Habitat use by radio-tagged Namib Desert golden moles (*Eremitalpa granti namibensis*)

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Abstract

The Namib Desert golden mole (*Eremitalpa granti namibensis*) is morphologically, physiologically and behaviourally specialized for living in the harsh loose-sand desert. Ecological studies have relied on visually tracking animals on the surface of sand dunes. A radio tag would allow individuals to be more reliably located, even while under the sand. We developed a radio attachment and gathered preliminary data on winter habitat use by six individuals during 21 days. We compare data from previous studies and suggest that the greater diurnal activity, smaller home ranges, and more restricted movement patterns that we found are related to the unusual thermal and metabolic biology of *Eremitalpa*.

Key words: activity budget, *Eremitalpa*, golden mole, home range, Namib Desert, Namibia, radio-tracking

Résumé

La taupe dorée du Désert du Namib (*Eremitalpa granti namibensis*) est morphologiquement, physiologiquement et comportementalement spécialisée pour vivre dans le rude désert de sable fin. Des études écologiques se sont basées sur l'observation visuelle des animaux à la surface des dunes de sable. Un marquage radio permettrait de localiser plus exactement les individus même sous la surface. Nous avons développé un dispositif radio et nous avons réuni des données préliminaires sur l'utilisation hivernale de l'habitat par six individus pendant 21 jours. Nous comparons les données d'études précédentes et nous suggérons que la plus grande activité diurne, les plus petits espaces vitaux et les schémas de déplacements plus restreints que nous avons relevés sont liés à la biologie thermique et métabolique inhabituelle d'*Eremitalpa*.

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Introduction

The golden moles (family Chrysochloridae, order Afrosoricida) are part of an ancient African radiation of mammals (supercohort Afrotheria) that includes elephants, sea cows, hyraxes, sengis or elephant-shrews, tenrecs and golden moles (Bronner & Bennett, 2005). The Namib Desert golden mole (*Eremitalpa granti namibensis*) is monospecific and is among the more unusual endemic vertebrates of the Namib Desert of south-western Africa.

The climate of the long and narrow sand sea areas of the Namib Desert is largely the result of being in a rain shadow from eastern monsoon systems and the influence of cool and moist (foggy) air off the cold coastal Benguela Current (Robinson & Seely, 1980). These geo-climatic conditions, present for at least the last five million years (Ward & Corbett, 1990), are associated with the evolution of a large number of endemic plants and animals (Seely & Griffin, 1986), including *Eremitalpa*.

The natural history of *Eremitalpa* is unusual in many respects, mostly related to its shifting desert-dunes habitat. Although it is relatively small (20–30 g), it has a typical subterranean egg-shaped body, with short powerful legs and no functional eyes, external pinnae or tail. In the past, biologists have gathered ecological information on these nomadic animals by visually tracking their footprints across the surface of dunes or their subsurface furrows that they leave while 'swimming' in loose sand (Holm, 1969; Fielden, Perrin & Hickman, 1990a; Narins *et al.*, 1997). Most studies have been done at the Namib Desert Ecology Research Unit at Gobabeb, Namibia (Seely, 1990), which is 110 km SW of Swakopmund and 58 km inland from the coast.

To understand better the unusual behavioural ecology of *Eremitalpa*, a reliable method of identifying and following individuals while they are inactive or sand swimming was needed. Although radio tracking would overcome the limitations of visual tracking, developing a radio tag attachment on a small mammal that swims through loose sand presents challenges not found in animals that 'swim' through air or water, or travel in burrows. Therefore, our main objective was to determine if we could develop a radio tag for golden moles. Our secondary objective was to establish the success of a radio tag by using it to gather preliminary information on the spatial and temporal ecology and thermal biology of *Eremitalpa*.

