Aspects of the biology and behaviour of the Bush Karoo Rat (*Otomys unisulcatus*) in the Central Karoo, South Africa.

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INTRODUCTION:

The Bush Karoo Rat (*Otomys unisulcatus*) is a common and widespread rodent endemic to the semi-arid western and west-central regions of South Africa. It is diurnal, only rarely emerging at night. In southern Africa this is the only rodent that constructs and occupies large, oval stick lodges at the base of bushes. These nests, along with its diurnal habits, make this species a relatively easy subject for field studies of its behavioural ecology.

Previous studies have been completed at the northern foot of the Great Swartberg range, the mountain barrier separating the Little and the Great Karoo, and in the far west along the Atlantic Ocean coastal plain.Vermeulen & Nel (1988) concentrated mainly on lodge building and structure, with Du Plessis, Erasmus & Kerley (1989) comparing thermoregulation of *Otomys unisulcatus* and *Parotomys brantsii*, Du Plessis, Kerley & Winter (1991) examined dietary patterns of these two species. Other aspects that have been studied are biomass and energy requirements (Kerley & Erasmus 1992), refuge strategies and habitat segregation (Du Plessis & Kerley 1991), refuge microclimates (Du Plessis, Kerley & Winter 1992) and the influence of fire on distributional range (Kerley & Erasmus 1992). Our study was undertaken in the heart of this rodent's range in the central Great Karoo and focused on lodge structure, diet, reproduction, and behaviour.

STUDY AREA:

Our study site was on the farm "Swaelkrans" (31ºS; 22ºE), 15 km west of the village of Loxton on the central Karoo plateau. The altitude at the study location is 1332 m above-sea-level and the topography is mainly flat to gently undulating. The soils in the area are derived mainly from Beaufort shales and sandstones. The natural vegetation at the site is dominated by low, to very low, woody bushes and shrubs, predominantly *Lycium cinereium* and *Pentzia incarna.* This is usually referred to as Mixed Karoo Veld. Also within the study area were fields of alfalfa (*Medicago sativa*) under flood irrigation. In general, non-cultivated areas have been degraded by prolonged overgrazing by livestock.

The study area is characterized by hot summers (January: average maximum 31.1° C / average minimum 14.7° C) and cold winters (July: average maximum 13.3° C / average minimum 0.5° C) . Precipitation occurs mainly in late Summer and into early Autumn, but is variable from year to year (average annual rainfall: 268 mm, range: 168 – 431 mm). During our study (February 2000 to May 2001),we recorded 255 mm of rainfall.

We selected three sites within the study area, two for live-trapping and observations, and a third where animals were collected on a monthly basis.

Study site 1 included two adjoining alfalfa (lucerne) fields under seasonal flood irrigation. At times the alfalfa fields were heavily grazed by sheep and goats and at other times the crops was cut and baled. The fields were fallow during the winter months. Natural vegetation ran along the fence line that bisected the two fields. It was in this narrow belt that rat lodges were located. *Lycium cinereium* bushes, under which lodges were constructed, dominated the vegetated fence line. The only other abundant perennial plant present was *Pentzia incarna*. After irrigation and during wetter periods *Atriplex semibaccata* and *Chenopodium mucronatum* covered extensive areas. Seasonally *Tribulus* sp., *Salsola kali, Malva parviflora* and certain grasses occurred. Fourteen lodges were located throughout this site, seasonal flooding occurred in depressions around five lodges, completely cutting them off from the feeding grounds.

Study site 2 was located 1.93 km from site 1, and within a fenced paddock but this did not hinder movement of the rats. The site was densely covered by *Psilocaulon absimile*, with many stands of *Lycium* species, as well as *Pentzia incarna* and *Bassia salsoloides*. During the rainy season *Chenopodium mucronatum* and *Atriplex semibaccata* were common and widely utilized by the rats. Twenty lodges were located throughout the site. During the study period no domestic livestock utilized the area, in contrast to site 1.

Study site 3 was located 650 m to the east of site 1 and 1.9 km to the south of site 2, it consisted of a sparsely vegetated low rocky ridge, with a scattering of old stone buildings and sheep pens at the edge of alfalfa fields. Nineteen lodges were scattered along two sides of the outer perimeter of the irrigated fields. The area sampled measured 170 m by 82 m and was periodically grazed and browsed by sheep and goats. The dominant natural vegetation included *Mesembryanthemum querichianum* and *Psilocaulon* species, as well as *Pentzia incarna* and *Lycium cinereium*.

