

# A new species of giant sengi or elephant-shrew (genus *Rhynchocyon*) highlights the exceptional biodiversity of the Udzungwa Mountains of Tanzania

F. Rovero<sup>1</sup>, G. B. Rathbun<sup>2</sup>, A. Perkin<sup>3,4</sup>, T. Jones<sup>5</sup>, D. O. Ribble<sup>6</sup>, C. Leonard<sup>4</sup>, R. R. Mwakisoma<sup>4</sup> & N. Doggart<sup>4</sup>

<sup>1</sup> Sezione di Zoologia dei Vertebrati, Museo Tridentino di Scienze Naturali, Trento, Italy

<sup>2</sup> Department of Ornithology and Mammalogy, California Academy of Sciences (San Francisco) & IUCN-SSC Afrotheria Specialist Group, Cambria, CA, USA

<sup>3</sup> Nocturnal Primate Research Group, Department of Social Science and Biology, Oxford Brookes University, Oxford, UK

<sup>4</sup> Tanzania Forest Conservation Group, Dar es Salaam, Tanzania

<sup>5</sup> Department of Life Sciences, Anglia Ruskin University, Cambridge, UK

<sup>6</sup> Department of Biology, Trinity University, San Antonio, TX, USA

## Keywords

elephant-shrew; sengi; new species; *Rhynchocyon udzungwensis*; Macroscelidea; Eastern Arc Mountains; Udzungwa Mountains; Tanzania.

## Correspondence

Francesco Rovero, Sezione di Zoologia dei Vertebrati, Museo Tridentino di Scienze Naturali, Via Calepina 14, Trento 38100, Italy. Tel: +39 3495970234  
Email: francesco.rovero@mtsn.tn.it

Received 4 April 2007; accepted 6 June 2007

doi:10.1111/j.1469-7998.2007.00363.x

## Abstract

A new species of sengi, or elephant-shrew, is described. It was discovered in the northern Udzungwa Mountains of Tanzania in 2005. Sengis (Order Macroscelidea, super-cohort Afrotheria) include four genera and 15 species of mammals that are endemic to Africa. This discovery is a significant contribution to the systematics of this small order. Based on 49 camera trap images, 40 sightings and five voucher specimens, the new sengi is diurnal and distinguished from the other three species of *Rhynchocyon* by a grizzled grey face, pale yellow to cream chest and chin, orange-rufous sides, maroon back and jet-black lower rump and thighs. The body weight of the new species is about 700 g, which is 25–50% greater than any other giant sengi. The new *Rhynchocyon* is only known from two populations that cover about 300 km<sup>2</sup> of montane forest. It has an estimated density of 50–80 individuals km<sup>-2</sup>. This discovery has important implications for the conservation of the high biodiversity that is found in the forests of the Eastern Arc Mountains.

## Introduction

Sengis, or elephant-shrews, include 15 species of *c.* 30–500 g mammals that form a well-defined order, the Macroscelidea (Corbet & Hanks, 1968; Simons, Holroyd & Bown, 1991; Schlitter, 2005). They are restricted to Africa and belong to the recently recognized super-cohort Afrotheria, which includes elephants, sea cows, hyraxes, the aardvark, golden moles, tenrecs and sengis (Springer *et al.*, 1997; Stanhope *et al.*, 1998; Douady *et al.*, 2003). According to the definitive taxonomic revision by Corbet & Hanks (1968), the single extant family Macroscelididae is divided into two subfamilies: the Rhynchocyoninae, with the single genus *Rhynchocyon*, and the Macroscelidinae, with three genera. *Rhynchocyon* includes three species that were described between 1847 and 1881 (Corbet & Hanks, 1968). They are known as ‘giant sengis’ because they are the largest members of the Macroscelidea.

The taxonomy of extant *Rhynchocyon* is based nearly exclusively on distinct colour patterns of the pelage and the

allopatric distributions of the different forms, with virtually no use of cranial features (Corbet & Hanks, 1968; Kingdon, 1974). The historical absence of skull metrics in the taxonomy of this genus is related to the similarity of the crania among the different forms, which is not surprising because giant sengis are considered ‘living fossils,’ showing little skeletal divergence from Miocene ancestors (Novacek, 1984; Butler, 1987; Holroyd & Mussell, 2005). Although Corbet & Hanks (1968) distinguished three species, Kingdon (1974) considered the genus monospecific due to colour patterns that he interpreted as hybridization between two of the three species.

We describe a new species of *Rhynchocyon* that is endemic to the Udzungwa Mountains of south-central Tanzania. These mountains are part of the Eastern Arc Mountains, which are a series of ancient and isolated mountain blocks stretching from southern Kenya to south-central Tanzania. Portions of the Eastern Arc Mountains are believed to have supported moist forest for *c.* 30 million years (Wasser & Lovett, 1993). The age, stability, isolation and fragmented

nature of these forests have combined to produce high levels of biological diversity and endemism (Burgess, Fjeldså & Botterweg, 1998; Myers *et al.*, 2000; Dinesen *et al.*, 2001). The Udzungwa Mountains have the largest area of moist forest and support the highest mammalian diversity in the Eastern Arc Mountains and adjoining Southern Highlands (Kingdon & Howell, 1993; Burgess *et al.*, 2007). In recent years, a number of undescribed vertebrates have been found in the Udzungwa Mountains, including a new genus and species of bird, the Udzungwa partridge *Xenoperdix udzungwensis* (Dinesen *et al.*, 1994); the Phillips' Congo shrew *Congosorex phillipsorum* (Stanley, Rogers & Hutterer, 2005); a new genus and species of monkey, the kipunji *Rungwecebus kipunji* (Jones *et al.*, 2005; Davenport *et al.*, 2006); and several amphibians (Clarke, 1988; Menegon, Salvidio & Loader, 2004) and reptiles (Salvidio *et al.*, 2004; Bauer & Menegon, 2006; see also Burgess *et al.*, 2007 for a complete list).

