromosomal set of the giant mole-rat consisted in all the cases of 40 biarmed chromosomes, of which one pair of small chromosomes was submetacentric to subtelocentric. The sex chromosomes were unusually large, Y chromosome being somewhat smaller than X. Correspondingly the fundamental number of autosomes was 74-76, that of a female full karyotype 78-80 (Fig. 56).

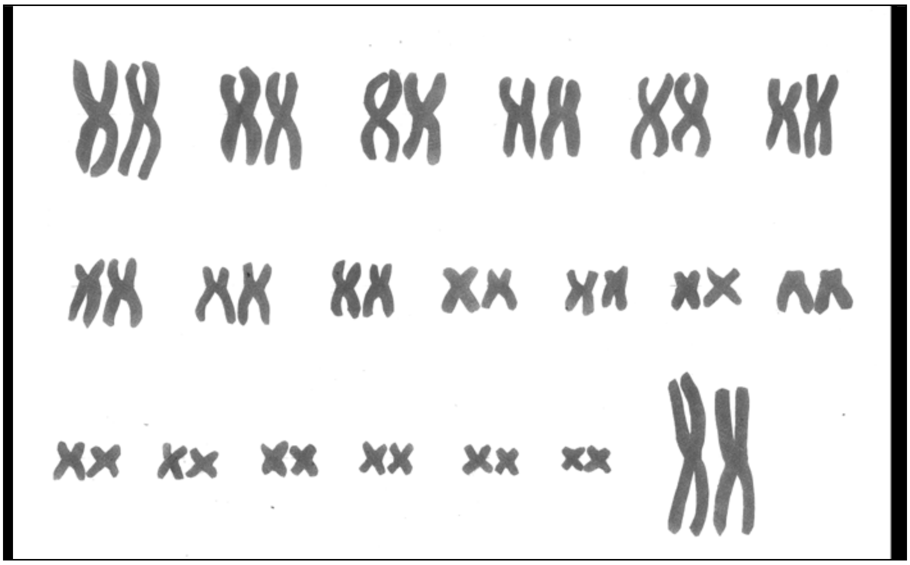


Fig. 56: Karyotype of *Coetomys mechowi*

Discussion

Thomas (1906) described *Cryptomys mellandi* from Mpika, reference grid 1131-C, which was later considered a subspecies or synonym of the giant mole-rat, *C. mechowi* (cf., Ansell, 1978). We have collected *C. mechowi* in the Copperbelt Province (reference grid 1228 and 1328) and near Chibale (Central Province, on the road between Mkushi and Serenje; 1330-C1; cf., Scharff et al. 2001). Mole-rats from these populations seemed to differ in body size (those from Chibale being smaller), yet karyologically (Scharff 2001) and genetically (Ingram et al. 2004) could be attributed to one and the same species. It has still to be checked whether "our" giant mole-rats and *C. (mechowi) mellandi* are taxonomically identical.

All the species of *Coetomys* could be so far diagnosed on the base of their distinct karyotypes. Validity of this diagnostic trait was confirmed by genetic analyses. Among all the karyotypes of *Coetomy*s known to date (cf., Table 15), *C. mechowi* is quite distinct through the lowest known diploid number (2n=40) and a high proportion of biarmed chromosomes in the karyotype. The higher proportion of biarmed chromosomes seems to be related to the more ancestral position (earlier radiation) in the phylogenetic tree (cf., Ingram et al. 2004). Indeed, we may assume that chromosomal speciation in *Coetomys* was characterized by Robertsonian fission rather than fusion. Considering this feature as reflecting the age of divergence, we may speculate that *C. mechowi* (with the majority of biarmed chromosomes in its karyotype) represents the most basal (most ancient) lineage (radiation) of *Coetomys* mole-rats, whereas *C. anselli* (exhibiting predominantly acrocentric chromosomes in its karyotype) represents the youngest radiation (cf. Table 16). This conclusion is fully consistent with molecular-genetic findings (Ingram et al. 2004).

Table 15. Known karyotypes of *Coetomys* and *Cryptomys* species. Zambian species are marked.

species	Occurrence	2n	M/2n	M/SM	A/ST	X	Y	a NF	NF	Authors
C. mechowi	ZM: Ndola, Chibale	40	90	18	1	M/SM	M/SM	74	78	Macholan et al. '93
DONGO	ZM: Dongo	42	50	17	3	M/SM	dot	74	78	VanDaele et al. '04
SALUJINGA	ZM: Salujinga	44	73	16	6				76	VanDaele et al. '04
LOCHINVAR	ZM: Lochinvar	45	73	16,5	6				78	VanDaele et al. '04
C. whytei	MW: Nyika	46	65	15	8				76	Burda et al. '04
C. amatus	ZM: Chibale	50	88	22	2	M	A	92	96	Macholan et al. '98
CHOMA	ZM: Kalomo	50	48	12	12	M	dot	72	76	Aguilar: unpubl..
CHINYINGI	ZM: Chinyingi	52	65	17	9				86	VanDaele et al. '04
C. hottentotus	SA: Transvaal	54	92	25	1	SM	?	102	106	Nevo et al. '86
C. natalensis	SA:-Natal	54	89	24	2	SM	A	100	104	Nevo et al. '86
C. darlingi	ZW: Goromonzi	54	52	14	12	A	M	80	82	Aguilar '93
MONZE	ZM (Monze)	54	44	12	15				78	VanDaele et al. '04
L/STONE	ZM: L/stone, Sekute	56	39	11	16	M	dot	76	80	VanDaele et al. '04
WATOPA	ZM: Watopa	56	32	9	18	M	dot	72	76	VanDaele et al. `04
C. bocagei	AN: Lubango	58	62	18	10	M	SM	92	96	Aguilar: unpubl.
SENANGA	ZM: Senanga	58	45	13	15	M	dot	82	86	VanDaele et al. '04
C. kafuensis	ZM: Itezhi-Tezhi	58	38	11	17	M	dot	78	82	Burda et al. '99
C. micklemi	ZM: Kataba	60	37	11	18	M	dot	80	84	VanDaele et al. '04
KASAMA	ZM (Kasama)	64	34	11	21				86	Kawalika et al. '01
C. foxi	Cameroon	66	79	26	6	SM	M	116	120	Williams et al. '83
C. anselli	ZM: Lusaka	68	15	5	28	M	A	76	80	Burda et al. '99
C. damarensis	ZM: West Zambezi	78	54	21	17	A	dot	118	122	VanDaele et al. '04
C. damarensis	NA: Dordabis	78	20	8	30	M	SM	92	96	Nevo et al. '86
SIOMA-NGWEZI	ZM: Sioma-Ngwezi	78								VanDaele et al. '04

2n = diploid chromosome number, M = metacentric, SM = submetacentric, A = acrocentric, ST = subtelocentric chromosomes, NF = fundamental numbers (of a female karyotype), a = autosomes, M/2n = proportion (in %) of biarmed chromosomes in the karyotype.

Table 16. Species of mole-rats (genera *Coetomys* and *Cryptomys*) ranked according to the proportion (in per cent) of biarmed chromosomes in their respective karyotypes (cf., M/2n in Table 1). *Coetomys mechowi* is marked.

M/2n	species (karyotype)
91-100	***C. hottentotus***
81-90	***C. mechowi*, *C. natalensis*, *C. amatus*,**
71-80	***C. foxi*, Salujinga, Lochinvar**
61-70	***C. whytei*, Chinyingi, *C. bocagei***
51-60	***C. damarensis* (ZM), *C. darlingi***
41-50	**Dongo, Choma, Senanga, Monze**
31-40	**Livingstone, *C. kafuensis*, *C. micklemi*, Kasama, Watopa**
21-30	
11-20	***C. damarensis* (NA), *C. anselli***

Morphology of the giant mole-rats

Pelage colour

Giant mole-rats are brownish, pups and juveniles being black to dark grey to dark brown, and with ageing they become subsequently paler. Old adults are golden ochre. The white head-spot is missing in most animals. In some few individuals (about one per cent) a whitish patch is apparent on the head. Giant mole-rats have a dark reddish moustache around the mouth (Fig. 57). Although this looks like an artefact - staining by some kind of food, all animals(i.e. irrespective of the season, region, and kind of available food) display this trait.

Fig. 57: Giant mole-rat displaying the rusty "moustache" (arrow).

Discussion

It is of interest that both *Coetomys mechowi* and *C. anselli* (cf. Burda 1989) exhibit the same colour age-related polymorphism. Since mole-rats are blind and live in darkness of their burrows it is doubtful that the colour polymorphism could be of adaptive significance. Also it should be noted at this point (see also below) that in both species mole-rats occur in soils of different type and colours, yet there is no apparent difference in their pelage colour which could be correlated with soil coloration (contrary to the situation in blind mole-rats, *Spalax ehrenbergi*, from Israel - cf., Heth et al. 1988). Although other authors studying other species of *Coetomys* do not mention age polymorphism, it is probable that the change of pelage colour in captive *C. hottentotus* as described by Poduschka and Nopp (1978) reflected actually ageing of those individuals.

White head spot is typical of *C. anselli*, *C. kafuensis*, *C. damarensis*, *C. micklem*i and other *Coetomys* species from southern and western Zambia (southwards of 15th latitude) (cf., Burda et al. 1999; Van Daele et al. 2004) but is missing in most *C. mechowi* and in the examined Kasama mole-rats, *C. amatus*, and *C. whytei* (cf., Macholan et al. 1998; Kawalika et al. 2001, Burda et al. 2004). It may be of significance that the headspots were small or missing also in “small” mole-rats collected by Paul Van Daele in the North-Western province (Van Daele et al. 2004). Even in species where it is present it is variable in size and shape. Lovegrove et al. (1993) speculated about the meaning of the white head spot and suggested that, being actually an unpigmented part of skin it may facilitate penetration of light to the pineal organ and thus be involved in photoperception and control of photoperiodicity. However, chronobiological data for *Cryptomys* and *Coetomy*s are very ambivalent and large polymorphism in the size and shape of the white head spot, even in its very presence, weaken the idea of its functional significance. The hypothesis of Burda (personal communication) should be tested that there is a latitude gradient of in the average size of the headspot, with a trend to increase southwards and correlating thus with a prolonging photoperiod.

Body size and mass

Altogether 69 mole-rats were sexed and weighed immediately after capture. Weight of adult males was on average 380 ± 95 (250-600; n = 20) g, the adult non-pregnant females weighed 260 ± 35 (range 200-355; n = 20) g. Weight between the sexes differed significantly ($p < 0.05$; $t = 338$). In Kabwe, in April 2001, I saw a giant mole-rat displayed by hunters the weight of which I assessed to be at least 800 g. On the other hand I have evidenced adult giant mole-rats from Chibale and Ndola-Chichele which (though being of the typical giant mole-rat's karyotype (see above) were rather small (about 200 g) and even after five years in captivity have not grown up (H. Burda, personal communication).

Discussion

As in other rodents, *Coetomys* is characterised by indeterminate growth. However, the growth is not continuous and its rate is subjected to accelerations and periods of stasis depending on diverse factors (reproductive and social status, age, and unknown factors). Due to these facts, the generally slow growth rate, and remarkable longevity (Burda, Dammann, personal communication, the body size and form and consequently also cranial proportions are subject to progressive and regressive changes (i.e. they fluctuate) during individual life (cf. Begall and Burda 1998). It is therefore difficult to calculate the average weight of adult animals because it is not clear which weight limit should be set as the lowest weight of adult animals. The limit I have set is arbitrary but it is based on long-term observation (Scharff et al. 1999) of the lowest body mass of breeding animals in captivity. There is significant sexual dimorphism in body mass (adult males being larger than adult females) in *C. mechowi*. This fact can be an evidence for intrasexual competition, specifically for the existence of behavioural suppression, hierarchy among males. I have not studied this aspect but there is some indication that this could be really the case (Burda 1995 and personal communication).