Materials and methods

We conducted our study on Die Duine Farm within the privately managed NamibRand Nature Reserve in south-western Namibia (25°13.401′S, 16°02.338′E). Die Duine is on the eastern edge of the Namib Desert sand sea, 1080 m above sea level, and about 120 km inland and 325 km south-west of the coastal town of Swakopmund. The region has cool dry winters and warm moist summers, which are typical of the Namib Desert (Robinson & Seely, 1980). The average rainfall (1967–2004) at Aandster Farm, which is about 15 km south of our study site, was 81.3 mm, with greater than 70% falling from January to March, inclusive. Mean daily maximum and minimum air temperatures (1999–2004) at Keerweder, about 30 km north of Die Duine, were 34.2 and 12.5°C, with the maxima occurring during November–April and the minima during May–October. We used miniature data loggers (iButton model DS1921G-F5, Maxim Integrated Products (Sunnyvale, CA, USA) 17 mm diameter × 6 mm deep, error = ±1°C) to gather hourly temperature profiles during our study. As we gathered information on the movements of the golden moles, we repositioned data loggers in the habitat, thus creating different data sets.

Golden moles were captured by hand after visually following their surface foot tracks to likely subsurface resting locations, where they were dug out with a spade. Although we had planned to radio-tag all the golden moles on a single dune line, our local field assistant could not hand-catch specific animals and we did not have the materials to use drift fences, which are more effective in capturing animals in a specific area (Seymour & Seely, 1996). Thus, our radio-tagged golden moles were located on four different dune lines spread across 5 km of the dune sea.

Newly captured golden moles were kept overnight in plastic pails full of sand and then tagged while torpid before sunrise. Our custom-built radio transmitters (Blackburn Transmitters, Nacogdoches, TX, U.S.A.) measured 12 × 5 × 4 mm and weighed 0.3 g. They had a 7.0-cm-long whip antenna made of nylon-coated stainless steel fishing leader wire (7 × 7 Surflon Micro Supreme 20 lb test), a pulse interval of 3 s at 164 MHz, a predicted battery life of 20 days (but lasted 30 days), and a line-of-sight range of *c.* 90 m (75 m when buried 10 cm in sand). We attached the transmitters to the apex of the rump by pushing the transmitter coated with cyanoacrylate adhesive (Devcon ZipGrip HV2200, product #44225) into the 1-cm-deep parted fur (Rathbun & Rathbun, 2006a). When the transmitter was seated against the rump, we immediately pressed the surrounding hair firmly against the radio, which was mostly hidden by the surrounding fur. The whip antenna trailed behind like a tail. Golden moles were put in a dark pail without sand for about 15 min while the adhesive cured, and then allowed to dig and hide in sand until they were released at their capture sites within 18 h of capture.

To test the accuracy of our radio-tracking system (Communications Specialist receiver model R-1000 and Telonics 'H' style receiving antenna), we buried a golden mole transmitter 20 cm below the surface of the sand and on five blind trials radio-located the surface position of the transmitter within 0, 5, 7, 10 and 0 cm. Because the golden moles frequently sheltered in 0.5–2.0 m diameter hummocks that were often covered with dense spiny bunch grasses, determining exact radio-locations was sometimes difficult. Nevertheless, we believe that our horizontal location errors were never greater than 30 cm, and most of the time they were within 10 cm.

We mapped all radio-tagged golden moles to within about 1 m by first determining the location of a nearby acacia tree trunk with a global positioning system (GPS) receiver and then subsequently calculating (O'Leary, 1998) all golden mole locations based on the distance and compass bearing to the trunk. We used this method because it is more accurate than using a GPS receiver alone (Rathbun & Rathbun, 2006b). Home ranges (Minimum Convex Polygon, or MCP, using 100% of loci) and straight-line distances between successive radio-locations were calculated with Ranges 6 software (Kenward, South & Walls, 2002).

From 10 June to 10 July 2005 inclusive, during the cold and dry austral winter, we located the radio-tagged golden moles three times each day: within an hour each side of sunrise (06:45 hours at compass bearing 80°), noon and sunset (17:15 hours at 315°). The golden moles did not move often enough to justify more frequent radio-fixes. Also, this regime reduced our habitat trampling and influence on golden mole behaviour. For example, if we walked heavily on the ground or brushed against clumps of grass near radio-tagged golden moles, the intensity of their radio signal sometimes decreased, suggesting that they burrowed deeper into the sand because of the disturbance.

Surface tracking the tagged golden moles was difficult because wind obliterated their furrows and footprints, the spoor of multiple golden moles at a site sometimes could not be distinguished, and other species disturbed spoor. When we were able to visually track the surface movements of a tagged individual, we included the most peripheral loci in our analysis of home range areas, but we did not include these data in calculating linear distances travelled.