In 2005, several camera-trap images of what appeared to be an undescribed giant sengi were obtained from the Ndundulu Forest, northern Udzungwa Mountains (Rovero & Rathbun, 2006). In 2006, we organized an expedition to collect voucher specimens. Here, we describe these as a new species of *Rhynchocyon*.

## Materials and methods

Specimens were collected during a 2-week expedition into the Ndundulu forest (Fig. 1) in March 2006. We deployed several trapping methods that have proven successful for giant sengis, including live traps (Tomahawk Trap Company, Tomahawk, WI, USA; model 102, 13 × 13 × 40.5 cm) and white nylon gill nets that were dyed black (21D/18 twine, 7.62-cm stretch mesh, 20-mesh deep, 45.7 m long). The live traps and net mesh proved to be too small for the unexpectedly large sengis. In addition, the nets were not deep enough and were too visible when the black dye leached out with the frequent rain. However, R. R. M. captured four *Rhynchocyon* with traditional nylon-twine snares set on presumed sengi trails. We also collected and preserved in formalin a partially eaten carcass, assumed to be abandoned by a raptor, found next to a footpath in the forest. Captured animals were photographed, measured, weighed, euthanized if alive and prepared as standard museum study skins and skulls. The remaining postcranial material from three of the four captured specimens was preserved in formalin. The specimens are deposited at the California Academy of Science (CAS), University of Dar es Salaam (UDSM), Natural History Museum (BMNH, formerly British Museum of Natural History), Field Museum of Natural History (FMNH) and Museo Tridentino di Scienze Naturali (MTSN). The study skins were compared with a diverse collection of *Rhynchocyon* specimens by G. B. R., including 57 *Rhynchocyon cirnei* Peters 1847 (chequered sengi), 15 *Rhynchocyon petersi* Bocage 1880 (black and rufous sengi) and four *Rhynchocyon chrysopygus* Günther 1881 (golden-rumped sengi). These specimens represented

all valid subspecies described by Corbet & Hanks (1968) except for *Rhynchocyon cirnei cirnei* Peters 1847 (Supplementary Material Appendix S1).

Data on distribution, activity patterns and abundance were derived from camera-trapping and visual sightings. Camera-traps (Vision Scouting cameras, Non Typical Inc., Park Falls, WI, USA) were set to take pictures 24 h a day with a 1-min delay between exposures. The date and time of each photograph were automatically imprinted on the film (ASA 200, colour, Kodak, Rochester, NY, USA) when exposed. Four cameras were deployed in pristine sub-montane and montane moist forest (*sensu* Lovett, 1993) in the Vikongwa River Valley of the Ndundulu forest within a 1 km radius of 7°48.203'S, 36°30.255'E at 1360–1440 m above sea level (a.s.l.) between September 2005 and March 2006. Camera-trap days were calculated as the total number of 24-h periods each camera was operating (i.e. from deployment until the film was full or the cameras were retrieved) and camera-trap rate was calculated as the ratio of sengi images to trap-days multiplied by 100. The total camera-trap days at these sites was 168, with a mean of 24 per camera. Twenty cameras were deployed at two sites in Mwanihana forest: site 1 was centred on 7°45.11'S, 36°51.974'E (altitude 900–1700 m a.s.l.) and site 2 was centred on 7°50.448'S, 36°56.912'E (altitude 900–1100 m a.s.l.). Sampling occurred during June–July 2006, totalling 557 camera-trap days with a mean of 29 trap-days per camera.

In addition to our giant sengi sightings ( $n = 40$ ), which were obtained opportunistically during *c.* 150 man-days of survey work, we used two sightings obtained by Thomas Butynski and Quentin Luke (Rovero & Rathbun, 2006). We calculated a visual encounter rate for the new sengi using 10 of the overall 40 sightings, which we obtained during an intensive 7-day survey in Ndundulu-Luhomero forest in March 2006 between 1350 and 1800 m a.s.l. [11 km<sup>2</sup> of forest area surveyed (Jones, 2006)]. Three teams of two observers slowly walked non-overlapping routes of least resistance through a different area of the forest each day, and recorded all giant sengis encountered between 6:50 and 18:00 h. Surveying was paused between 12:30 and 14:30 h, and whenever it was raining, yielding a survey effort of 132.5 h. All records were geo-referenced using portable global positioning system receivers (Garmin Ltd, Romsey, Hampshire, UK).