Distinctly larger body size in *Cryptomys mechowi* cannot be explained easily: according to the genetic analysis (Faulkes et al. 2004; Ingram et al. 2004), *C. mechowi* represents a basal lineage of the genus. Consequently, the larger body size could be considered an ancestral trait. I shall discuss it still in the chapter on ecological aspects.

Skull

Reproductive males have broad heads due to well developed, massive chewing muscles. The examined skulls (n=10) displayed large, thin-walled, elliptical infraorbital foramen (Fig. 58).

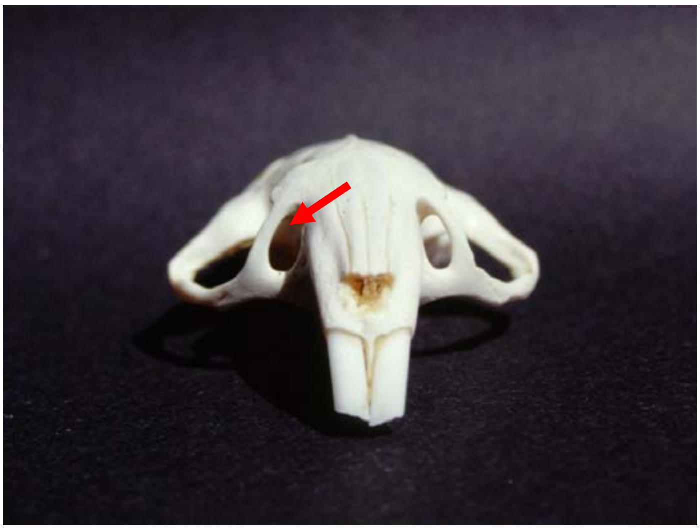


Fig. 58: Frontal view of a skull of a giant mole-rat displaying the infraorbital foramen (arrow).

Discussion

Honeycutt et al. (1991) considered thick-walled outer foramina to be characteristic of the *C. damarensis*, *C. mechowi* and *C. bocagei* group (and west and central African species), while thin-walled foramina should characterise the *C. hottentotus* group. Consequently, *C. anselli* should be grouped with *C. damarensis* and *C. mechowi*, whereas *C. kafuensis* (cf., Burda et al. 1999) should be more related with *C. hottentotus*. However, the results of genetic studies (Faulkes et al. 2004; Ingram et al. 2004) and allozymic studies (Filippucci et al. 1994, 1997) do not support any relationship between *C. kafuensis* and *C. hottentotus*. Besides that, it should be noted that our specimens of *C. mechowi* from Ndola exhibit the thin-walled condition. In any case, it seems that the size and shape of the infraorbital foramen can be used as a species-diagnostic trait, while it is probably not useful as a correlate of phylogenetic relatedness.

Distribution of giant mole-rats: a case for cryptozoology?

At this point I want to make some additional notes on distribution and diversification of mole-rats in Zambia. Unfortunately, the area and limits of the distribution could not be established for any of the given *Coetomys* species in Zambia (and elsewhere). It remains also unclear whether there are hybrid zones between neighbouring species or not, it remains unclear whether the areas of distribution overlap at some places and whether some of the species occur sympatrically.

Indeed, even the map of distribution of the giant mole-rat published by Ansell (1978) (Fig. 59), i.e. a species of mole-rats which can be distinguished from other species by its size, needs revision. Ansell himself admits that the record from Malawi is questionable. Also, no giant mole-rats were captured during recent rather intensive mole-rat collecting in the Southern, Western and North western Province (i.e., the strip between the Zambezi and the Kafue rivers) (van Daele et al. 2004).

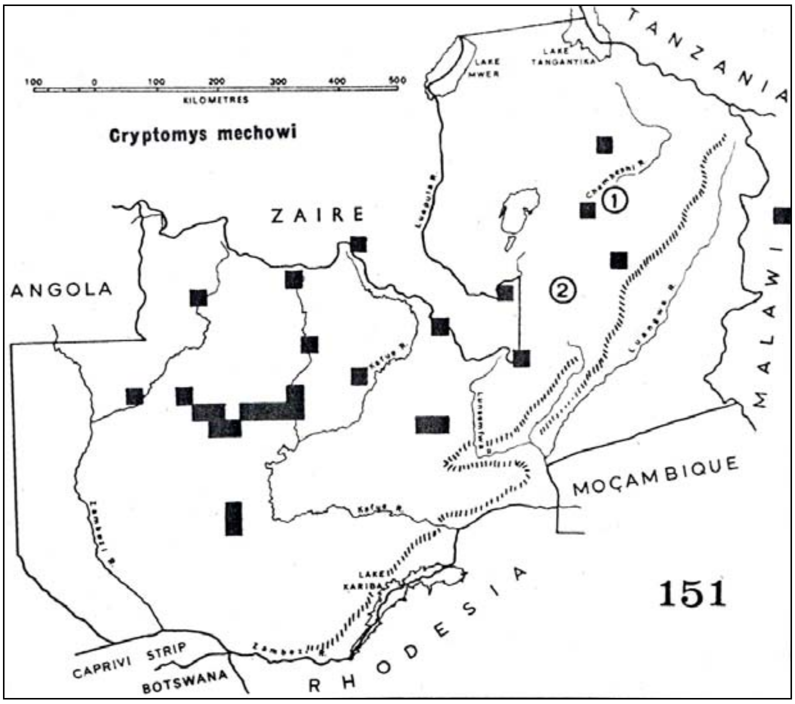


Fig. 59: Map of distribution of the giant mole-rat (*C. mechowi*) (Ansell 1978).

However, it should be of interest to note that in Kabwe as well as in Kasama I have been assured by local hunters that there live both, small and giant mole-rats sympatrically. The locals distinguish both species even by name: kakoko and mfuko, respectively. They claimed that even a "super-giant mole-rat" occurs in the area. Similarly, in Chongwe, two types of mole-rats (giant and common) were reported. In Chibale, the sympatric occurrence of *C. amatus* and *C. mechowi* could be proved (Scharff 1998, and own unpublished observations). In Ndola (Chichele) I have captured medium-sized mole-rats which also do not grow in captivity (Burda personal communication), yet subsequent karyological study revealed a karyotype typical for *C. mechowi*. It should be noted that in this locality, occurrence of two distinct forms was indicated also by parameters of the burrow system. Thus, I have found at one site (in early June 2000) within an area of 50x25 m 225 mounds and tunnels having 75-110 mm in diameter, whereas just about 100 m from this sector there were tunnels which ranged from 50 mm to 75 mm in diameter and there were only about 60 mounds within the same size area. There is no doubt that further field studies are needed to verify or falsify the claims of local hunters and to answer the points raised in this section.

It may be of interest to record here also my experience from Kasama. Interviewing of several hunters lead to the assumption that there are four types of mole-rats in the area: a. common (small) mole-rats; b. giant mole-rats; c. multi-coloured giant mole-rats; d. white super giant mole-rats. The super giant mole-rats are about the size of small puppies which puts them above 800g. This was evident from one animal already prepared and cooked in a pot. (Interestingly super-giant mole-rats are recorded also from the Kabwe area.). The hunter (in Bwembya village) revealed that the animal had a white coat which is usually the case for all the super giant animals he has ever caught. The common moles have been described by all hunters as always grey without the white head spot. The giant mole-rats are of two types, the normally colours (as we know from Ndola) and the multi-coloured which usually have a white belly and brown upper coloured body. The giant mole-rats (type b, c and d) can coexist in the same location whereas they cannot and never share their habitat with those of common mole-rats (type a). This was evident also from the size of the burrows inspected. The common mole-rats were more confined to lower altitudes with grey sandy soils whereas the giant were confined to brown soils. The closest distance observed between the habitat of the giant mole-rats and that of the common ones was 1 km and both localities were separated by the escarpment.

Local hunters clarified that the super giant mole-rat was less common in comparison to the giant mole-rat. They capture it only occasionally. Although one has to be sceptical towards some of the claims of hunters (see also the below chapter on interviewing the hunters) it is quite possible that there are still many interesting and surprising discoveries to be done.

Field ecology studies of the giant mole-rat

In this part of my thesis I shall focus on *Coetomys mechowi* which we have studied in the field. Much of the below presented information has been described and reviewed in two papers co-authored by myself: Burda and Kawalika (1993) and Scharff et al. (2001).

Subterranean rodents share many convergent adaptations, not only in their morphologies, but also in aspects of behavioural ecology. They also display divergent adaptations to different habitats (e.g., soil, vegetation, climates) and they are moulded by independent phylogenetic histories (Nevo 1979; 1999, Cook et al. 2000). To address the question, to what extent does *C. mechowi* diverge ecologically from "common" *Coetomys* mole-rats, and to provide ecological correlates for laboratory data, we examined seven free living colonies of giant mole-rats, including aspects of population structure, habitat, burrowing patterns, parasites and commensals.

Materials and Methods

Study areas

Study areas and habitats have been described above.

Soil analysis

At Dambo, Ndeke and Chichele, soils were analysed according to Carter (1993). Two vertical soil profiles (150 by 200 cm) were uncovered at Ndeke and Chichele (Fig. 60), and one at Dambo at burrows of giant mole-rats. Soils were classified (FAO 1988). Soil colour was determined according to colour charts of Munsell (1988). We examined also further parameters like air content (porosity) and bulk density. For description of the methods and results see Grütjen (1999) and Scharff et al. (2001).

Fig. 60: Field work (excavating a soil profile) in the Chichele Forest
(Photo Andreas Scharff or Oliver Grütjen)

Mole-rats

Altogether more than 120 giant mole-rats were captured under my auspices, of which 80 belonged to clearly determined colonies, the burrow systems of which were (at least partly) excavated and examined. A colony was considered to be caught completely if there was no digging activity (defined as occurrence of new mounds or plugging of opened burrows) for one week after the last catch.

Three of six burrow systems (Ndeke, Dambo1 and Dambo2) were partly excavated, mapped and measured. Complete excavation and mapping was not possible because of the extension, depth, and three-dimensional complexity of the burrow systems and the inaccessibility of some study sites. Food items from storage rooms, nesting material and invertebrates encountered in burrows were collected.

Altogether 69 mole-rats were sexed and weighed immediately after capture. Three age-classes were distinguished according to body weight: juvenile (< 50 g), subadult (50 g to 200 g in females and 50 g to 250 g in males) and adult (> 200 g in females, and > 250 g in males). This division was based on reproductive and growth data in captive animals (Scharff et al. 1999) with average weight at weaning reached at about 3 months and the weight at maturity (first successful breeding). Statistical comparisons were executed with the Mann-Whitney-U-test. Values are means and standard deviations (SD).

Immediately after capture, giant mole-rats were examined for macroscopic ectoparasites.