Within 20 cm of each radio-location, we scored the general topography (upper sand dune, slope of sand dune, and flat between dune lines), specific topography (hummock or not), orientation to hummock (four primary compass co-ordinates), and the dominant perennial plant associated with each locus (five species of grass and a small bush). Statistical tests were carried out using Microsoft Excel software, and probability values less than 0.05 were considered significant.

Results

Nine *Eremitalpa* were captured, but because of the dense fur surrounding their genital area, we may have incorrectly determined some sexes. One of the nine (20 g female) died in captivity while we experimented with a radio collar, another (20.5 g ?female) was released without a tag, and the transmitter failed on a third (25.0 g ?female). Six animals were successfully radio-tracked (Table 1). Radio-tags were shed from three animals when the fur pulled off the skin, two transmitters were removed on final re-capture by clipping the fur between the radio and skin, and one animal was abandoned after multiple re-capture attempts failed.

The average home range size for the six radio-tagged golden moles was 0.16 ha, with a range of 0.05–0.56 ha. The mean maximum home range span was 71.7 m, with a range of 38.0–125.0 m (Table 1). The average distance moved during consecutive 24-h periods was 13.5 m, with a range of 0–82.0 m. Although the variation between individuals was significant (ANOVA, df = 5, $F = 2.94$, $P < 0.02$), our data do not allow us to assess the factors contributing to the variation.

The golden moles moved during day and night; they changed position by at least one metre during daylight an average of 46% of days (range 25–74%) and at night an average of 84% of days (range 47–100%). Based on the same data set, the average straight-line distance moved during daylight was 8.8 m (variance = 118.5) compared with 5.6 m (variance = 137.6) at night. These averages, however, are not significantly different (*t*-test, $t = -1.9$, df = 176, two-tailed $P = 0.057$). The six golden moles did not change positions an average of 42.6% of 24-h days, with a range of 33.3–50.8%. Inactivity was not restricted to daylight or night periods. There were 25 cases when an animal did not move for two consecutive days, two cases for 3 days, three for 4 days, two for 5 days, and one case for eleven consecutive days.

We excavated two torpid golden moles that were located about 15 cm below the surface on separate vegetated hummocks. We found no permanent burrows or chambers associated with the animals. Based on signal strength and crude triangulation, inactive golden moles were within about 30 cm of the surface. An exception to this was when

Table 1 Summary data for *Eremitalpa* captured at Die Duine Farm, NamibRand Nature Reserve, Namibia

ID no.	Sex	Weight (g)	Date tagged	Fate	Days tracked (no. of loci)	Mean distance ± SE, n (range)	Home range, ha (max diameter, metres)
2	M	15.5	16 June 2005	Shed TX	7 (19)	16.8 ± 4.1, 7 (2.2–29.4)	0.12 (73)
3	F?	22.0	19 June 2005	Shed TX	14 (43)	8.7 ± 1.5, 13 (1.0–18.7)	0.05 (38)
5	M?	20.0	19 June 2005	Shed TX	20 (80)	14.9 ± 4.9, 18 (0–82.0)	0.56 (125)
6	F?	17.5	20 June 2005	Recaptured	20 (64)	11.8 ± 1.4, 19 (1.0–23.6)	0.09 (60)
7	F?	20.5	20 June 2005	Abandoned	21 (68)	5.5 ± 1.2, 21 (0–19.0)	0.05 (41)
9	M	29.5	1 July 2005	Recaptured	10 (31)	23.3 ± 7.4, 9 (0–60.5)	0.11 (93)

Sex column: F = female, M = male, ? = uncertain. Fate column: TX = transmitter. Mean distance column: mean metres moved during consecutive 24-h periods; SE = standard error of the mean, n = sample size. Home range column: calculated as minimum convex polygons with 100% of radio fixes.

Table 2 Location frequency distribution for six radio-tracked *Eremitalpa* on vegetated hummocks in the morning, at noon and evening (see Materials and methods for definitions) at Die Duine Farm, NamibRand Nature Reserve, Namibia

	North	East	South	West	Total
Morning	31	16	6	8	61
Noon	36	17	4	5	62
Evening	43	9	1	18	71
Total	110	42	11	31	194

we tried to excavate nontorpid animals, which often escaped by digging deeper than 50 cm.