METHODS AND MATERIALS:

Fieldwork took place from February 2000 to May 2001. *Otomys unisulcatus* were trapped at study sites 1 and 2 with Sherman-type live traps baited with fresh alfalfa. Traps were set in grids. At Site 1 the trapping formation formed a 'T', with the horizontal arm covering 130 m x 40 m (24 traps in 3 rows 20 m x 20 m apart), and the vertical arm 60 m x 10 m (15 traps in 3 rows 15m x 5m apart). Thirty nine traps were used in this grid. At Site 2 forty traps were laid 15 m apart in an evenly spaced grid over the entire area measuring 70 m x 40 m.

Grid trapping was undertaken on four consecutive days each month at sites 1 and 2 for a period of 12 months. Traps were checked four times each day during daylight hours. During extremely hot periods in summer and below freezing days in winter, traps were closed for varying periods to prevent rats from succumbing to the extreme conditions. This procedure ensured that trapping mortality was kept to a minimum. Traps were set 30 minutes before sunrise and were closed 30 minutes after sunset. Only during May and June 2000, traps were left set for 24 hours to ascertain which species of nocturnal rodents were active within the trapping grids.

Live trapping was also undertaken around all nests at both site 1 and 2 during the period of 19 February to 24 April 2000 and again from 11 December 2000 to 25 April 2001. Trapping was continued until 20 animals were captured at each of the 2 study sites. Rats captured in live traps were sexed, weighed, measured, reproductive condition noted (females: perforate or not, lactating; males: abdominal or scrotal and enlarged testes), toe-clipped for subsequent identification and released at point of capture.

At Site 3, a total of 123 rats were captured in break-back traps over a period of 12 months, 58 sexually mature males and 65 mature females. No live trapping was undertaken at this site. Aspects

examined included females being checked for the presence of embryos and foetuses. All material was preserved in 10% formaldehyde, with selected specimens being later transferred to 70 % ethyl alcohol. Skulls were cleaned and dried, upper and lower incisors were examined for absence or presence of grooves.

Within study sites 1 and 2, each lodge was marked with a numbered peg and its position mapped. Length, breadth and height were recorded for ten selected lodges, as were widths and lengths of pathways linking lodges and "safe zones". Five lodges were dismantled to note construction , four of these lodges were also weighed. The locations within the five lodges of openings, nests, latrines, and passages were noted. Associated fauna within lodges was also recorded.

Feeding records were established by direct observations and samples of plants were collected when identity needed to be established. Direct observations of behavioural activities were noted. Approach was usually close enough to obviate the need for binoculars as individuals at regularly observed lodges soon became used to the observer. Lodge number 10 at Lucerne Site 1 and Lodge number 22 at the Reservoir Site 2 were selected for observation as most activity was noted there. The two lodges were kept under observation one morning and one afternoon each week throughout the study period. Maximum number of *Otomys* observed at one time, length of feeding and length of basking periods were recorded.

RESULTS:

Body measurements:

Sexual dimorphism was found to exist, with adult males averaging slightly larger than adult females (Tables 1 and 2; Student T-test for head and body measurements: p=0.000428 (two-tailed, equal var.), Student T-test for Skull width: p=0.00105 and Student T-test for Skull length p=0.01296).

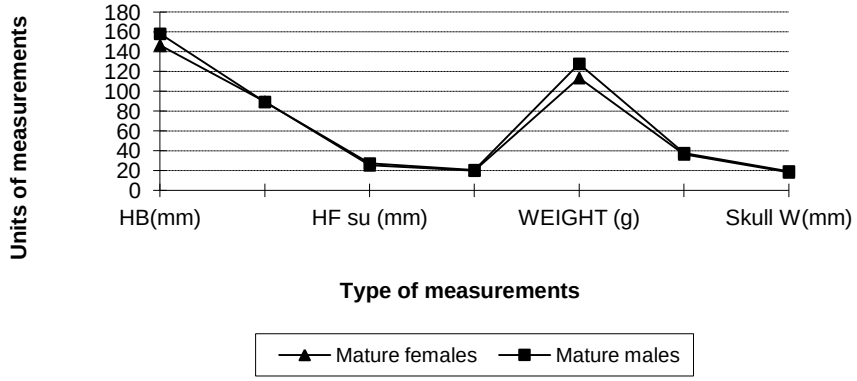
Table 1: Summary of body and skull measurements for 39 adult male *Otomys unisulcatus.*