Capturing methods

The most common method employed by experienced mole-rat hunters is to open a burrow (the shallow "runway" tunnel) between two mole hills. The soil lying above the burrow is scraped away until about 2 cm is left roofing the burrow. Care is taken to ensure that the section of burrow used for capture of the mole-rat is straight and unbranched for at least 120 cm (check with a stick). Then two or three very small holes can be made with a sharp instrument (long nail, skewer) or a hard stick along the length of the almost exposed burrow section and fine straws are inserted through the holes into the burrow. Soil is piled around the base of these straws to seal the holes and prevent air leaks. Then wait patiently till one or more animals come to investigate and seal tunnel opening. The movement of the straws indicates the approach of a mole rat in the opening. When the straw nearest the opening moves, a spade, hoe or knife is driven smartly through the burrow behind the mole-rat, thereby cutting off its retreat into the main burrow system. With the spade still in the place, the captured animal is then carefully dug out. Mole-rats are sensitive to sounds and vibrations, they are very careful and suspicious and may block off the burrow deeper inside. When it happens, it becomes necessary to dig back and prepare a fresh section of the burrow. Alternatively (in soft soil), the hunters are digging following the tunnels down to the nest chamber. Nest chamber is usually under the biggest mound.

Keeping mole-rats

Mole-rats are robust animals and can be kept even in small metallic, glass or plastic containers (pail, barrel) on a layer of soil, sand, saw dust, tissue papers or dry grass (so that they can build a nest). They do not jump and do not climb. However, the cage should be sheltered, otherwise cats, dogs, etc. may steal the animals. The mole-rats can be fed on potatoes (sweet and Irish, cassava, carrots, and/or bulbs and roots of those local plant species which were found in their storage chambers). Sometimes they need few days to adapt to a new diet. They do not drink. The cage litter has to be changed regularly (particularly when soaked with urine and faeces). Note that animals from different colonies (burrow systems) put together in one container may fight severely. To avoid casualties, mole-rats originating from different burrow systems should be kept separately. Locality of origin, date and other circumstances of the capture were always recorded.

Results

Habitat

Within the vicinity of Ndola, burrow systems of giant mole-rats are frequent and found in cultivated fields, abandoned land turned to bushland, *dambos* and forests (pine forest as well as dense acacia forest), in a variety of soil types (cf., Fig. 61, 62).

Soil characteristics varied vertically as well as horizontally. Five soil types were determined: rhodic ferralsol, xanthic ferralsol (Ndeke); gleyic histosol (Dambo); ferralitic arenosol/entisol, lateritic ferralsol (Chichele). In all soils, the upper layer was grey or black ashes but the colour changed in profiles close to the surface. In most soils but in the lateritic ferralsol in the acacia forest, digging was rather easy throughout the year in upper horizons.

Burrow systems

The smallest burrow systems (encompassing 0.2 ha) occurred at the *dambo*. Burrow systems in the acacia forest were slightly larger. The burrow system of colony Ndeke covered an area of about 2.5 ha. In the forest and cultivated and uncultivated fields, burrow systems encompassed about 2 to 3 ha.

Fig. 61 (left): Opened burrow of giant mole-rats in a maize field

Fig. 62: (right, above): Mounds of giant mole-rats in a pine forest

In Chichele, in May/June 2000 I counted within an area of 50 x 25 m a total of 225 mounds. Interestingly, there was no sign of fresh burrowing activity indicating that burrowing (or rather building of mounds) may be a seasonal affair restricted during the dry season. (This could be tied in with the fact that burrowing was mainly when the soils were softer, thus conserving the much needed energy, other than spending it on very hard soils. Most of the burrowing was therefore during the times of dry spells of the rainy season and a month just after the rainy season when the soil was still soft.)

Burrow systems of *C. mechowi* consisted of superficial foraging tunnels, nests, food and defecation chambers, and deeper connecting tunnels. All burrow systems were sealed with mounds and additional "plugs". Diameter of most tunnels was 8 cm, whereas a few tunnels measured about 6 to 7 cm, some had up to 11 cm in diameter. Connecting tunnels between surface foraging burrows and deeper galleries had a mild slope and were straight or simply curved (i.e., not spiral). Maximum depth of burrows was about 200 cm. The main tunnel ("runway") was in one examined burrow system (Kangonga) 200 m long, 30 cm deep, mounds were 2-3 m apart. The level from the surface to the roof of the tunnel was minimum 5 cm.

Eight nests from four colonies were excavated in an average depth of 91 ± 41 (range 50-160) cm. Nests measured 20 to 40 cm in diameter and were 10-20 cm high. Nest materials weighed on average 238 ± 102 (range 100-430) g and consisted of dry grass, root fibres and/or plastic materials. Five nests had 4 and one nest had 3 openings which ramified close to the nest. Three food chambers in two burrow systems were exposed in an average depth of 67 ± 11 (60-80) cm in a horizontal distance of 111 ± 101 (range 20-220) cm to respective nests. Food chambers were similar in size to nests and contained a mixture of undetermined roots (85 g and 185 g, respectively), although one food chamber was filled exclusively with sweet potatoes (790 g). Four defecation chambers (colony Ndeke) were excavated with an average depth of 98 ± 46 (range 50-160) cm, and were stuffed with faecal pellets covered by fungi. They were the same depth as nests which were an average of 222 ± 131 (range 85-400) cm distant. All food and defecation chambers were short side branches of main tunnels. Interestingly, in Chichele area, nests seem to be located always in termite hills.

Colony size and structure

Colony sizes were 3, 4, >12, and in two cases >20. The two completely captured Dambo colonies consisted of 3 and 4 animals, each embodied a breeding pair with 1 and 2 young, respectively. Twelve animals were caught from colony Ndeke, nevertheless there was persisting digging activity at the end of the study. At Chichele, 40 mole-rats were caught within an area which was difficult to survey so some animals may have originated from a neighbouring colony. Continuing burrowing activity indicated the colony size exceeded forty (alternatively; size of two combined neighbouring colonies amounted to 40 which means that at least one single colony had to exceed 20). Animals from other localities may have originated from multiple colonies and hence the colony size could not be determined. According to experienced mole-rat hunters, colonies of 40 individuals are not exceptional and they may consist of up to sixty or more members.

Three age-classes were distinguished according to body weight: juvenile (< 50 g), subadult (50 g to 200 g in females and 50 g to 250 g in males) and adult (> 200 g in females, and > 250 g in males). This division was based on reproductive and growth data in captive animals (Scharff et al. 1999) with average weight at weaning reached at about 3 months and the weight at maturity (first successful breeding). In a sample of 72 mole-rats captured within two months (July-August) at the peak of the dry season) adults amounted to 53 %, subadults to 39 % and juveniles to 8%. In colonies with juveniles, only one youngster of the most recent litter was captured. Based on an extended range of weight of juveniles and smaller subadults (28-96 g; n = 12) it can be concluded that there is no seasonality of reproduction in free-living giant mole-rats. Concordantly, hunters reported to me that giant mole-rats breed throughout the year, whereas only one to two females are reproductive at one time, and the average litter size is two.

Sex ratio

The sex ratio among wild captured young (< 1 year, < 200-250 g in females and males respectively) giant mole-rats was male-biased (1.22, n=401) (Table 17). Among adults (> 1 year, heavier), proportion of males decreased (0.96, n=45). Taken wild-captured animals together, the overall sex ratio was equal (1.07).

Table 17. Sex ratio in wild-captured and captive-born giant mole-rats. male values and male-biased ratios are marked in blue, those of females are marked in pink.

	wild captured				captivity
		> 1 year	< 1 year		
	total	adult >250 g >200 g	subadult 50-250 g 50-200 g	juvenile 25-50 g	neonate < 20 g
total	85	45	31	9	1ß3
male	44	22	17	5	36
female	41	23	14	4	67
sex ratio	1.07	0.96	1.21	1.35	0.54
			1.22		

Reproduction

Breeding males of Dambo colonies were comparatively small (330 g and 255 g), and females weighed 290 g and 295 g. The heaviest animals of colony Ndeke were assumed to be the reproductive pair (male 560 g; female 290 g). At colony Chichele, one female with prominent teats was probably breeding. However, two additional adult females with perforated vaginas were captured. The biggest male of 30 animals weighed 300 g and we assumed that the breeding male was not captured.

Food

We found giant mole-rats in cultivated fields of sweet potatoes, Irish potatoes, cassava, groundnuts and corn. The plant diet in non-cultivated areas involved grass rhizomes (particularly in forests), roots, bulbs, and tubers of diverse weeds, shrubs, and trees. As food plants of *C. mechowi* we identified *Albizia* sp., *Aframomomum biauriculatum, Crossopteryx febrifuga, Lannea discolor*, *Mucuna* sp., *Pristachya* sp., *Pseudolachnostylis* sp., *Rhynchosia resinosa*, *Sissus* sp., *Steganotaenia* sp., *Syzygium guineense, Tacca* sp., and *Tephrosia* sp. I have found also three separate small storage chambers which contained animals prey (about 20 items in each: earthworms and larvae of a scarabeid beetle, probably *Anomala* sp.).

Surface activity

Interacting with several mole-rat hunters revealed that (giant) mole-rats use to be observed and picked up on the open ground, during daylight, away from their burrow system. This information has been confirmed even by non-hunters, and there are too numerous confirmations of people in the cultivated fields and indeed also in the non-cultivated fields. It appears that most cases of finding a mole-rat on the ground occur between March and May which in Zambia coincides with the end of rains and with the harvesting season. I found diverse items in the nests of mole-rats (rests of plastic bags, nylon stockings, green leaves, nuts) which had to be collected aboveground. Recently (in May 2004) I found an adult male mole-rat running frantically in a trench dug in my garden - apparently the animal had fallen inside shortly before. I inspected the trench very carefully and there were no indications of digging a burrow, which means that the animal had fallen from above and did not have time yet to make an own burrow and escape.

Ectoparasites and commensals

Although I have found also some helminthic endoparasites in giant mole-rats, these were determined and described by others (cf. papers by Scharff) and won't be discussed here. No macroscopic ectoparasites were found on giant mole-rats or in the nesting material, except a pup that had undetermined small red mites, which dispersed quickly. A variety of commensal insects were collected from the burrow systems of *C. mechowi*. In defecation chambers, small dungflies (family Sphaeroceridae, Diptera), carabid and staphylinid beetles were found. According to hunters, also toads and snakes (e.g. mole vipers, *Atractaspis*) can be encountered in burrows of giant mole-rats.

Discussion

Habitat selection

Coetomys mechowi occurs over a wide geographic range covering different climate regimes, particularly with respect to annual rain distribution. Little genetic divergence or geographic variation has been detected (Faulkes et al. 1997; Faulkes et al. 2004; Ingram et al. 2004) suggesting no or little specialisation across environmental conditions. This situation contrasts with high species diversification of "common" *Coetomys* in Zambia (Burda 2001; Ingram et al. 2004; Van Daele et al. 2004), Eurasian *Spalax* blind mole-rats (Nevo 1999) or *Ctenomys* in South America (Cook et al. 2000).

We found *C. mechowi* in a variety of soils in different habitats including open cultivated land, marshland, bushland, and dense forests.

The hardness and porosity of soils are factors which may influence physiology and burrowing activity (Arieli 1990; Lovegrove 1989, 1991; Vleck 1979) and indirectly distribution of underground dwellers. These factors varied in both vertical and horizontal dimensions. Although the foraging risk models of Vleck (1979) and Lovegrove (1989, 1991), and the aridity-food distribution hypothesis of sociality in mole-rats (Jarvis et al. 1998, Bennett and Faulkes 2000) are based partially on "soil hardness", the parameter itself has seldom been quantified. Because the costs of digging in fossorial mammals should increase with body mass (Lovegrove 1991; Vleck 1979), larger mole-rats are expected to dig rather shallow burrows and/or to avoid hard soils, an assumption supported by the finding that larger *Cryptomys damarensis* live in sandy soils while *Heterocephalus glaber* living in hard soils are small (Lovegrove 1989). The observation that *C. mechowi* - and in the same way also the solitary silvery mole-rat, *Heliophobius argneteocinereus*, (Sumbera et al. 2003, 2004) - dig in both soft and hard soils (and also in deep layers) challenge these and other burrowing models for subterranean mammals (Best 1973; Heth 1989; Nevo 1999; McNab 1999).