The distribution of radio-locations (n = 271) for the six golden moles was 73.8% on upper sand dunes, 18.8% on sand dune slopes (edges) and 7.4% on flats between sand dune lines, but none were located farther than a few metres into the flats. Using the same data set, 70.5% of loci were located within 20 cm of hummocks and 29.5% were beyond.

The radio-located (n = 271) golden moles were within 20 cm of vegetation, either on or off of hummocks, 94% of the time. In decreasing frequency, 78.8% were found to be associated with Ostrich Grass (*Cladoraphis spinosa*), 15.3% Long Bushman Grass (*Stipagrostis ciliata*), 2.0% Grey Bush (*Hermannia mimifolia*), 1.6% Gha Grass (*Centropodia glauca*), 1.6% Bushy Bushman Grass (*Stipagrostis lutescens*) and 0.8% Dune Grass (*Stipagrostis sabulicola*). Based on a subjective visual assessment, Ostrich Grass and Long Bushman Grass clearly dominated all other vegetation on the dunes and thus the golden moles appeared to be associated with the different plants according to their approximate frequencies of occurrence.

To determine the spatial and temporal use of vegetated hummocks, we used a data set with 194 radio locations (Table 2). The golden moles used the north side of hummocks 56.7% of the radio-locations, east side 21.6%, south side 5.6% and west side 15.9%. The side of the hummocks that they used tended to track the temporal position of the rising and setting winter sun, avoiding the deeply shaded southern side at all times (Table 2; Fisher Exact Contingency, $P = 0.013$). This pattern was probably related to the diel changes in sand temperature (Fig. 1).

Discussion

All but one of our radio-tags remained attached long enough for us to gather meaningful data; indeed, half the animals remained tagged for the duration of the expected life of the batteries (20 days). This success allowed us to gather sufficient data for comparison with published results from previous studies.

Comparisons between studies that use different methods should be done with care, but when the results are extreme some discussion is warranted. The studies of *Eremitalpa* at Gobabeb indicate nearly exclusive nocturnal activity (Fielden, Hickman & Perrin, 1992), whereas our animals were active during the day as well as at night. Our radio-tagged golden moles also had much smaller mean home ranges (0.16 ha) and on average moved remarkably shorter distances (13.5 m) compared with those at Gobabeb, which occupied mean ranges of 4.63 ha (±standard deviation = 3.57, n = 8; Fielden, 1991) and made average daily movements of 1.41 km (95% confidence limit = 434 m, n = 13; Seymour, Withers & Weathers, 1998). There are three main factors that should be considered when evaluating these differences.

First, it is possible that the radio tags hindered movements, and altered the behaviour, of the golden moles. However, we do not believe this is the case because none of our transmitters were shed because of antenna entanglement, which was the case during a previous radio-tagging attempt with larger radios (G. Bronner, pers. comm.). Also, we found no detectable weight loss, which often occurs when radio-tags adversely affect mammals.

Second, there are biases inherent in gathering spatial data by visually tracking golden moles. For example, spoor (Holm, 1969; Fielden *et al.*, 1990a; Narins *et al.*, 1997) is susceptible to obliteration from wind (common in the Namib), and degradation from the activities of other animals, possibly resulting in home range and movement underestimation. Alternatively, individual identification is not possible with spoor tracking and it is possible that tracks from multiple individuals will be confused, resulting in exaggerated home ranges. However, we assume that these potential biases are not contributing greatly to our comparison.

The third, and potentially most significant factor is the short duration of our study, which was restricted to the cold winter months of June and July compared with monthly sampling through a year during Fielden's (1991) study. If we had gathered data during a broader period the result may have been more similar to those from Gobabeb.