	HB(mm)	*TAIL(mm)*	*HF su (mm)*	*EAR (mm)*	*WEIGHT (g)*	*Skull L (mm)*	*Skull W(mm)*
average	158.09	89.35	27.24	20.58	127.79	37.72	19.27
maximum	186.00	110.00	30.00	23.40	172.00	43.00	21.90
minimum	127.00	46.00	24.40	17.20	78.00	32.50	16.20
standard deviation	13.85	10.98	1.11	1.40	20.03	2.14	1.30

Table 2: Summary of body and skull measurements for 32 adult female *Otomys unisulcatus*

	HB(mm)	*TAIL(mm)*	*HF su (mm)*	*EAR (mm)*	*WEIGHT (g)*	*Skull L (mm)*	*Skull W(mm)*
average	146.54	89.56	25.43	20.05	113.44	36.48	18.31
maximum	172.50	107.40	27.20	27.50	176.00	40.00	20.40
minimum	115.00	67.00	21.00	16.60	80.00	31.10	16.10
standard deviation	12.08	7.46	1.31	1.95	23.00	1.91	1.00

Figure 1: Sexual dimorphism *Otomys unisulcatus* comparing averages of all measurements



Incisors:

In a sample of 123 skulls collected in the present study (no attempt has been made to separate male and female), 10 (8.1%) had no, or only very slight, grooves on the front surface of the upper incisors, and 3 (2.4%) exhibited slight ridges, or lines in the lower incisors. The rest were found to have distinct but shallow grooves on the upper incisors but no grooves on the lower incisors.

Diet:

Otomys unisulcatus are strictly herbivorous, with their diet consisting of stems, leaves, flowers and fruits of a range of bushes, shrubs and herbaceous plants, including succulents, perennials, and annuals. Although grasses and their seedheads were observed as being harvested and carried to the lodges, we observed none being eaten.

At study sites 1 and 2 *Lycium cinereium* constituted a large proportion of the diet, including stems, leaves, inflorescences, and fruits being harvested and eaten throughout the year. However, during the drier periods when *Lycium* spp. lose their leaves, other plant species formed a greater part of their diet. Alfalfa and *Pentzia incarna* were particularly important at study site 1, whereas at study site 2, where no alfalfa was available, the most important food plants in the dry season were *Psilocaulon absimile* and *Pentzia incarna*. During the summer / autumn rainy season the diet was more varied. At this time food plants included *Atriplex semibaccata*, *Chenopodium mucronatum*, *Tribulus terrestris*, *Salsola kali* and the seed pods of the alien tree *Prosopsis glandulosa*, which dropped to the ground.

Check-list of plants, or parts, eaten by *Otomys unisulcatus* during our study.

Argemone ochroleuca
Atriplex nummularia
Atriplex semibaccata
Atriplex vestita
Bassia salsoloides
Chenopodium mucronatum
Erodium cicutorium
Hibiscus sp.
Lycium cinereium
Malva parviflora
Meticago sativa

Mesembryanthemum querichianum
Pentzia incarna
Prosopsis glandulosa
Pseudognaphalium undulatum
Psilocaulon absimile
Psilocaulon utile
Salsola kali
Salsola sp.
Tribulus terrestris

Reproduction:
Of the 32 adult female *Otomys unisulcatus* collected from study site 3(Table 4), 27 were pregnant. Pregnant females were collected in all months except June. The number of foetuses per female (n = 27) ranged from two to five, with a mean of 2.6. Only one female carried five foetuses, and just one carried four foetuses. The lightest pregnant female *Otomys* weighed 82 g, 31 g lighter than the mean for the sample. She was carrying four foetuses and was collected in November. The female carrying the five small foetuses weighed 135 g and was collected in April.

Immature and juvenile *Otomys unisulcatus* were trapped and observed in all months of the year with notable peaks in January, May, June and July. Table 3 shows distribution of non-pregnant and pregnant females through the months of the year, table 4 shows distribution of mature and immature *O.unisulcatus* through the year.

Table 3: Distribution of non-pregnant and pregnant female *Otomys unisulcatus* through the months of the year.