## Description of the new species

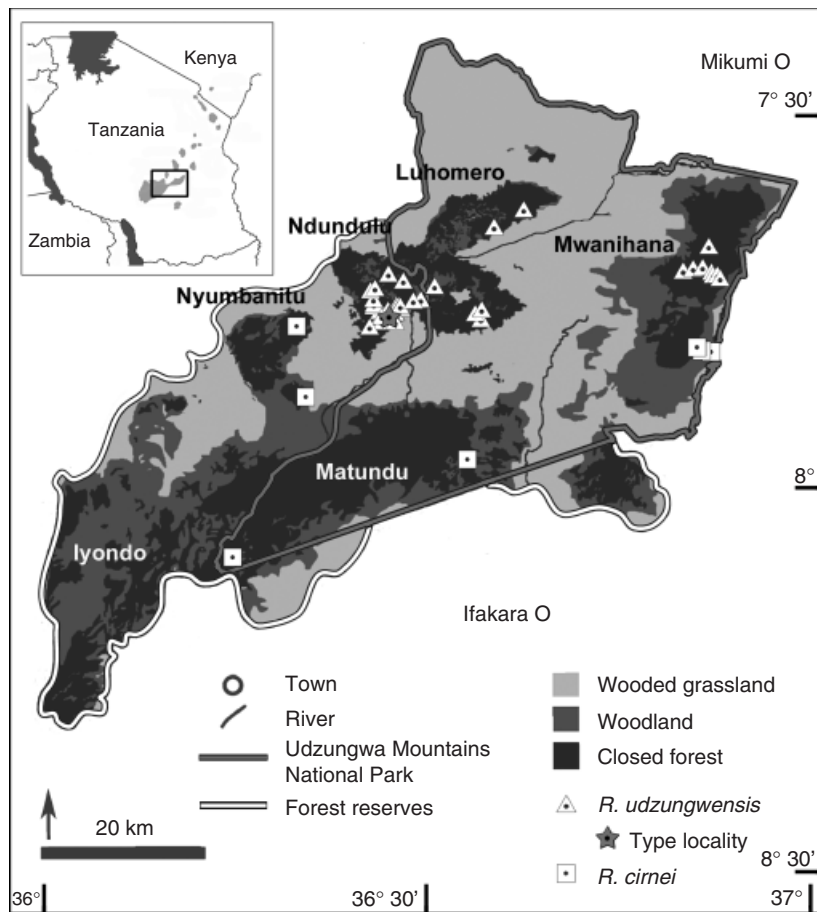
### *Rhynchocyon udzungwensis* Rathbun & Rovero sp. nov.

#### Holotype

CAS 28043, adult female prepared as skin, skull, postcranial carcass in formalin and tissue samples in alcohol. Collected on 18 March 2006 (Figs 1 and 2).

#### Paratypes

UDSM 467, entire adult male in formalin and tissue samples in alcohol, collected on 12 March 2006 at 7°47.665'S,



**Figure 1** Map of the northern portion of the Udzungwa Mountains, Tanzania, showing records of *Rhynchocyon udzungwensis* sp. nov. and of *Rhynchocyon cirnei*. The grey tones indicate gross habitat categories within protected areas: 'wooded grassland' is grassland with widely scattered trees; 'woodland' is deciduous forest with an open canopy; and 'closed forest' is evergreen, closed-canopy forest. The major closed forests are named. The inset shows the location of the Udzungwa Mountains within the Eastern Arc Mountains (in grey) of Kenya and Tanzania (map created by A. Pallaveri, MTSN). MTSN, Museo Tridentino di Scienze Naturali.

36°29.513'E, which is 2.5 km north-west of the type locality; BMNH 2007.7, adult male skin, skull, post-cranial carcass in formalin and tissue samples in alcohol, collected on 18 March 2006 at the type locality; FMNH 194127, adult female skin, skull, post-cranial carcass in formalin and tissue samples in alcohol, collected on 20 March 2006 at 7°48.214'S, 36°30.354'E, which is 0.1 km north of the type locality; MTSN 6000, adult male skin, skull and tissue samples in alcohol, collected on 23 March 2006 at 7°48.214'S, 36°30.354'E, which is 0.1 km north of the type locality (Fig. 2).

#### Type locality

Vikongwa River Valley, Ndundulu Forest, West Kilombero Scarp Forest Reserve, Udzungwa Mountains, Iringa Region, Tanzania [7°48.269'S, 36°30.355'E (Arc 1960 datum)], at 1350 m a.s.l. This location is *c.* 15 km south-east of Udekwa Village, Iringa Region, Tanzania.

#### Etymology

The specific epithet is derived from the Udzungwa Mountains in Tanzania, where this species is endemic. We recom-

mend the common name grey-faced sengi or grey-faced elephant-shrew, which maintains the tradition of naming each giant sengi for its most defining colour pattern.

#### Diagnosis

The mean weight of *R. udzungwensis* is 710 g, which is 25–50% greater than other giant sengis. The mean total body length is 564 mm, which exceeds that of other giant sengis by 10–20%. The upper tooth row is also remarkably longer than other giant sengis (Table 1). *Rhynchocyon udzungwensis* differs in coloration and pattern (colours as used in Corbet & Hanks, 1968) from all other *Rhynchocyon* by its grizzled grey forehead and face, jet-black fur restricted to the lower rump and thighs and slightly grizzled yellow-rufous pelage extending from behind the ears to the shoulders, where it becomes orange-rufous (with no grizzling) on the sides and indistinctly separated from a wide maroon (= dark rufous) stripe down the back (Fig. 2).

#### Description

The pelage is sparse, glossy, stiff and colourful – similar to other *Rhynchocyon* species and in contrast to the shorter,



**Figure 2** Photographs of *Rhynchocyon udzungwensis* sp. nov.: above, captive live animal (holotype, CAS 28043, photo F. R.); below, four specimens (three paratypes and holotype) prepared as study skins. From top to bottom: BMNH 2007.7, FMNH 194127, MTSN 6000, CAS 28043 (photo D. Lin, CAS). BMNH, British Museum of Natural History; CAS, California Academy of Science; FMNH, Field Museum of Natural History; MTSN, Museo Tridentino di Scienze Naturali.