In conclusion, *C. mechowi* should be considered a habitat generalist based on its geographical and ecological distribution. Detailed time and space analyses of above-ground habitat structure, soil quality and microclimate in giant mole-rats and the other species of Bathyergidae are needed to identify factors determining their occurrence.

Burrow systems

The main structure of burrow systems of *C mechowi* was similar to other members of the genus as well as for other Bathyergidae (Hickman 1979, 1990; Jarvis and Bennett 1991; Nevo 1999, Bennett and Faulkes 2000, Sumbera et al. 2003) and consisted of nests, food chambers, defecation chambers, superficial foraging burrows and deeper connecting tunnels. While a long axial main runway as described in other subterranean rodents (Brett 1991; Heth 1989; Eloff 1951; Hickman 1979; Nevo 1999; Sumbera et al. 2003) was found in some burrow systems (Kangonga) it could not be identified in others (.e.g. Dumbo and Ndeke). However, the existing data are heterogeneous thus far and preclude generalisations, perhaps due to different sample techniques, sample sizes, or temporal and habitat variation across studies.

The nests of *C. mechowi* were comparatively deep (60-160 cm) with respect to most other species of the genus. Nests with several entrances (3-4 in *C. mechowi*) are common in social bathyergids (Davies and Jarvis 1986; Genelly 1965; Hickman 1979) while the solitary *Bathyergus suillus* has only one entrance (Davies and Jarvis 1986), whereas the solitary *Heliophobius argenteocinereus* has nests with two or three entrances (Sumbera et al. 2004). Most subterranean mammals (with the exception of some Talpidae and Bathyergidae) only have one entrance to their nest (Nevo 1999). There seems to be no correlation between depth of nests (and potential predation risk) and number of entrances in subterranean mammals. Number of entrances may affect ventilation under different microclimatic conditions, but this aspect has not been investigated. The localisation of a nest in a termite hill (Chichele) may have to do with avoiding the nest being flooded during the rainy season.

Spiral burrows leading to the nest are known in *C. hottentotus, Spalax* and *Geomys* (Hickman 1990; Nevo 1999) but have not been recorded in *C. mechowi*. In *C. mechowi* and *C. anselli* (own observations), these tunnels were straight or curved ramps.

Grass and root fibres constitute common litter material for nests of mole-rats. Usage of plastic materials as nest materials was reported also in *Cryptomys hottentotus natalensis* (Hickman 1979), *Coetomys anselli* (Scharff and Grütjen 1997), *C. whytei* (Burda et al. 2004), *Heliophobius argenteocinereus* (Sumbera et al. 2004), *Spalax ehrenbergi* (Nevo 1999), and *Spalacopus cyanus* (Begall and Gallardo 2000). In general, food and defecation chambers were located near the nest, a strategy encountered in other bathyergids and subterranean rodents (Nevo 1999).

Similar to other species of *Coetomys*, giant mole-rats stored their food in special chambers, a feature prevalent in subterranean mammals (Nevo 1999). Dependent on location of the burrow system (i.e. cultivated fields or uncultivated landscape), giant mole-rats constructed food chambers either filled with mixed contents or filled only with one available sort of food. Blind mole-rats (*Spalax ehrenbergi*) collect and hoard different food types in separate storage areas (Heth et al. 1989; Nevo 1999). A similar tendency is displayed by laboratory colonies of giant mole-rats and *C. anselli* (Burda personal communication). We did not find diversified food caches in field colonies, perhaps due to the uniformity and prevalence of food (e.g. sweet potatoes) in some sites or a large diversity of food types at other sites. We suggest that selective departmentalisation of food storing may differ according to the diversity, quantity and quality of the available food resources and hence may vary temporally and spatially. However, (separate) storing of animal prey should be considered an unusual feature and indeed this has not been recorded in any subterranean rodent so far.

Colony size

We have reported giant mole-rats to be highly social and consist of large families with up to 40 or more individuals (Burda and Kawalika 1993), but others considered them to be solitary (Faulkes and Abbott 1997; Kingdon 1974) or in pairs or small groups (Bennett and Aguilar 1995; Faulkes et al. 1997; Hill 1941). Laboratory studies (Scharff et al. 1999; Wallace and Bennett 1998) demonstrate that *C. mechowi* tend to live in extended families. Our field study confirmed that giant mole-rat colonies exceed twenty animals with some up to forty (probably even more) animals.

Age structure

Juveniles made a small proportion of the sample (8 %), suggesting that recruitment, dispersal and turnover of giant mole-rats are very low. This contrasts with naked mole-rats (Braude 2000) with very high recruitment and high losses due to predation or dispersal. Apparently, large colony sizes in these eusocial species are attained in different ways (Burda et al. 2000). Genelly (1965) reported 22% juveniles in *C. darlingi*, but he used tooth wear as a measure of age. Although low proportion of juveniles is common in subterranean rodents (Nevo 1979, 1999, Busch et al. 2000), the percentage of juvenile giant mole-rats is one of the lowest reported.

Sex ratio

Sampling was roughly equally distributed throughout space and time as well as with respect to capture methods so that there was probably no bias due to the sampling method. Whereas the overall sex ratio was near to equality, the sex ratio among youngsters was slightly female-biased. Captive colonies have a neonate sex ratio of 0.54 (Scharff et al. 1999). *C. anselli* show a female biased neonate sex ratio of 0.85 (Begall and Burda 1998) and even 0.44 in wild captured animals (Kawalika et al. 2003). Data for other social bathyergids and other subterranean mammals (Nevo 1979; 1999; Busch et al. 2000), are rather inconsistent. The extreme sex ratios reported in the literature may be also affected by small sample sizes. Sex-ratios in vertebrates are influenced by multiple factors and depend also on environmental conditions (Burda personal communication). The subterranean habitat is considered structurally simple and microclimatically stable (Nevo 1995; 1999), thus subterranean mammals may be suitable models for the study of sex-ratio adjustment.

There seems to be inconsistency between laboratory and field data as far as the sex ratio is concerned.

Following explanations should be considered:

1) The skew towards neonate females is an artefact of captivity breeding and does not reflect the natural situation. A reverse (i.e., male biased) sex ratio should be expected among neonates in the field to explain a higher proportion of males among young wild-captured mole-rats.
2) With growing older, males disappear from the population. However, there are no indications for higher dispersal and/or higher mortality of adult males. On the contrary, female-female inter-colonial encounters are more aggressive and lethal (Burda personal communication).
3) There is a sex-linked age-polyethism, expressed in higher activity and/or trapability of subadult males. With increasing age, males may become more cautious or less active. However, the hitherto observations on captive animals do not suggest any marked difference in this aspect (Burda personal communication).

Finding answers to the questions, why sex ratios in newborn captivity-bred giant mole-rats deviate so markedly from equality, may prove to be significant for getting insight into ecology of mole-rats in particular, and for understanding phenomena affecting sex-ratios in mammals in general.

The exciting hypothesis of H. Burda (personal communication) could explain the phenomenon and should be tested: In C*oetomys anselli* and *C. mechowi*, two types of females occur: homogametic females: XX and heterogametic females: XY*. Due to early loss of YY* zygotes, XY* females would produce twice as many phenotypical females as males. XY* females in the S. American field mice (*Akodon*) have been described already 35 years ago. It was shown that in *Akodon*, XY* females persist at high frequencies (up to 30%) and are better breeders than XX (Bianchi 2002). An unusual sex determination system has been found also in an unrelated subterranean rodent: the mole-lemming (Just 2002). Existence of heterogametic (XY*) females at different frequencies in the populations and in our captive breeding stock and higher mortality of younger males (observed also in breeding colonies) could explain all the observed phenomena.

Reproduction

The estimated age of the juveniles and subadults suggests that there is no distinct breeding period for Zambian giant mole-rats. This is also supported by reports of interviewed hunters, by a long term laboratory study (Scharff et al. 1999) and observations of Ansell (1978), who caught new-born animals throughout the year. Similarly, *Coetomys anselli* (Burda 1989, 1990), *C. damarensis*, and *Heterocephalus glaber* (Jarvis and Bennett 1991) are continuous non-seasonal breeders. *C. hottentotus* of southern Africa are reported as seasonal breeders (Jarvis and Bennett 1991).

Surface activity

Interestingly, the period when mole-rats found aboveground are mostly recorded coincides with the period when breeding dispersal and mating takes place also in the solitary silvery mole-rats (*Heliophobius argenteocinereus*) in neighbouring Malawi (Sumbera et al., 200). However, breeding dispersal in giant mole-rats is apparently provoked by an incidental encounter of two unfamiliar animals of opposite sex (Burda personal communication). Laboratory experiments do not indicate that there would be a specific age when breeding takes place for the first time (Burda personal communication). It should be noted that families of mole-rats are very xenophobic and any intruder will be immediately attacked and killed by residents of the same sex. Also, breeding in mole-rats is seasonally not limited.

In summary, although abundant food and soft soil may promote establishing of new territories (burrow systems), other facts do not support the idea of a synchronised seasonal breeding dispersal (searching for mate) in mole-rats. Also, at the end of the rainy period, rains become more sporadic and flooding of burrow systems cannot explain more observations of aboveground-moving mole-rats. The higher agricultural activity and associated disturbances can be excluded as well: burrow systems of mole-rats are extensive and deep; farmers use simple tools (hoes) and mole-rats, if disturbed, escape in the depth and not on the surface. Last but not least, the observations were made in the non-cultivated land as well. There is no obvious reason why aboveground foraging should be concentrated in time when also underground food is abundant and soil is well workable.

Noteworthy, that the analysis of owl pellets of two barn owls (see the respective chapter) has not revealed any rests of mole-rats. However, adult giant mole-rats (weight above 250 g) may be a too big prey item for this bird. In any case, the conclusion can be made that either the younger mole-rats (under one year of age) do not dare aboveground or do not do it during night when owls are hunting.

Parasites and commensals

It is generally assumed that the subterranean ecotope supports high parasite infestation (Nevo 1979, 1999). Most reports of parasitic infections of Bathyergidae are accidental findings (cf., De Graaff 1964, 1981 for review) suggesting low infestation rates. In the intensively studied naked mole-rat, descriptions of parasitic infections are sparse (De Graaff 1964; Sherman et al. 1991). It has been even suggested (Alexander et al. 1991) that the adaptive significance of hairlessness of the naked mole-rat should be seen in the avoidance of ectoparasites. It is, however, apparent that the haired relatives (i.e. *Cryptomys* and *Coetomys* mole-rats) do not have ectoparasites either. As far as the endoparasites are concerned, in *Cryptomys*, helminthic infestations (35 % in *C. mechowi* and 27 % in *C. anselli*) apparently are not as rare as the paucity of literature data would imply yet they are lower than in most aboveground rodents examined so far (Scharff et al. 1997; Scharff 1998). The relatively low incidence of parasitic infections in *Coettomys* contrasts with the view that the subterranean ecotope in combination with a social life style should favour pathogens (Alexander et al. 1991). Absence of ectoparasites may be an evidence for isolation of colonies and minimal contact between them.

The spectrum of helminths found in *C. mechowi* indicates that they feed regularly on invertebrates which serve as intermediate hosts (Scharff et al. 1997). Although mole-rats generally are considered herbivorous (e.g., Jarvis and Bennett 1991) there is direct evidence of carnivory in the giant mole-rat (Burda and Kawalika 1993).