	J	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*
Total mature	1	3	2	8	2	1	3	1	2	2	4	3
Non-pregnant	0	1	0	0	1	1	1	0	0	0	1	1
Pregnant	1	2	2	8	1	0	2	1	2	2	3	2
% pregnant	100	67	100	100	50	0	67	100	100	100	75	67

Table 4: Distribution of mature and immature *Otomys unisulcatus* through the months of the year.

	J	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*
Total	12	9	9	13	10	10	10	10	10	10	10	10
Immature	7	3	3	2	6	7	6	2	2	3	1	1
% immature	58	33	33	15	60	70	60	20	20	30	10	10

Lodge structure and observations:


Location of lodges:

At the study sites lodges were only located near human habitation, adjacent to irrigated alfalfa fields, along banks of river courses and around seasonal pans and dams, and this was directly related to the availability of fresh food close to lodges. Along river courses, pans and dams where the water had dried out lodges were abandoned, or only continued to be occupied for short periods after the water had disappeared. No lodges were observed far from water.

Of the 209 Otomys unisulcatus lodges located within and around the selected study sites the vast majority were situated at the bases of *Lycium cinereium* bushes. (See table 5)

Table 5: Location of lodges within the study area in association with specific plant species; that is where bushes were incorporated into the lodges.

Plant species	**Number**
Lycium cinereium	195
Lycium prunus-spinosa	9
Psilocaulon absimile	2
Rhus lancea	2
Pentzia incarna	1

Composition of lodges:

Not only was the bush *Lycium cinereium* critical to the construction of lodges, because of their densely tangled and thorny branches, but they were also an important source of food. In the study area the lodges were constructed to a large extent from the branches and twigs of *Lycium* spp. and *Psilocaulon absimile*. Other items recorded to have been used in lodge construction included tree bark, pine needles, sheep, horse and cattle droppings, grass and alfalfa stems, sheep wool, stones, bones, rags, wire, plastic, and string.

Ten lodges were measured (Table 6).

Table 6: Lodge measurements.

Lodge number	**Width (m)**	**Depth (m)**	**Greatest height (m)**
1	1.80	1.00	0.65
2	2.30	1.30	0.43
3	1.85	1.37	0.40
4	1.57	1.40	0.45
5	1.80	1.68	0.70
6	1.87	1.57	0.52
7	1.60	1.70	0.55
8	1.60	1.20	0.49
9	1.42	1.20	0.46
10	1.60	1.69	0.50

A further five lodges were measured as well as dismantled and weighed to establish materials used in nest construction, as well as internal structures (Table 7).

Table 7: Lodge composition.

Lodge number	**Weight**	**Entrances**	**Clean Chambers**	**Toilet Chambers**	**Main construction material**
1	15 kg	12	2 (1 grass lined)	1	*Pentzia* twigs
2	38.2 kg	8	4 (3 grass lined)	2	*Lycium* twigs; pine bark + needles

3	32.3 kg	12	2 (1 grass lined)	4 (possibly 2 more but partially collapsed)	*Lycium* + *Pentzia* twigs; only one incorporating porcupine quills
4	39.1 kg	12	2 (perhaps more)	2 clearly defined possibly several more	*Lycium* + *Pentzia* twigs
5	-	13	3 (all grass lined)	5	*Lycium* + *Pentzia* twigs

The clean chambers were generally located deeper within the lodge, with the toilet chambers (right) with floors of compacted faeces and urine mainly located on the outer sides and often open to the air. No stored food was located in any of the chambers of the five active nests opened. Grass seed heads were used as lining in some chambers.

During the study period two lodges were abandoned by *Otomys unisulcatus* and occupied by *Parotomys littledalei.* Typical whistling of *Parotomys* was heard from within the lodges over a period of at least three months. The lodges were modified by the "invaders" with a network of burrows below the stick structures. Similarly, several *Parotomys* burrow systems were occupied by *Otomys*, with the latter rapidly constructing stick lodges over the burrows. To what extent the burrows were utilized by *Otomys* was not ascertained during the course of the study. Neither was it clear as to whether *Otomys* constructed burrows themselves, if at all.

Radiating out from *Otomys unisulcatus* lodges were up to 15 runways (see right). Networks of pathways linked lodges, 'safe areas' used for storing food and eating, and feeding grounds. Pathway widths range from 6.5 to 9 cm. The feeding areas were often located at the intersections of pathways and were up to 10 m from the nearest lodge. Most lodge entrances were located at ground level, but several were situated at higher levels and usually terminating at the lodge surface in a flattened platform. Some of these platforms were clean, others bedded with compacted faeces and urine. Burrow systems constructed by *Rhabdomys pumilio* were frequently recorded in association with lodges.