denser, fluffier and greyish or brownish fur of the Macroscelidinae. The first 2 cm of the exceptionally long nose are essentially naked and black. The hair on the sides and top of the face back to the base of the ears has black bases and cream to pale white tips, giving a grizzled grey appearance. A maroon nuchal crest 2–2.5 cm high, about 1 cm higher than the ear crowns, starts between the ears and extends back about 3 cm. The maroon colour of the crest encroaches about 1 cm into the grey pelage of the forehead and forms an indistinct stripe that widens along the back from behind the ears to the rump, where it narrows and integrates with the jet-black fur over about 3 cm to a point about 3 cm above the tail insertion. The lower rump is jet black. In certain lights and from certain angles, two parallel slightly darker lines are barely visible within the maroon dorsal stripe, each with up to four very faint pale spots near the leading edge of the black rump. This vestigial chequering is similar to that of *R. petersi* and *R. chrysopygus*. The black rump hair is about the same length as the pelage on the surrounding areas. The jet-black fur on the lower rump extends to the upper thighs and down onto the rear legs. The fur behind the ears and on the shoulders is grizzled yellow-rufous and becomes orange-

rufous on the sides and lacks grizzling, forming an indistinct boundary with the maroon dorsal stripe. The grizzled appearance of the shoulders is due to black tips on the hair, which become slightly shorter on the sides. The orange-rufous sides integrate over about 2 cm with the jet-black fur on the leading edge of the thighs. The belly and inner thighs have very sparse pale rufous fur about the same length as on the sides, but starting at about the base of the sternum and onto the chest the fur becomes denser and pale yellow, becoming pale cream on the chin. The inner forelegs are a mixture of short pale yellow fur that extends from the chest and orange-rufous fur that extends from the shoulders. The feet are black with sparse and short rufous fur on the dorsum. The tail skin is slightly bi-coloured, nearly black dorsally and dark brown ventrally, with a sub-terminal white band 4–6 cm long. The short and very sparse tail hairs are the same colour as the skin. The pinnae are essentially naked and dark brown to nearly black.

### Distribution

All records of *R. udzungwensis* are from the Ndundulu–Luhomero forest and the Mwanihana forest to the east (Fig. 1). These two forest blocks are separated by about 20 km of grassland and woodland that is unlikely to be suitable habitat for *R. udzungwensis* (Corbet & Hanks, 1968). *Rhynchocyon udzungwensis* occurs in closed canopy forest from 1350 to 2300 m a.s.l. in Ndundulu–Luhomero (estimated range 200 km<sup>2</sup>) and from 1000 to 1700 m a.s.l. in Mwanihana forest (estimated range 100 km<sup>2</sup>). At site 1 in the Mwanihana forest (see ‘Methods’), we only camera-trapped *R. udzungwensis*, whereas at site 2, which is about 10 km south, we only recorded *Rhynchocyon cirnei reichardi* Reichenow 1886.

### Variation

There is little colour variation in the five specimens from Ndundulu, except for the length of the sub-terminal white zone on the tail (73, 94, 52, 50 and 58 mm). The weight, body measurements and length of the upper tooth row of the specimens are remarkably consistent, but there appears to be sexual dimorphism in canine length (Table 1). The vestigial checkers on the back vary from hardly visible on the Ndundulu specimens to more defined on some individuals camera-trapped at Mwanihana.

### Comparison

The differences in pelage pattern between *R. udzungwensis* and *R. chrysopygus* and most forms of *R. cirnei* are clear and unambiguous. A bright yellow rump patch (with slightly longer hair) is found only on *R. chrysopygus*, while distinct checkers (a series of six dark and light stripes and spots on the back) are only found on *R. cirnei*. Although there are some similarities in the coloration of *R. udzungwensis*, *R. petersi* and the dark coastal form of *Rhynchocyon cirnei macrurus* Günther 1881, the defining characteristics can be summarized as follows: the feet, tail and pinnae of *R.*

**Table 1** Comparative biometrics for *Rhynchocyon* taxa

Taxon	W	HB	T	TL	HF	E	UTR	CF	CM
<i>R. udzungwensis</i>	710.8 (4) 19.8 658–750	310.0 (5) 4.3 297–318	254.0 (5) 4.1 239–262	564.0 (5) 5.7 550–580	82.0 (5) 1.6 79–88	34.6 (5) 1.0 31–37	31.4 (5) 0.4 30.2–32.6	6.2 (2) N/D 5.9–6.5	6.9 (3) N/D 6.3–7.2
<i>R. chrysopygus</i> <sup>a</sup>	534.8 (40) 8.6 410–690	277.9 (80) 1.5 218–304	240.5 (80) 1.4 213–270	518.4(80) 2.3 464–561	74.0 (80) 0.2 68–79	33.5 (80) 0.2 30–38	27.5 (4) N/D 23.5–29.8	4.6 <sup>b</sup> (10) 0.2 3.6–5.2	6.6 <sup>b</sup> (10) 0.2 5.5–7.5
<i>R. petersi</i> <sup>c</sup>	N/D	275.4 (8) 4.4 252–290	233.5 (8) 3.9 218–252	508.9 (8) 4.3 493–525	71.2 (8) 1.1 65–74	29.1 (8) 0.7 25–31	27.6 (8) 0.2 26.5–28.1	N/D 0.6 2.2–6.5	4.4 (6) 0.6 2.2–6.5
<i>R. cirnei stuhlmanni</i> <sup>d</sup>	N/D	272.7 (67) 1.4 242–303	243.5 (66) 1.2 220–265	515.1(67) 2.3 458–556	85.7 <sup>e</sup> (67) 2.2 81–91	31.0 (67) 0.1 29–34	27.7 <sup>c</sup> (11) 0.3 25.7–29.0	4.9 <sup>c</sup> (4) N/D 3.7–6.9	6.5 <sup>c</sup> (4) N/D 5.7–7.5
<i>R. cirnei macrurus</i> (chequered form) <sup>c</sup>	N/D	N/D	N/D	N/D	N/D	N/D	26.5 (13) 0.2 25.1–27.4	4.3 (4) N/D 3.2–5.9	5.5 (3) N/D 4.5–6.3
<i>R. cirnei macrurus</i> (melanistic form) <sup>c</sup>	N/D	254.7 (9) 3.7 240–273	230.8 (9) 3.0 221–249	485.4 (9) 4.7 461–509	71.4 (9) 1.0 67–76	28.1 (9) 0.3 27–30	27.4 (6) 0.4 25.8–28.7	N/D N/D N/D	N/D N/D N/D
<i>R. cirnei reichardi</i> <sup>f</sup>	352.0 (10) 10.0 320–420	242.0 (10) 2.0 229–253	213.8 (10) 3.8 196–234	455.8(10) 3.6 439–474	66.8 (10) 0.7 63–70	29.6 (10) 0.3 28–31	25.4 <sup>b</sup> (9) 0.4 23.8–26.9	2.2 (5) 0.2 1.7–2.9	3.4 (5) 0.04 3.3–3.5