Our knowledge of the commensals of subterranean rodents is still meagre see (De Graaff 1962, 1972). We found a variety of species of insects in burrows of giant mole-rats. We do not know, however, whether collected beetles are regularly eaten by giant mole-rats and therefore may serve as vectors of parasites. The study of commensals in burrow systems of subterranean animals may enlighten unknown aspects of parasitic life cycles and new species of insects may be expected in burrows of subterranean rodents.

The value and methods of documenting indigenous knowledge

The following text is basically a part of the article published earlier already (Burda and Kawalika 1993). However, some new information is added here.

Though virtually unknown to scholars, giant mole-rats are well known to the local population: they are serious pests to many crops; their meat is highly appreciated, nest materials and parts of the animals are used as medicinal and magical charms. There are reported cases at the Ministry of Agriculture of Zambia that fields have been abandoned due to damage to the crop which can reach as high as over 95%. No wonder that some people have specialised in hunting these animals. An experienced mole-rat hunter captures yearly 600-800 giant mole-rats, visiting as many burrows as possible. Much information can be gained by questioning the hunters (Figs. 63, 64). However, this is not an easy task. The hunters are superstitious and reluctant to provide information, even when offered a reward. I have eventually persuaded several mole-rat hunters to collaborate with me on a regular basis. Information obtained independently from the hunters as well as information given by each particular hunter throughout the year was cross-compared. According to the character of the data and explanation given, the information was categorised as irrational, pseudorational, and rational. Only the latter category was further tested.

As *irrational* I considered statements referring to medicinal and magical use of these animals or their nests, as well as the use of diverse charms as repellents to keep giant mole-rats off cultivated fields, or as attractants to trap them.

Figs. 63, 64: Hunters selling live giant mole-rats for food.

I had to face problems of irrational attitude towards mole-rats particularly in the Kasama area. Here, some people believe that the blood of a live mole-rat mixed with other charms forms a very potent charm to kill the person who caught the animal and indeed his family and relatives. They associated the live mole-rat to the skink (zorilla) which if caught in a trap and killed signifies a death of an immediate family member. If they found a mole-rat (very rarely) wandering out of its burrow system they consider is a bad omen that your house will catch fire within a week. Against these odds therefore did I have to operate in order to establish myself and to succeed. It is of interest, however, that at the same time there were also people engaged in hunting of mole-rats. However, I had to learn that no hunter had ever sold any animal: if they catch it, they eat it immediately or exchange killed (but never live) animals for any other eatables but not for money. I am thus responsible for setting up precedence and educating them that they can profit financially from hunting moles. The men in rural areas near Kasama seem to live mainly on local beer. Small birds and rodents (incl. mole-rats) are their only source of protein and as such it is difficult for them to part away with their catch. It always took more than money, because after a successful beer drinking spree one always wanted some protein to crown their merry making.

Pseudorational was, for instance, the information that giant mole-rats are immune against snake venom and bacterial infection. When I asked the hunters how they know they answered that they think so because the favourite food of mole-rats includes roots of a plant (with a vernacular name "kasabo", Daucales) which is used in the local medicine as antiphlogisticum and snake antivenom.

According to some hunters in the Kasama area, the super giant mole-rats (see above) are actually white because their coat has aged and greyed just like the hair of human beings. At this time it is believed that the animals attain the status of old people in society who are well taken care of by their society members and as a result put on extra weight.

Information which could be considered *rational* was further tested as to its reliability through comparison with the information provided on similar aspects of biology of common mole-rats which we (H. Burda and me) had studied already before in Lusaka and which had been known also from studies of other authors (particularly Bennett, Jarvis, Lovegrove). If this information was (according to our knowledge) correct, we had no reason to question the answers provided on similar aspects with regard to giant mole-rats. This comparison was relevant in areas where giant and small mole-rats live apparently sympatrically and/or where the hunters had experience with both forms of mole-rats.

I have checked the correctness of information on the size and structure of burrow systems, existence of special caches for animal prey, social coexistence (i.e., existence of larger colonies), occurrence of young animals throughout the year, etc. directly in the field.

A lot of information provided by hunters proved correct by subsequent studies (Burda personal communication). Carnivorous habits were evidenced by the examination of stomach contents and by recording feeding habits of captive animals. The existence of reproductive skew (only one female breeding in a family) was confirmed by dissection of adult animals, and by the fact that in a group of animals only one female was mated and was breeding. Reproduction of animals in captivity fully confirmed information given on litter size and pup development (cf., Burda and Kawalika 1993; Scharff et al. 1999).

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APPENDIX

Tables 1-7

Proven records of particular rodent species in respective degree squares. Compiled from Ansell (1978). map # corresponds to the original number of the respective distribution map in Ansell (1978). Yellow marked is the degree square where Ndola is located.
1 codes positive record, 0 codes no record. Abbreviations of species names are explained in Table 8.

species	CME	CSP	HAR	HAF	TSW	TGR	HGA	HRU	PBO	PLU	PCE	ADE	PCA	GMO	GSP	GPL	CGA	SCA	BHI	DME	DMY	DML	DNY	SPR	SKR	SMI	OTY	
map #	**151**	**152**	**153**	**154**	**155**	**156**	**157a**	**157b**	**158a**	**158b**	**159**	**160**	**161**	**162**	**163**	**165**	**166**	**167**	**168**	**169**	**170**	**171**	**172**	**173**	**174**	**175**	**176**	
0828	0	0	1	0	1	0	1	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**6**
0829	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	**3**
0830	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**3**
0831	0	0	0	0	1	1	1	0	0	0	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	**7**
0928	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
0929	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**3**
0930	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	**4**
0931	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	**2**
0932	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	**4**
0933	0	1	0	0	0	0	1	0	1	0	0	1	0	0	1	0	1	0	1	1	1	0	0	1	0	0	0	**10**
1024	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	**3**
1028	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1029	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1030	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
1031	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**3**
1032	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**2**
1033	0	1	1	1	0	0	1	0	0	1	1	0	0	0	1	0	1	0	1	1	1	1	1	0	0	0	1	**14**
1122	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1124	0	1	0	0	0	0	1	0	0	0	0	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	0	**15**
1125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1126	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1127	1	0	0	1	0	0	1	0	0	0	1	1	0	0	1	0	1	1	0	0	0	0	0	1	0	0	0	**9**
1128	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**2**
1129	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	**2**
1130	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	**5**
1131	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	**7**
1132	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**4**
1133	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
1222	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
	5	**9**	**4**	**8**	**3**	**1**	**12**	**1**	**2**	**2**	**8**	**4**	**1**	**1**	**7**	**3**	**7**	**6**	**4**	**3**	**6**	**2**	**3**	**8**	**2**	**1**	**1**	**114**

species	CME	CSP	HAR	HAF	TSW	TGR	HGA	HRU	PBO	PLU	PCE	ADE	PCA	GMO	GSP	GPL	CGA	SCA	BHI	DME	DMY	DML	DNY	SPR	SKR	SMI	OTY	
map #	**151**	**152**	**153**	**154**	**155**	**156**	**157a**	**157b**	**158a**	**158b**	**159**	**160**	**161**	**162**	**163**	**165**	**166**	**167**	**168**	**169**	**170**	**171**	**172**	**173**	**174**	**175**	**176**	
1223	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1224	1	1	0	1	0	0	1	0	0	0	1	1	0	0	1	0	1	1	0	1	1	1	0	1	0	0	0	**13**
1225	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
1226	1	0	0	1	1	1	0	0	0	0	1	1	0	0	1	0	1	1	0	1	1	0	0	1	0	0	0	**12**
1227	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	**3**
1228	1	0	0	1	1	1	1	0	0	0	1	1	1	0	1	0	1	1	0	0	1	1	0	1	0	0	0	**14**
1229	1	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	**6**
1230	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	**6**
1231	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
1232	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**4**
1233	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	**4**
1322	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	1	1	0	0	**7**
1323	1	1	0	0	0	1	1	0	0	0	0	0	0	0	1	1	1	1	0	1	1	1	0	1	1	1	0	**14**
1324	1	1	0	1	0	0	1	0	0	0	1	0	0	1	1	1	1	1	0	0	1	1	0	1	0	1	0	**14**
1325	0	1	0	1	0	0	1	0	0	0	1	1	0	1	1	0	0	1	0	0	1	0	0	1	0	0	0	**10**
1326	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	**5**
1327	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	**6**
1328	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	**5**
1329	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	**3**
1330	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0	**6**
1331	0	1	1	1	1	0	0	1	0	0	1	0	0	0	1	0	1	1	0	0	0	0	1	1	0	0	0	**11**
1332	0	0	1	1	1	1	0	1	0	0	1	0	0	0	0	0	1	1	0	0	1	0	0	1	0	0	0	**10**
1333	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1422	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**2**
1423	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**2**
1424	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
1425	1	1	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	1	1	1	0	**10**
1426	1	1	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	1	0	1	0	1	0	**10**
1427	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	0	0	0	1	0	1	0	0	0	**7**
1428	1	0	0	1	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	**7**
	14	**13**	**4**	**14**	**8**	**5**	**13**	**2**	**0**	**0**	**13**	**8**	**9**	**2**	**10**	**2**	**14**	**17**	**0**	**3**	**9**	**9**	**2**	**18**	**3**	**5**	**0**	**197**

species	CME	CSP	HAR	HAF	TSW	TGR	HGA	HRU	PBO	PLU	PCE	ADE	PCA	GMO	GSP	GPL	CGA	SCA	BHI	DME	DMY	DML	DNY	SPR	SKR	SMI	OTY	
map #	151	152	153	154	155	156	157a	157b	158a	158b	159	160	161	162	163	165	166	167	168	169	170	171	172	173	174	175	176	
1429	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
1430	0	0	1	1	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	**7**
1431	0	0	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	**7**
1432	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**2**
1433	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
1522	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	**3**
1523	0	1	0	0	0	0	1	0	0	0	1	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0	0	**7**
1524	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1525	1	1	0	1	1	0	0	0	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	1	1	0	0	**10**
1526	0	1	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	**6**
1527	0	1	0	1	1	0	0	0	0	0	1	0	1	0	1	0	1	1	0	0	0	0	0	1	0	0	0	**9**
1528	0	1	0	1	0	0	0	1	0	0	1	0	1	0	1	1	1	1	0	0	0	0	0	1	0	0	0	**10**
1529	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	**4**
1530	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**2**
1622	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**4**
1623	0	1	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	**6**
1624	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**1**
1625	0	1	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**6**
1626	0	1	0	1	0	1	0	0	0	0	1	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	**8**
1627	0	1	0	1	0	0	0	1	0	0	1	0	1	0	1	0	1	0	0	0	1	0	0	1	0	0	0	**9**
1628	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	**5**
1629	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
1722	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
1723	0	1	0	1	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**5**
1724	0	0	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	0	1	0	0	**6**
1725	0	1	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	1	1	0	0	1	1	0	**10**
1726	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
1727	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	**4**
1728	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
1825	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
	1	**15**	**3**	**18**	**8**	**1**	**1**	**6**	**0**	**0**	**18**	**1**	**15**	**0**	**11**	**2**	**6**	**16**	**0**	**0**	**4**	**3**	**1**	**7**	**4**	**1**	**0**	**142**