The seasonal temperature and rainfall regimes at Gobabeb and Die Duine, which are about 120 km apart, are similar (Robinson & Seely, 1980; Southgate, Masters &

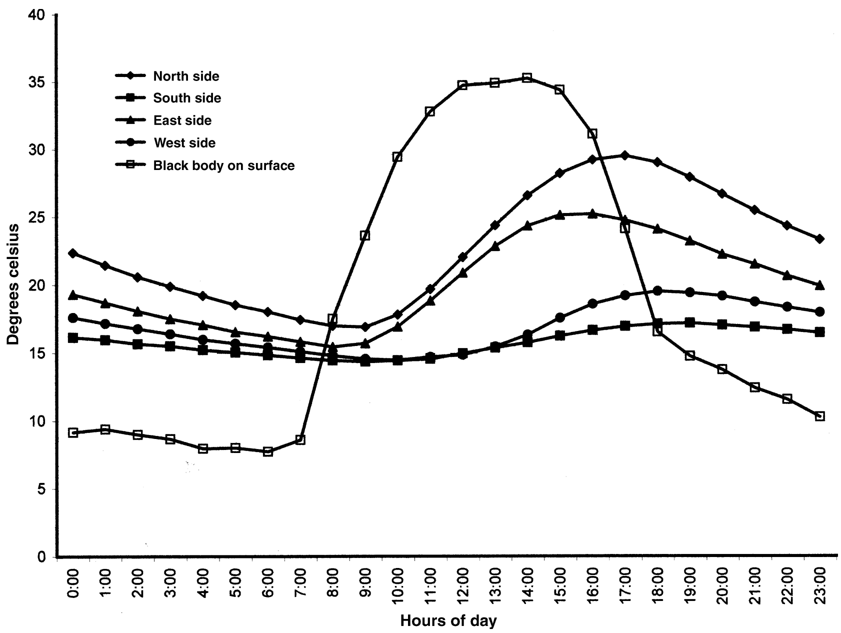

Fig 1 Twenty-four-hour mean hourly temperature on top of a dune line, Die Duine Farm, NamibRand Nature Reserve, Namibia, from 24 June to 10 July 2005 inclusive. Black body temperature logger was at the surface of sand with no vegetation nearby, while the other loggers were 10 cm deep in the sand and 10 cm from the edge of a hummock covered with ostrich grass (*Cladoraphis spinosa*)

Seely, 1996), but Gobabeb's annual (1962–1991) average precipitation is 56 mm year^{-1} (19 mm from rain and 37 mm from fog), whereas the mean rainfall at Die Duine is 81.3 mm year^{-1}, with little or no fog. The more mesic conditions in the Die Duine area result in greater plant biomass than at Gobabeb, although species composition is similar (Southgate *et al.*, 1996). Presumably, there is also a greater invertebrate prey base for golden moles at Die Duine, possibly resulting in smaller home ranges and shorter movements. Indeed, Fielden *et al.* (1990a) suggested that more mesic inland conditions result in higher densities and greater sand-swimming (versus surface locomotion) by *Eremitalpa*. We believe, however, that the unusual metabolic traits of *Eremitalpa* are more important than prey availability in explaining the different behaviours and habitat use at the two sites.

Eremitalpa has a high rate of thermal conductance, a lower than expected body temperature and metabolic rate, and an overall poor ability to thermo regulate, which results in animals being sluggish at temperatures below about 26°C, uncoordinated below 20°C and torpid below about 15°C (Fielden, Perrin & Hickman, 1990b; Fielden *et al.*, 1990c; Seymour *et al.*, 1998). Considering that sand temperatures at 10 cm deep during our study often were below 26°C and in the shade never rose above 20°C, the small home ranges, limited movements, and torpor we observed were probably because of the cold winter temperatures and the golden mole's thermolability. However, the warmer sand temperatures near the surface, from about mid-day to mid-night (Fig. 1), probably explain the unexpected diurnal activity of the golden moles at Die Duine.

The unusual metabolic traits of *Eremitalpa* are thought to be closely related to the conservation of energy during their wide-ranging movements in the harsh desert environment, where prey are scarce and widely dispersed (Fielden *et al.*, 1990a) and moisture is often nonexistent (Fielden *et al.*, 1990b). Our winter season findings of reduced home ranges, considerable diurnal activity, and preference for the warm sides of hummocks, further demonstrates the importance of thermal regimes and metabolism in determining the behavioural ecology of *Eremitalpa*. With a successful method of radio-tracking *Eremitalpa*, more rigorous field studies are now possible.

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