Data are mean (sample size), SD (when the sample size is greater than four) and range. W, weight; HB, head and body; T, tail; TL, total length; HF, hind foot *sin unguis* (without nail); E, ear; UTR, upper tooth row; CF, canine length females; CM, canine length males; N/D, no data. UTR excludes rudimentary incisor, which is sometimes absent. All measurements are in mm, except weight (g).

Data source:

<sup>a</sup>G. B. R. (unpubl. field data).

<sup>b</sup>Rathbun (1978).

<sup>c</sup>G. B. R. (data from BMNH specimens).

<sup>d</sup>Allen (1922).

<sup>e</sup>Presumably measured *con unguis* (with nail); *con unguis* data for *R. udzungwensis*: 91.4 mm ( $n=5$ ),  $\pm 1.2$  mm, 89–96 mm.

<sup>f</sup>Ansell & Ansell (1973).

*udzungwensis* are mostly black compared with orange-rufous in *R. petersi* and the face is grizzled grey in *R. udzungwensis* and orange-rufous in *R. petersi*; the jet-black rump of *R. udzungwensis* is restricted to the lower rump and thighs while in *R. petersi* it extends up the back to the shoulders. The fur on the chest of *R. udzungwensis* is pale yellow, whereas it is orange-rufous in *R. petersi*. The dark forms of *R. c. macrurus* and *R. udzungwensis* are more difficult to distinguish. *Rhynchocyon c. macrurus* has a grizzled yellow forehead that extends below the eyes, whereas in *R. udzungwensis* the forehead is grizzled grey and extends below the eyes and to the pinnae. In *R. c. macrurus*, the outer surface of the pinnae is orange-brown, the chin and chest are orange-rufous and the rump and thighs are maroon, whereas in *R. udzungwensis* the pinnae are dark brown to black, the chin and chest are pale cream and pale yellow and the rump and thighs are jet black. We found no evidence of a dermal shield on the rump of *R. udzungwensis*, as occurs in *R. chrysopygus* (Rathbun, 1978), and there was no evidence of a dermal shield in any of the other forms of *Rhynchocyon* examined by G. B. R. at the BMNH.

## Ecology, behaviour and reproductive biology

We found *R. udzungwensis* in different forest types, but always within moist, sub-montane and montane evergreen to upper montane closed-canopy forest, including bamboo thickets. The canopy of sub-montane and montane forest was typically 25–50 m high, while that of the upper montane forest was 10–25 m. The forest floor vegetation varied from relatively open areas covered in leaf litter to more densely covered with clumps of grasses, herbs and tree seedlings.

*Rhynchocyon udzungwensis* constructs nests similar to congeneric species (Rathbun, 1979). We examined five nests: each had an oval cup excavated in the soil lined with layered leaves and loose leaves piled on top to form an indistinct dome surrounded by thick leaf litter on the forest floor. Four of the five nests were each situated at the base of a tree (tree-base diameters *c.* 20 cm for two sites, and 10 cm for other two).

Camera-trapping data indicate that *R. udzungwensis* is strictly diurnal. The 10 images from Ndundulu were obtained between 06:29 and 15:16 h, and the 39 images from Mwanihana were obtained between 06:50 and 17:21 h. We

obtained a total of 37 daylight sightings in Ndundulu–Luhomero and three in Mwanihana forest. During intensive primate surveys at Ndundulu (Jones, 2006), we obtained 10 sightings, yielding an encounter rate of 0.08 animals h<sup>-1</sup>. The mean camera-trapping rate was 7.4 ( $n = 10$  photographs) in Ndundulu and 11.1 ( $n = 39$ ) in Mwanihana.

One of the females captured (MTSN 6000) was pregnant with one foetus in each horn of the uterus (33 mm crown–rump lengths). Single and twin births are common in *R. cirnei* and *R. petersi*, but only single births are known for *R. chrysopygus* (Rathbun, 1979).