species	OAN	ODE	TBO	TLE	TVA	TBR	MMU	MMI	MSO	MTR	MNA	PJA	PDE	PDN	RRA	TPA	DIN	ANA	ACH	ANY	AKA	PFA	PMI	LGR	LST	ANI	HUN	
map #	177	178	179	180	181	182	183	184	184	185	186	187	187	188	189	190	191	192	193	194	195	196	197	198	198	199	200	
0828	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**2**
0829	0	0	1	0	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**6**
0830	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	**5**
0831	0	0	0	0	1	0	0	1	0	1	1	1	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	**8**
0928	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
0929	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	**6**
0930	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	**6**
0931	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
0932	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**2**
0933	1	0	1	1	0	0	0	0	0	1	1	0	1	0	1	0	1	0	1	1	0	1	0	0	1	0	0	**12**
1024	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	**6**
1028	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1029	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	**2**
1030	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	**2**
1031	0	0	0	1	1	0	0	1	0	1	1	1	0	1	1	0	1	0	1	0	0	1	0	0	1	0	0	**12**
1032	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
1033	1	1	1	1	0	0	0	1	0	1	1	0	1	0	1	0	1	0	1	1	1	1	0	0	1	0	0	**15**
1122	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1124	1	0	1	1	1	0	0	0	0	1	1	1	0	0	0	0	1	0	0	1	1	1	1	1	0	0	1	**14**
1125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1126	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1127	1	0	1	1	1	0	0	1	0	1	1	0	0	0	1	0	1	0	0	0	1	1	0	1	0	0	0	**12**
1128	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	**2**
1129	1	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**5**
1130	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	1	1	0	0	0	0	0	**6**
1131	0	0	0	0	1	0	0	0	0	0	1	1	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0	**7**
1132	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**2**
1133	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
1222	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	5	**1**	**5**	**9**	**11**	**0**	**0**	**4**	**0**	**9**	**17**	**8**	**2**	**3**	**11**	**0**	**10**	**0**	**6**	**3**	**10**	**8**	**3**	**5**	**4**	**0**	**1**	**135**

species	OAN	ODE	TBO	TLE	TVA	TBR	MMU	MMI	MSO	MTR	MNA	PJA	PDE	PDN	RRA	TPA	DIN	ANA	ACH	ANY	AKA	PFA	PMI	LGR	LST	ANI	HUN	
map #	177	178	179	180	181	182	183	184	184	185	186	187	187	188	189	190	191	192	193	194	195	196	197	198	198	199	200	
1223	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1224	1	0	0	1	1	0	0	1	0	1	1	1	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	**10**
1225	1	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	0	0	1	0	1	0	0	0	0	0	**7**
1226	1	0	1	0	1	0	0	1	0	1	1	1	0	0	0	0	1	0	0	1	1	1	0	1	0	0	0	**12**
1227	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
1228	1	0	1	1	1	0	0	1	0	1	1	0	0	0	1	0	1	0	0	1	1	1	0	0	0	0	0	**12**
1229	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**3**
1230	0	0	1	1	1	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	1	1	0	1	0	0	0	**10**
1231	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
1232	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	**5**
1233	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0	1	0	1	0	1	1	0	0	0	0	0	**8**
1322	1	0	0	1	1	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	**8**
1323	1	0	0	1	1	0	0	1	0	1	1	0	0	0	0	0	1	0	0	1	1	1	0	1	0	0	0	**11**
1324	1	0	1	1	1	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1	1	1	0	1	0	0	0	**11**
1325	0	0	1	0	1	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1	1	1	0	1	0	1	0	**10**
1326	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**4**
1327	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	**6**
1328	1	0	1	1	1	0	0	1	0	1	1	0	0	0	1	0	1	0	0	0	1	1	0	0	0	0	0	**11**
1329	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**2**
1330	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	1	1	0	1	0	0	0	**9**
1331	0	0	0	1	0	0	0	1	0	0	1	1	0	0	1	1	0	1	1	0	0	1	0	1	0	0	0	**10**
1332	0	0	0	1	0	0	0	1	0	1	1	0	0	0	1	1	1	0	1	0	1	1	0	1	0	0	0	**11**
1333	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1422	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	**4**
1423	1	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**5**
1424	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	**4**
1425	1	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	1	0	0	0	1	0	**9**
1426	0	0	1	0	1	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	**7**
1427	1	0	0	1	1	0	0	0	0	1	1	0	0	0	1	0	1	0	1	0	1	1	0	1	0	0	0	**11**
1428	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**3**
	13	**0**	**9**	**18**	**18**	**0**	**0**	**14**	**0**	**11**	**23**	**5**	**0**	**3**	**9**	**3**	**17**	**1**	**8**	**9**	**15**	**18**	**0**	**10**	**0**	**3**	**0**	**207**

species	OAN	ODE	TBO	TLE	TVA	TBR	MMU	MMI	MSO	MTR	MNA	PJA	PDE	PDN	RRA	TPA	DIN	ANA	ACH	ANY	AKA	PFA	PMI	LGR	LST	ANI	HUN	
map #	**177**	**178**	**179**	**180**	**181**	**182**	**183**	**184**	**184**	**185**	**186**	**187**	**187**	**188**	**189**	**190**	**191**	**192**	**193**	**194**	**195**	**196**	**197**	**198**	**198**	**199**	**200**	
1429	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	**2**
1430	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	**2**
1431	0	0	1	1	0	0	0	1	0	0	1	0	0	0	1	1	0	0	1	0	0	1	0	1	0	0	0	**9**
1432	0	0	1	1	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	**7**
1433	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**2**
1522	1	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	**6**
1523	1	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	**7**
1524	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1525	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	1	1	0	1	0	0	1	0	1	0	1	0	**10**
1526	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	**4**
1527	1	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	1	0	1	0	0	1	0	1	0	1	0	**10**
1528	0	0	0	1	1	0	0	1	0	1	1	0	0	0	1	1	1	0	1	0	1	1	0	1	0	0	0	**12**
1529	0	0	0	1	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	**6**
1530	0	0	0	1	0	0	0	0	1	0	1	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0	**7**
1622	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	**5**
1623	1	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	**7**
1624	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	**2**
1625	1	0	0	1	1	0	0	0	0	0	1	0	0	0	0	1	1	0	1	0	0	1	0	1	0	1	0	**10**
1626	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	1	0	0	0	**6**
1627	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	**7**
1628	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	0	0	0	0	1	0	0	0	**6**
1629	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1722	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1723	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
1724	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	**6**
1725	0	0	0	1	0	1	1	1	0	0	1	0	0	0	0	0	1	1	1	0	0	1	0	1	0	0	0	**10**
1726	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	**3**
1727	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	**5**
1728	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1825	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	5	**0**	**2**	**18**	**6**	**4**	**1**	**8**	**3**	**1**	**19**	**0**	**0**	**2**	**8**	**9**	**12**	**6**	**15**	**0**	**3**	**10**	**0**	**16**	**0**	**4**	**0**	**152**

species	RPU	LFL	MLO	VGO	ZHI	GDO	GCO	ASP		species	RPU	LFL	MLO	VGO	ZHI	GDO	GCO	ASP		species	RPU	LFL	MLO	VGO	ZHI	GDO	GCO	ASP	
map #	200b	201	202a	202b	202c	203a	203b	204		map #	200b	201	202a	202b	202c	203a	203b	204		map #	200b	201	202a	202b	202c	203a	203b	204	
0828	0	0	0	0	0	0	0	0	**0**	**1223**	0	0	0	0	0	0	0	0	**0**	**1429**	0	0	0	0	0	0	0	0	**0**
0829	0	1	0	0	0	1	0	0	**2**	**1224**	0	0	0	0	0	1	0	0	**1**	**1430**	0	0	0	0	0	0	0	1	**1**
0830	0	0	0	0	0	1	0	0	**1**	**1225**	0	1	0	0	0	1	0	0	**2**	**1431**	0	0	0	0	0	1	0	1	**2**
0831	0	1	0	0	0	1	0	0	**2**	**1226**	0	1	0	0	0	1	0	0	**2**	**1432**	0	0	0	0	0	0	0	0	**0**
0928	0	0	0	0	0	0	0	0	**0**	**1227**	0	0	0	0	0	0	0	0	**0**	**1433**	0	0	0	0	0	0	0	0	**0**
0929	0	0	0	0	0	1	0	0	**1**	**1228**	0	0	0	0	1	1	0	1	**3**	**1522**	0	0	0	0	0	0	0	0	**0**
0930	0	0	0	0	0	0	0	0	**0**	**1229**	0	0	0	0	0	0	0	0	**0**	**1523**	0	0	0	0	0	0	0	0	**0**
0931	0	0	0	0	0	0	0	0	**0**	**1230**	0	0	0	0	0	1	0	0	**1**	**1524**	0	0	0	0	0	0	0	0	**0**
0932	0	0	0	0	0	0	0	0	**0**	**1231**	0	0	0	0	0	0	0	0	**0**	**1525**	0	0	0	0	1	1	0	1	**3**
0933	0	1	0	0	0	1	0	1	**3**	**1232**	0	1	0	0	0	0	0	1	**2**	**1526**	0	0	0	0	0	1	0	1	**2**
1024	0	0	0	0	0	1	0	0	**1**	**1233**	0	0	0	0	0	1	0	1	**2**	**1527**	0	0	0	0	0	0	0	1	**1**
1028	0	0	0	0	0	0	0	0	**0**	**1322**	0	0	0	0	0	1	0	0	**1**	**1528**	0	0	0	0	1	1	0	1	**3**
1029	0	1	0	0	0	0	0	0	**1**	**1323**	0	0	0	0	0	1	0	0	**1**	**1529**	0	0	0	0	0	0	0	1	**1**
1030	0	1	0	0	0	0	0	0	**1**	**1324**	0	0	0	0	0	1	0	0	**1**	**1530**	0	0	0	0	0	1	0	0	**1**
1031	0	0	0	00	0	1	0	0	**1**	**1325**	0	0	0	0	0	0	0	0	**0**	**1622**	0	0	0	0	0	0	0	0	**0**
1032	0	1	0	0	0	0	1	0	**2**	**1326**	0	0	0	0	0	0	0	0	**0**	**1623**	0	0	0	0	0	0	0	0	**0**
1033	1	0	0	0	1	0	1	1	**4**	**1327**	0	0	0	0	0	1	0	1	**2**	**1624**	0	0	0	0	0	0	0	0	**0**
1122	0	0	0	0	0	0	0	0	**0**	**1328**	0	0	0	0	0	0	0	1	**1**	**1625**	0	0	0	0	0	0	0	0	**0**
1123	0	0	0	0	0	0	0	0	**0**	**1329**	0	0	0	0	0	0	0	0	**0**	**1626**	0	0	0	0	0	0	0	0	**0**
1124	0	1	1	1	0	1	0	0	**4**	**1330**	0	0	0	0	0	1	0	1	**2**	**1627**	0	0	0	0	0	0	0	0	**0**
1125	0	0	0	0	0	0	0	0	**0**	**1331**	0	0	0	0	0	1	0	1	**2**	**1628**	0	0	0	0	0	0	0	1	**1**
1126	0	0	0	0	0	0	0	0	**0**	**1332**	0	0	0	0	0	1	0	1	**2**	**1629**	0	0	0	0	0	0	0	0	**0**
1127	0	0	0	0	0	1	0	1	**2**	**1333**	0	0	0	0	0	0	0	0	**0**	**1722**	0	0	0	0	0	0	0	0	**0**
1128	0	0	0	0	0	0	0	0	**0**	**1422**	0	0	0	0	0	0	0	0	**0**	**1723**	0	0	0	0	0	0	0	0	**0**
1129	0	0	0	0	0	0	0	0	**0**	**1423**	0	0	0	0	0	0	0	0	**0**	**1724**	0	0	0	0	0	0	0	0	**0**
1130	0	0	0	0	0	0	0	0	**0**	**1424**	0	0	0	0	0	0	0	0	**0**	**1725**	0	0	0	0	0	0	0	1	**1**
1131	0	0	0	0	0	0	0	0	**0**	**1425**	0	0	0	0	1	0	0	0	**1**	**1726**	0	0	0	0	0	0	0	0	**0**
1132	0	0	0	0	0	0	0	0	**0**	**1426**	0	0	0	0	0	0	0	0	**0**	**1727**	0	0	0	0	0	0	0	1	**1**
1133	0	0	0	0	0	0	0	0	**0**	**1427**	0	0	0	0	1	1	0	0	**2**	**1728**	0	0	0	0	0	0	0	0	**0**
1222	0	0	0	0	0	0	0	0	**0**	**1428**	0	0	0	0	0	0	0	1	**1**	**1825**	0	0	0	0	0	0	0	0	**0**
	1	**7**	**1**	**1**	**1**	**9**	**2**	**3**	**25**		**0**	**3**	**0**	**0**	**3**	**14**	**0**	**9**	**29**		**0**	**0**	**0**	**0**	**2**	**5**	**0**	**10**	**17**

Table 8

List of rodent species recorded for Zambia by Ansell (1978), the codes for respective species names (abbr), original number of the map of distribution (map), number of squares with positive records (N), relative number of squares with positive records (%, related to the total number of considered degree squares, = 90).

species	abbr	map	N	%
Acomys spinosissimus	ASP	204	22	24
Aethomys chrysophilus	ACH	193	29	32
Aethomys kaiseri	AKA	195	28	31
Aethomys namaquensis	ANA	192	7	8
Aethomys nyikae	ANY	194	12	13
Anomalurus derbianus	ADE	160	13	14
Arvicanthis niloticus	ANI	199	7	8
Beamys hindei	BHI	168	4	4
Coetomys mechowi	CME	151	20	22
Coetomys spp.	CSP	152	37	41
Colomys goslingi	CGO	202b	1	1
Cricetomys gambianus	CGA	166	27	30
Dasymys incomtus	DIN	191	39	43
Dendromus melanotis	DML	171	14	15
Dendromus mesomelas	DME	169	6	7
Dendromus mystacalis	DMY	170	19	21
Dendromus nyikae	DNY	172	6	7
Grammomys cometes	GCO	203b	2	2
Grammomys dolichurus	GDO	203a	28	31
Graphiurus monardi	GMO	162	3	3
Graphiurus platyops	GPL	165	7	8
Graphiurus spp.	GSP	163	28	31
Heliophobius argenteocinereus	HAR	153	11	12
Heliosciurus gambianus	HGA	157a	26	29
Heliosciurus rufobrachium	HRU	157b	9	10
Hybomys univittatus	HUN	200a	1	1
Hystrix africaeaustralis	HAF	154	40	44
Lemniscomys griselda	LGR	198a	31	34
Lemniscomys striatus	LST	198b	4	4
Lophuromys flavopunctatus	LFL	201	20	22
Malacomys longipes	MLO	202a	1	1
Mastomys natalensis	MNA	186	59	65
Mus minutoides	MMI	184a	26	29
Mus musculus	MMU	183	1	1
Mus sorella	MSO	184b	3	3
Mus triton	MTR	185	20	22
Otomys angoniensis	OAN	177	23	25
Otomys denti	ODE	178	1	1
Otomys typus	OTY	176	1	1
Paraxerus boehmi	PBO	158a	2	2
Paraxerus cepapi	PCE	159	39	43

Paraxerus lucifer	PLU	158b	2	2
Pedetes capensis	PCA	161	25	28
Pelomys fallax	PFA	196	36	40
Pelomys minor	PMI	197	3	3
Praomys delectorum	PDE	187b	3	3
Praomys denniae	PDN	188	8	9
Praomys jacksoni	PJA	187a	13	14
Rattus rattus	RRA	189	28	31
Rhabdomys pumilio	RPU	200b	1	1
Saccostomus campestris	SCA	167	39	43
Steatomys krebsi	SKR	174	9	10
Steatomys minutus	SMI	175	7	8
Steatomys pratensis	SPR	173	33	37
Tatera boehmi	TBO	179	16	18
Tatera brantsi	TBR	182	4	4
Tatera leucogaster	TLE	180	45	50
Tatera valida	TVA	181	35	39
Thalomys paedulcus	TPA	190	12	13
Thryonomys gregorianus	TGR	156	7	8
Thryonomys swinderianus	TSW	155	19	21
Zelotomys hildegardae	ZHI	202c	6	7

Table 9: Food intake of the Barn Owl from Namboard as estimated from owl pellets and an average body mass of prey animals.

month	**mass (g)**	**Feb 02**	**Mar 02**	**Apr 02**	**May 02**	**Jun 02**	**Jul 02**	**Aug 02**	**Sep 02**	**Oct 02**	**Nov 02**	**Dec 02**	**Jan 03**	**M**
Frog/toad	15	0	0	0	0	0	0	0	0	15	15	0	0	**30**
reptile	20	0	0	0	0	0	0	0	0	20	0	0	0	**20**
bird	30	60	0	60	0	60	30	30	120	60	90	120	120	**750**
Tad. pumilla	15	15	0	0	0	0	0	0	0	0	0	0	0	**15**
Crocidura	10	60	70	0	120	80	10	20	10	20	30	30	10	**460**
***Crocidura* L**	25	0	0	0	0	0	0	0	0	0	0	25	25	**50**
***Crocidura* M**	12	0	0	0	0	0	0	0	36	0	0	0	24	**60**
***Crocidura* S**	8	0	8	0	0	0	0	0	0	0	0	0	0	**8**
Suncus	5	5	5	0	5	5	0	0	0	0	0	0	0	**20**
Elephantulus	50	0	50	0	0	0	0	50	0	0	0	0	0	**100**
Acomys	27	0	0	0	0	0	0	0	0	20	0	0	0	**20**
A. chrysophilus	75	0	75	0	0	0	0	0	0	0	0	0	0	**75**
A. nyikae	90	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Dasymys	125	0	0	0	125	0	0	0	0	0	0	125	0	**250**
Dendromus	10	10	30	20	0	0	10	30	10	20	10	20	40	**200**
***Dendromus* L**	14	0	0	0	42	0	0	0	0	0	0	0	0	**42**
***Dendromus* M**	11	0	0	0	0	0	0	11	0	0	0	0	0	**11**
***Dendromus* S**	8	0	0	8	16	16	0	8	0	0	0	0	0	**48**
Graph. surdus	28	0	0	0	0	0	0	0	0	28	0	0	0	**28**
***Mastomys* ad.**	55	1650	1155	1100	1320	660	935	880	715	1485	770	935	660	**12265**
***Mastomys* juv.**	20	40	0	0	40	0	0	100	40	60	40	0	0	**320**
Mus	6	30	24	36	0	6	36	60	72	84	0	12	12	**372**
Pelomys	100	0	0	0	0	100	100	0	0	100	100	0	0	**400**
Praomys	40	0	0	40	40	0	40	0	40	40	0	0	0	**200**
Rattus rattus	145	0	0	0	0	0	145	145	0	0	0	0	0	**290**
Saccostomus	32	0	32	32	0	0	0	32	32	0	0	0	32	**160**
Steatomys	45	0	90	135	0	45	135	0	0	0	45	0	0	**450**
Tatera	95	190	95	380	95	190	190	285	285	95	95	0	285	**2185**
***Tatera* juv.**	35	0	0	70	0	0	35	0	70	0	0	0	0	**175**
		2060	1634	1881	1803	1162	1666	1651	1430	2047	1195	1267	1208	**19004**

Table 10: Food intake of the Barn Owl from Namboard as estimated from owl pellets and an average body mass of prey animals.

month	**mass (g)**	**Feb 02**	**Mar 02**	**Apr 02**	**May 02**	**Jun 02**	**Jul 02**	**Aug 02**	**Sep 02**	**Oct 02**	**Nov 02**	**Dec 02**	**Jan 03**	**M**
Frog/toad	15	0	0	30	0	0	0	0	0	0	0	0	0	**30**
reptile	20	0	0	40	0	20	0	0	0	0	0	0	0	**60**
bird	30	150	150	330	90	30	30	30	120	120	0	0	0	**1050**
Tad. pumilla	15	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Crocidura	10	80	10	0	20	0	0	20	0	20	30	0	30	**210**
***Crocidura* L**	25	0	0	25	0	0	0	0	0	25	0	0	0	**50**
***Crocidura* M**	12	0	0	12	0	0	0	0	0	0	0	0	36	**48**
***Crocidura* S**	8	0	0	0	8	16	0	0	0	8	0	0	0	**32**
Suncus	5	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Elephantulus	50	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Acomys	27	0	0	0	0	0	0	0	0	0	0	27	0	**27**
A.chrysophilus	75	0	0	0	0	0	0	0	0	0	0	0	0	**0**
A. nyikae	90	0	0	0	0	0	0	90	0	0	0	0	0	**90**
Dasymys	125	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Dendromus	10	40	60	70	30	30	10	30	0	0	40	10	20	**340**
***Dendromus* L**	14	0	0	0	0	0	0	0	0	0	0	0	0	**0**
***Dendromus* M**	11	0	0	0	0	0	11	0	0	0	0	22	0	**33**
***Dendromus* S**	8	0	0	0	8	0	0	0	0	0	0	0	0	**8**
Graph. surdus	28	0	0	0	0	0	0	0	0	0	0	0	0	**0**
***Mastomys* ad.**	55	1100	1375	770	1045	770	600	1320	1375	1540	1100	715	1210	**12920**
***Mastomys* juv.**	20	0	20	40	0	40	72	120	0	0	0	0	0	**292**
Mus	6	18	18	0	12	36	48	30	6	0	6	12	0	**186**
Pelomys	100	0	0	0	100	0	0	0	0	0	0	0	0	**100**
Praomys	40	0	0	0	0	40	40	0	80	0	0	0	0	**160**
Rattus rattus	145	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Saccostomus	32	0	0	0	32	0	96	32	64	0	64	96	64	**448**
Steatomys	45	0	0	0	45	0	0	0	0	0	0	0	0	**45**
Tatera	95	0	190	95	0	190	95	475	475	190	95	665	285	**2755**
***Tatera* juv.**	35	0	0	35	0	0	35	0	0	0	0	0	0	**70**
		1388	**1823**	**1447**	**1390**	**1172**	**1037**	**2147**	**2120**	**1903**	**1335**	**1547**	**1645**	**18954**

Table 10: Food intake of the Barn Owl from Mansansa Forest as estimated from owl pellets and an average body mass of prey animals.