## Discussion

Corbet & Hanks (1968) defined the three species of *Rhynchocyon* based on their geographic distribution and pelage coloration, but they used no skull features. Based on their keys and descriptions, *R. udzungwensis* is clearly deserving of species status. The authors, however, made note of a peculiar cline of *R. c. macrurus* specimens in south-eastern Tanzania that grade from a dark coastal form with indistinct chequers to a highly chequered form inland. Kingdon (1974) viewed evidence like this as supporting his description of *Rhynchocyon* as being monotypic (*R. cirnei*), with distinct chequers being more common in forms inhabiting open woodlands and darker coloration being more common in forests and areas of high humidity. Kingdon (1974) also viewed the chequered pattern on the back, visible in many *Rhynchocyon*, as further proof of the monospecific nature of *Rhynchocyon*. However, Kingdon (1974) did recognize *R. chrysopygus* and *R. petersi* as likely incipient species. The distinct chequering found on the back of most *R. cirnei*, and the vestigial chequers of *R. chrysopygus*, *R. petersi* and *R. udzungwensis*, suggest that this colour pattern is ancestral and therefore not helpful in distinguishing species of *Rhynchocyon*. Unfortunately, there are few published craniometric data for *Rhynchocyon* for comparison with the new species.

The large size of *R. udzungwensis* suggests that this dark form is different from *R. petersi* and the coastal form of *R. c. macrurus*. This larger size may be due to climatic factors such as a lower temperature and therefore concordant with Bergmann's rule, although, as indicated by a recent review (Millien *et al.*, 2006), the factors contributing to a larger body size are complex and might be correlated with a number of ecological factors. Moreover, other forms such as *Rhynchocyon cirnei hendersoni* Thomas 1902 and *Rhynchocyon cirnei shirensis* Corbet & Hanks (1968) occur at similar altitudes as *R. udzungwensis*, but they are not reported to be unusually large (Corbet & Hanks, 1968). We believe that the large size of *R. udzungwensis* is of considerable taxonomic significance.

*Rhynchocyon udzungwensis* appears to be restricted to submontane and montane forest in the Ndundulu–Luhomero and Mwanihana forests. Based on our results, and camera-trapping and surveys conducted before this study at elevations ranging from 300 to 1000 m a.s.l., the highly chequered *R. c. reichardi* occurs between 450 and 870 m a.s.l. (Fig. 1; F. Rovero, unpubl. data), whereas *R. udzung-*

*wensis* occurs above 1000 m a.s.l. In Mwanihana forest, there appears to be a spatial gap of about 10 km between the known localities of these two species, where no giant sengis have yet been recorded, despite camera-trapping and visual surveys. Thus, the difference in size and the observed lack of any hybrids support the idea that this new *Rhynchocyon* is a different species, which is also consistent with the number of other endemics in the same area.

An estimate of the abundance of *R. udzungwensis* can be made using population density data for other *Rhynchocyon*. Based on home-range sizes (Rathbun, 1979; FitzGibbon, 1997) and surveys of nest densities (FitzGibbon & Rathbun, 1994), *R. chrysopygus* attains densities of up to 150 individuals km<sup>-2</sup> in protected habitats (FitzGibbon, 1994), but there are no data relating these densities to visual encounter rates. In Tanzania, *R. petersi* nest surveys indicate densities of up to 80 individuals km<sup>-2</sup>, which are also more typical of *R. chrysopygus*, but in the South Pare Mountains (northern Eastern Arc Mountains of Tanzania) an estimated density of 19 individuals km<sup>-2</sup> was determined (Coster & Ribble, 2005), with a visual encounter rate of 0.001 animals per survey hour (S. Coster, pers. comm.). Our encounter rate for *R. udzungwensis* of 0.08 per survey hour, therefore, suggests a relatively high density, even though differences in visibility between sites might also affect this comparison. Assuming a density range of 50–80 individuals km<sup>-2</sup>, which is within the mid-range for other giant sengis, the total population estimate for *R. udzungwensis* is 15 000–24 000 in the 300 km<sup>2</sup> of forested habitat. This is similar to the estimated population of 20 000 individuals (FitzGibbon, 1994) for the Endangered *R. chrysopygus* (IUCN, 2007).

The newly described *R. udzungwensis* adds to at least 25 new vertebrate species from the Eastern Arc Mountains and Tanzanian Southern Highlands in the last decade, five of which are mammals (Burgess *et al.*, 2007). In the Udzungwa Mountains alone, the number of strictly endemic mammals is now five, and 13 out of the 17 Eastern Arc endemic or near-endemic mammals (Burgess *et al.*, 2007) are found in this area. The discovery of *R. udzungwensis* is yet further evidence of the global importance of the Eastern Arc and Southern Highlands for conservation of endemic vertebrates in general and mammals specifically (Myers *et al.*, 2000; Burgess *et al.*, 2007).

All current records of *R. udzungwensis* occur either within the Udzungwa Mountains National Park or within the West Kilombero Scarp Forest Reserve, which are fully protected areas designated for biodiversity and ecosystem protection. Anthropogenic disturbance, such as forest fragmentation and destruction, and subsistence hunting, are documented threats to giant sengis (FitzGibbon, Mogaka & Fanshawe, 1995; Rathbun & Kyalo, 2000; IUCN, 2007). During our surveys, we did not encounter signs of human disturbance, such as hunting or tree cutting. However, as the human population around the Eastern Arc Mountains continues to expand and move closer to protected areas (Schipper & Burgess, 2004), threats to the very localized *R. udzungwensis* are likely to increase.

## Acknowledgements

We are grateful to Thomas Butynski, Gordon Corbet, Bill Stanley and two anonymous reviewers for valuable comments on earlier versions of the manuscript; Kim Howell for support and advice; and Paula Jenkins and Wim Wendelen for access to the collections at BMNH and Royal Museum of Central Africa, respectively. Research permits were granted by the Tanzania Commission for Science and Technology; Tanzania Wildlife Research Institute; Tanzania National Parks; Wildlife Division; and Forestry and Beekeeping Division. Funds were from the Critical Ecosystem Partnership Fund (to Tanzania Forest Conservation Group, MTSN and T.J.); Provincia Autonoma di Trento through MTSN (to F.R.); National Geographic Society (grant 7433-03 to F.R. through Thomas Struhsaker); and Fauna and Flora International Flagship Species Fund to T. J. Amani Kitegile, Richard Laizzer, Athumani Mndeme, Arafat Mtui, Amos Lumagi and several forest scouts from Udekwa and Mang'ula provided invaluable field assistance.

## References

- Allen, J.A. (1922). The American Museum Congo Expedition collection of Insectivora. *Bull. Am. Mus. Nat. Hist.* **47**, 1–38.
- Ansell, W.F.H. & Ansell, P.D.H. (1973). Mammals of the north-eastern montane areas of Zambia. *Puku* **7**, 21–69.
- Bauer, A.M. & Menegon, M. (2006). A new species of prehensile-tailed Gecko, *Urocotyledon* (Squamata: Gekkonidae), from the Udzungwa Mountains, Tanzania. *Afr. J. Herpetol.* **55**, 13–22.
- Burgess, N.D., Butynski, T.M., Cordeiro, N.J., Doggart, N., Fjeldsá, J., Howell, K.M., Kilahama, F., Loader, S.P., Lovett, J.C., Mbilnyi, B., Menegon, M., Moyer, D.C., Nashanda, E., Perkin, A., Rovero, F., Stanley, W.T. & Stuart, S.N. (2007). The biological importance of the Eastern Arc Mountains of Tanzania and Kenya. *Biol. Conserv.* **134**, 209–231.
- Burgess, N.D., Fjeldsá, J. & Botterweg, R. (1998). Faunal importance of the Eastern Arc Mountains of Kenya and Tanzania. *J. East Afr. Nat. Hist. Soc.* **87**, 37–58.
- Butler, P.M. (1987). Fossil insectivores from Laetoli. In *Laetoli: a Pliocene Site in Northern Tanzania*: 85–87. Leakey, M.D. & Harris, J.M. (Eds). Oxford: Oxford University Press.
- Clarke, B.T. (1988). The amphibian fauna of the East African rainforests, including the description of a new species of toad, genus *Nectophrynoides* Noble 1926 (Anura Bufonidae). *Trop. Zool.* **1**, 169–177.
- Corbet, G.B. & Hanks, J. (1968). A revision of the elephant-shrews, Family Macroscelididae. *Bull. Br. Mus. (Nat. Hist.) Zool.* **16**, 47–111.
- Coster, S. & Ribble, D.O. (2005). Density and cover preferences of black-and-rufous elephant-shrews *Rhynchocyon petersi* in Chome Forest Reserve, Tanzania. *Belg. J. Zool.* **135** (Suppl.), 175–177.
- Davenport, T.R.B., Stanley, W.T., Sargis, E.J., De Luca, D.W., Mpunga, N.E., Machaga, S.J. & Olson, L.E. (2006). A new genus of African monkey, *Rungwecebus*: morphology, ecology, and molecular phylogenetics. *Science* **312**, 1378–1381.
- Dinesen, L., Lehmberg, T., Rahner, M.C. & Fjeldsá, J. (2001). Conservation priorities for the forests of the Udzungwa Mountains, Tanzania, based on primates, duikers and birds. *Biol. Conserv.* **99**, 223–236.
- Dinesen, L., Lehmberg, T., Svendsen, J.O., Hansen, L.A. & Fjeldsá, J. (1994). A new genus and species of perdicine bird (Phasianidae, Perdicini) from Tanzania: a relict form with Indo-Malayan affinities. *Ibis* **136**, 2–11.
- Douady, C.J., Catzeflis, F., Raman, J., Springer, M.S. & Stanhope, M.J. (2003). The Sahara as a vicariant agent, and the role of Miocene climatic events, in the diversification of the mammalian order Macroscelidea (elephant shrews). *Proc. Natl. Acad. Sci. USA* **100**, 8325–8330.
- FitzGibbon, C.D. (1994). The distribution and abundance of the golden-rumped elephant shrew *Rhynchocyon chrysopygus* in Kenyan coastal forests. *Biol. Conserv.* **67**, 153–160.
- FitzGibbon, C.D. (1997). The adaptive significance of monogamy in the golden-rumped elephant-shrew. *J. Zool. (Lond.)* **242**, 167–177.
- FitzGibbon, C.D., Mogaka, H. & Fanshawe, J.H. (1995). Subsistence hunting in Arabuko-Sokoke Forest, Kenya, and its effects on mammal populations. *Conserv. Biol.* **9**, 1116–1126.
- FitzGibbon, C.D. & Rathbun, G.B. (1994). Surveying *Rhynchocyon* elephant-shrews in tropical forest. *Afr. J. Ecol.* **32**, 50–57.
- Holroyd, P.A. & Mussell, J.C. (2005). Macroscelidea and Tubulidentata. In *The rise of placental mammals*: 71–83. Rose, K.D. & Archibald, J.D. (Eds). Baltimore: The Johns Hopkins University Press.
- IUCN (2007). IUCN Red List of Threatened Species, <http://www.redlist.org>
- Jones, T. (2006). Kipunji in Ndundulu Forest, Tanzania: Distribution, Abundance and Conservation Status. *Unpublished report for the Critical Ecosystem Partnership Fund, Fauna and Flora International and the Wildlife Conservation Society*, [http://www.cepf.net/xp/cepf/static/pdfs/Jones\\_kipunji\\_report\\_2006\\_website.pdf](http://www.cepf.net/xp/cepf/static/pdfs/Jones_kipunji_report_2006_website.pdf)
- Jones, T., Ehardt, C.L., Butynski, T.M., Davenport, T.R.B., Mpunga, N.E., Machaga, S.J. & De Luca, D.W. (2005). The Highland Mangabey *Lophocebus kipunji*: a new species of African monkey. *Science* **308**, 1161–1164.
- Kingdon, J. (1974). *East African mammals; an atlas of evolution in Africa*, Vol. IIA. New York: Academic Press.
- Kingdon, J. & Howell, K.M. (1993). Mammals of the forests of eastern Africa. In *Biogeography & ecology of the rain forests of Eastern Africa*: 229–241. Lovett, J.C. & Wasser, S.K. (Eds). Cambridge: Cambridge University Press.