Mansansa Forest					
	mass (g) prey item	**Jun 03**	**Jul 03**	**Aug 03**	**Jan 04**
bird	30	30	0	0	0
Crocidura	10	10	90	80	20
Scotophilus dinganii	27	27	0	0	0
Scotophillus leucogaster	33	33	0	0	0
Pipistrellus	7	0	0	0	7
Aethomys	80	0	80	0	80
Aethomys chrysophilus	75	0	0	0	225
Aethomys nyikae	90	0	0	0	90
Dendromus	14	60	12	12	14
Grammomys dolichurus	37	0	37	0	0
***Mastomys* ad.**	55	880	550	660	660
***Mastomys* juv.**	20	0	20	0	0
Mus	6	6	6	12	6
Pelomys	100	100	0	0	0
Praomys	40	0	40	0	0
Rattus rattus	145	0	145	0	0
Saccostomus	32	0	0	32	0
Steatomys	45	45	90	0	0
Tatera	95	190	760	855	950
***Tatera* juv.**	35	35	35	0	0
		1416	**1865**	**1651**	**2052**

CURRICULUM VITAE

NAME:	***Mathias Kawalika***
NATIONALITY:	Zambian
DATE AND PLACE OF BIRTH:	17th JULY 1962, Chipata
MARITAL STATUS:	Married with seven children
ADDRESS PRIVATE:	P.O. Box 73796 Ndola Tel./Fax: 02-681841 Cell: 095-883200 E-mail: kawamat@zamtel.zm
QUALIFICATIONS:	M.Sc. in Zoology. Knightsbridge University, UK. 2001 B.Sc. in Biology and Chemistry double major. University of Zambia. 1988 Form five Cambridge Certificate. Katete Secondary School. 1980
SHORT COURSES	Certificate in Effective Management 2001 Certificate in Research Methodologies 2000 Certificate in environmental protection 1996 Certificate in quality control 1993
CURRENT EMPLOYER:	Kafubu Water and Sewerage Co. Ltd. P.O. Box 71278 Ndola Tel: 02-622495 **Fax: 02-622177** From 2001 to date
JOB TITLE:	Head of production and water quality
JOB DESCRIPTION:	Research and development in aquatic environment, for the purpose of managing water production, water and wastewater quality within the city of Ndola, and the towns of Luanshya and Masaiti. I am in charge of the entire city of Ndola as regards to water production and quality assurance, whereas in Luanshya and Masaiti, I am only responsible for water quality assurance, which also includes monitoring all pollution affecting the aquatic environment from industries within the city and towns.

PREVIOUS EMPLOYMENT:

Ndola city council 1988-2001
Job Title: senior Biochemist.
I was carrying out the same functions as my current employment, the only difference being that my area of responsibility was confined to Ndola. The function of provision of water and sewerage services was privatised and transferred from Ndola City Council to my new employers in July 2001.

Middle Zambezi River Basin Research Project 1987-1988. Job title: Graduate Research Assistant.
I was working under the Chairmanship of the project leader Prof. Dr. G. W. Howard a renowned ecologist. My work involved creating a database for the fauna and flora of the Middle Zambezi River Basin. This was achieved through intense fieldwork collecting soil samples, plant samples, small mammals, insects and birds and finally identifying them using standard identification keys. I then had to catalogue the findings on computer.

ACHIEVEMENTS

Awarded Honorariums to attend conferences in Kruger National Park (1994), Paris (1998), Ceske Budejovice (2000), Louvain-La-Neuve (2002), Morogoro (2003) and Brno (2003).

I was appointed external trainer in the field of water quality assurance at an international course for Water Supply and Wastewater Management Systems in Ndola from 1st – 20th September 2003.

Appointed member to the Water and Environmental Pollution Technical Committee of the Zambia Bureau of Standards, now charged with the responsibility of formulating national test methods for drinking and wastewater. (2002)

Elected vice President North in the Chemical Society of Zambia, during the elections of 2002.

I was resource person to the trainer of trainers' course in water quality monitoring, which was run by Interconsult International AS at the Copperbelt University, to which my input formed part of the training modules and protocols that were used in the water quality-training component (1998).

I conducted an in house short training course to Lever Brothers Zambia Ltd organised by Tina consultants in the field of Cleaner Production (1996).

Appointed member to the Water and Environmental Pollution Technical Committee of the Zambia Bureau of Standards charged with the formulation of Zambian standards for drinking water, which task was completed and now adopted as national standards for drinking water. (1990)

	I have been resource person to several workshops conducted by Environmental Council of Zambia in the area of water quality management on the Copperbelt.
	I offered consultancy services in the field of water and wastewater management to the following industries in Ndola: - Ndola Knitting Mills Ltd., Ndola Weaving Textiles Ltd., Mukuba Textiles Ltd., Zambezi Paper Mills Ltd., Tropics (Z) Ltd., Lyons Brook bond Ltd and Lynx Zambia Ltd.
	I was resource person at a training workshop organised by WASAZA on management of wastewater systems course Ndola 2003
	I was resource person at a training workshop organised by WASAZA on management of wastewater systems course in Malawi, May/June 2004
EXPERIENCE	Field survival tactics. Field data collection, preservation analysis and interpretation. Driving licence. Electronic data processing (PC-programmes Windows 2000, Word 7.0, Excel 7.0, Access 2.0, and Power Point 7.0).
PUBLICATIONS	See the attached list: 10 research papers in peer-reviewed scientific journals, 12 presentations at international scientific meetings
RESEARCH PROJECT AND FIELD OF INTERESTS	Diversity and Ecology of Zambian subterranean mole rats (genus *Cryptomys*, Bathyergidae, Rodentia). Composition and dynamics of a small mammal community studied by owl pellet analysis. Zoology (evolutionary biology, taxonomy, animal biology, biogeography, mammalogy, sociobiology) Studies are carried out on a private basis in co-operation with Prof. Dr. H. Burda, Essen, Germany, since 1985 to date.
REFEREES	Prof. E. Chidumayo, UNZA, P.O.Box 32379, Lusaka Prof. K. Mbata, UNZA, P.O.Box, 32379 Lusaka Dr. M. Banda, P.O.Box, 30135 Lusaka

DATED: ________________ *SIGNED:* ____________________

List of Publications

Peer-reviewed research papers

2003 Van Daele, P.A.A.G., Dammann, P., **Kawalika, M.**, Meier, J.-L., Van De Woestijne, C., Burda, H. (in press): Chromosomal diversity in *Cryptomys* mole-rats (Rodentia: Bathyergidae) in Zambia; with the description of new karyotypes. *Journal of Zoology, London.*

2002 Scharff A., Locker-Gruetjen O., **Kawalika M.**, Burda H. (2002): Natural history of the giant mole rat, *Cryptomys mechowi* (Rodentia: Bathyergidae) from Zambia. *J. Mammalogy* 82(4): 1002-1015.

2001 **Kawalika M.**, Burda H., Bruggert D. (2001): Was Zambia a cradle of the genus *Cryptomys* (Bathyergidae, Rodentia)? A further new ancestral (?) species of *Cryptomys* from Zambia. In: *African small mammals (Denys C., Granjon L., Poulet A., eds.). IRD Editions, collection Colloques et seminaries,* Paris, pp 256-261.

1999 Burda H., Zima J., Scharff A., Macholan M., and **Kawalika M.** (1999): The karyotypes of *Cryptomys anselli sp. nova* and *Cryptomys kafuensis sp. nova*: new species of the common mole rat from Zambia (Rodentia, Bathyergidae). *Z. Saugetierk.* 64: 36-50.

1997 Filippuci M.G., **Kawalika M.**, Macholan M., Scharff A., Burda H. (1997) Allozyme differentiation and taxonomic status of Zambian giant mole rats, *Cryptomys mechowi* (Bathyergidae, Rodentia). *Z. Saugetierk.* 62(3): 172-178.

Scharff A., Burda H., Tenora F., **Kawalika M.**, Barus V. (1997): Parasites in social subterranean Zambian mole rats (*Cryptomys* spp., Bathyergidae, Rodentia). *J. Zool. Lond.* 241: 571-577.

1996 Scharff A., Tenora F., **Kawalika M.**, Barus V., Burda H. (1996): Helminths from Zambian mole rats (*Cryptomys*, Bathyergidae, Rodentia). *Helminthologia* 33(2): 105-110.

1993 Burda H., **Kawalika M.** (1993): Evolution of eusociality in the Bathyergidae: The case of the giant mole rat (*Cryptomys mechowi*). *Naturwissenschaften* 80:235-237.

Macholan M., Burda H., Zima J., Misek I., **Kawalika M.** (1993): Karyotype of the giant mole rat, *Cryptomys mechowi* (Bathyergidae, Rodentia). *Cytogenetics and Cell Genetics* 64:261-263.

1992 Burda H., **Kawalika M.** (1992): Ecology and behaviour of giant mole rats, *Cryptomys mechowi* (Bathyergidae, Rodentia), from Zambia. *Z. Saugetierk. Suppl.* 57; 12-13.

Presentations at scientific meetings

2003 Dammann, P., Van Daele, P., **Kawalika, M.**, Lange, S. Wegner, R., Burda, H. (2003): A hot spot for chromosomal speciation in *Cryptomys* (Rodentia, Bathyergidae). *Oral presentation.* 4th European Congress of Mammalogy, Brno, Czech Republic, July 27-August 1, 2003.

Kawalika, M., Begall, S., Dammann, P., Scharff, A., Burda, H. (2003): Sex ratios and their age-dependent changes in two species of Zambian mole-rats (*Cryptomys anselli* and *C. mechowi*, Bathyergidae). *Oral presentation.* 4th European Congress of Mammalogy, Brno, Czech Republic, July 27-August 1, 2003.

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Statement regarding animal use and welfare

None of the mammals sacrificed in the course of this study belong to endangered animal species. They are not listed among the species protected by the Washington Convention or by any other national or international convention or regulation on the animal species protection. Typically, all these rodents including mole-rats are rather commonly occurring in agricultural areas, and are considered agricultural and horticultural pests.

All efforts were taken to minimize stress of the animals. Animal husbandry and all experimental procedures complied with Zambian and European Community regulations on the care and use of experimental animals and – with regard to karyotyping – the only relevant experimental procedure - were approved by the institutional animal care and use committee of the University of Duisburg–Essen. Ethics clearing was issued by the Bezirksregierung Düsseldorf (File Number: 50.05-240-107/02). Export and capture permits were issued by the Zambian Wildlife Authority (for most recent permits see Nr. 014508 & 009534).

Statement regarding the authorship

I do assure herewith that this thesis is based on results of my own study or studies done in collaboration within joint research projects and identified clearly as such in the text above. All other sources of information are cited, and references are provided, to the best of my knowledge throughout the text.

I do certify herewith that this thesis has not been submitted for any other comparable academic award and that I have never before attempted to obtain a PhD degree elsewhere. Neither has such an attempt been done in parallel elsewhere.

Ndola , 21st July 2004

Mathias Kawalika, MSc.

Erklärung:

Hiermit erkläre ich, gem. § 6 Abs. 2, Nr. 7 der Promotionsordnung der Fachbereiche 6 bis 9 zur Erlangung des Dr. rer. nat., dass ich das Arbeitsgebiet, dem das Thema „Studies on Rodents of Ndola (Copperbelt Province, Zambia)," zuzuordnen ist, in Forschung und Lehre vertrete und den Antrag von Herrn Mathias Kawalika befürworte.

Essen, 27. 07. 2004

(Prof. Dr. Hynek Burda)

Erklärung:

Hiermit erkläre ich, gem. § 6 Abs. 2, Nr. 6 der Promotionsordnung der Fachbereiche 6 bis 9 zur Erlangung des Dr. rer. nat., dass ich die vorliegende Dissertation selbständig verfasst und mich keiner anderen als der angegebenen Hilfsmittel bedient habe.

Ndola, 21. 07. 2004

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Erklärung:

Hiermit erkläre ich, gem. § 6 Abs. 2, Nr. 8 der Promotionsordnung der Fachbereiche 6 bis 9 zur Erlangung des Dr. rer. nat., dass ich keine anderen Promotionen bzw. Promotionsversuche in der Vergangenheit durchgeführt habe und dass diese Arbeit von keiner anderen Fakultät abgelehnt worden ist.

Ndola, 21. 07. 2004

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