- Lovett, J.C. (1993). Eastern Arc moist forest flora. In *Biogeography & ecology of the rain forests of Eastern Africa*: 33–55. Lovett, J.C. & Wasser, S.K. (Eds). Cambridge: Cambridge University Press.
- Menegon, M., Salvidio, S. & Loader, S. (2004). Five new species of *Nectophrynoides* Noble 1926 (Amphibia Anura Bufonidae) from the Eastern Arc Mountains, Tanzania. *Trop. Zool.* **17**, 97–121.
- Millien, V., Kathleen Lyons, S., Olson, L., Smith, F.A., Wilson, A.B. & Yom-Tov, Y. (2006). Ecotypic variation in the context of global climate change: revisiting the rules. *Ecol. Lett.* **9**, 853–869.
- Myers, N., Mittermeier, R.A., Mittermeier, C.G., de Fonseca, G.A.B. & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature* **403**, 853–858.
- Novacek, M. (1984). Evolutionary stasis in the elephant-shrew, *Rhynchocyon*. In *Living fossils*: 4–22. Eldredge, N. & Stanley, S.M. (Eds). New York: Springer.
- Rathbun, G.B. (1978). Evolution of the rump region in the golden-rumped elephant-shrew. *Bull. Carnegie Mus. Nat. Hist.* **6**, 11–19.
- Rathbun, G.B. (1979). The social structure and ecology of elephant-shrews. *Z. Tierpsychol.* **20** (Suppl.), 1–77.
- Rathbun, G.B. & Kyalo, S.N. (2000). Golden-rumped elephant-shrew. In *Endangered animals, a reference guide to conflicting issues*: 125–129, + 340–341 Reading, R.P. & Miller, B. (Eds). Westport: Greenwood Press.
- Rovero, F. & Rathbun, G.B. (2006). A potentially new giant sengi (elephant-shrew) from the Udzungwa Mountains, Tanzania. *J. East Afr. Nat. Hist.* **95**, 111–115.
- Salvidio, S., Menegon, M., Sindaco, R. & Moyer, D.C. (2004). A new species of elongate seps from Udzungwa grasslands, southern Tanzania (Reptilia, Gerrhosauridae, *Tetradactylus* Merrem, 1820). *Amphibia-Reptilia* **25**, 19–27.
- Schipper, J. & Burgess, N. (2004). Eastern Arc forests. In *Terrestrial ecoregions of Africa and Madagascar*: 250–252. Burgess, N., D'Amico Hales, J., Underwood, E., Dinerstein, E., Olston, D., Illanga, I., Schipper, J., Taylor, R. & Newman, K. (Eds). USA: World Wildlife Fund.
- Schmitter, D.A. (2005). Order Macroscelidea. In *Mammal species of the world*: 82–85. Wilson, D.E. & Reeder, D.M. (Eds). Baltimore: Johns Hopkins University Press.
- Simons, E.L., Holroyd, P.A. & Bown, T.M. (1991). Early Tertiary elephant-shrews from Egypt and the origin of the Macroscelidea. *Proc. Natl. Acad. Sci. USA* **88**, 9734–9737.
- Springer, M.S., Cleven, G.C., Madsen, O., de Jong, W.W., Waddell, V.G., Amrine, H.M. & Stanhope, M.J. (1997). Endemic African mammals shake the phylogenetic tree. *Nature* **388**, 61–64.
- Stanhope, M.J., Waddell, V.G., Madsen, O., de Jong, W.W., Hedges, S.B., Cleven, G.C., Kao, D. & Springer, M.S. (1998). Molecular evidence for multiple origins of Insectivora and for a new order of endemic African insectivore mammals. *Proc. Natl. Acad. Sci. USA* **95**, 9967–9972.
- Stanley, W.T., Rogers, M.A. & Hutterer, R. (2005). A new species of *Congosorex* from the Eastern Arc Mountains, Tanzania, with significant biogeographical implications. *J. Zool. (Lond.)* **265**, 269–280.
- Wasser, S.K. & Lovett, J.C. (1993). Introduction to the biogeography and ecology of the rain forests of eastern Africa. In *Biogeography & ecology of the rain forests of Eastern Africa*: 3–6. Lovett, J.C. & Wasser, S.K. (Eds). Cambridge: Cambridge University Press.

## Supplementary material

The following supplementary material is available for this article:

**Appendix S1.** Material examined by G.B.R. Specimen acronyms are BMNH (Natural History Museum), CAS (California Academy of Sciences), RMCA (Royal Museum of Central Africa). Taxa of *Rhynchocyon* follow Corbet & Hanks (1968). Collection locations are transcribed from specimen labels.

This material is available as part of the online article from: <http://www.blackwell-synergy.com/doi/10.1111/j.1469-7998.2007.00363.x>

(This link will take you to the article abstract).

Please note: Blackwell Publishing are not responsible for the content or functionality of any supplementary materials supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.