Lodge building and additions to the lodges appears to take place throughout the year, with both males and females participating. On occasion, branches and other debris was seen to be collected but left in proximity of the lodge to be added later. Branches up to 18 inches in length were held in the mouth and dragged, or carried lying across the back, from collection sites up to 13 metres from the lodge. During the course of lodge building one female was seen gathering stones, and one dropped by her weighed 50 g.

The sizes of clean nesting chambers, lined and unlined chambers, and toilet chambers were fairly uniform and ranged from 15 cm by 15 cm to 30 cm by 20 cm length by width.

Associated fauna:

Only associated vertebrate fauna within and in close proximity to the lodges was recorded during this study. Both four-striped grass mice (*Rhabdomys pumilio)* and reddish-grey musk shrews (*Crocidura cyaneae)* coexist in the lodges of *Otomys unisulcatus*. Both species, a rodent and an insectivore, enter the lodges, forage in and around them, and make use of the cleared pathways. *Rhabdomys* frequently were observed to bask in close proximity to *Otomys*, after joining them in

the lodge bushes, especially in the cold winter months. *Otomys* were also frequently seen to chase *Rhabdomys* at the lodges and occasionally along the pathways. At site 2, located away from the alfalfa fields, particularly high numbers of *Rhabdomys* were present during the study period. During one day's trapping effort within the grid of 40 traps a total of 102 individual *Rhabdomys* were trapped. Each was marked and released.

During sampling of lodges and in the process of dismantling them to examine internal structure, *Crocidura* were seen leaving lodges on two occasions. The shrews were trapped regularly at lodges. When trapped, shrews were released and they immediately retreated into the lodges, suggesting that they use them to provide permanent shelter. A single marked *Crocidura* was recaptured at the same lodge five times.

Other rodents caught in proximity to lodges included Namaqua rock mouse (*Micaelamys namaquensis)*, multimammate mouse (*Mastomys coucha)* and pygmy mouse (*Mus minutoides)* but it is not known whether, or to what extent, they made use of *Otomys* lodges.

At three different lodges Cape skinks (*Trachylepis capensis*) were regularly seen entering and exiting over a period of several months. Ground agamas (*Agama hispida*), Bibron's geckos (*Pachydactylus bibronii*) and Cape gecko (*Pachydactylus capensis*) were trapped at lodges. During wet periods, Karoo toads (*Bufo gariepensis*) and Cape caco (*Cacosternum boettgerii*) were collected at lodges.

Three snake species, puffadder (*Bitis arietans*), mole snake (*Pseudaspis cana*) and Cape cobra (*Naja nivea*), all potential *Otomys* predators, were seen at various times entering lodges. The only other snake seen in the vicinity of *Otomys* lodges was the Karoo Sand Snake (*Psammophis notostictus*).

Predation:
During the study period 95 scats were collected within the study area of nine species of mammalian carnivores. Although positively identified *Otomys* remains were only found in the scats of Yellow Mongoose (*Cynictis penicillata*) and Small Grey Mongoose (*Galerella pulverulenta*), rodent remains were found in the scats of six of the other carnivore species. Both of the positive *Otomys* predation records were noted from diurnal carnivores.
Remains of *Otomys* were also found in the regurgitated pellets of both Grey Heron (*Ardea cinerea*) and Black-headed Heron (*Ardea melanocephala*) . These birds frequently were observed hunting in areas used by *Otomys* to forage.

Home range and lodge occupation:

During the study period 50 individual *Otomys unisulcatus* were trapped at Study Site 2 (Reservoir Site), of which 26 were female and 24 male. At Study Site 1 (Lucerne Site) 92 *Otomys* were captured during the course of the study, of which 46 were female and 46 were male. The animals were marked individually through clipping of toes. No animals were marked in such a way that individuals could be identified from a distance.

Ten lodges at site 1 and 12 lodges at site 2 were kept under regular observation throughout the study period. Number of *Otomys* observed on, or in close proximity to, a single lodge at one given time ranged from 1 individual to a high of 11 animals. The average for the maximum number of rats observed at 20 of the nests was 3.6. Nest 10 at site 1 and nest 22 at site 2 were observed regularly and in detail between June 2000 and May 2001. The numbers of occupants at both nests gradually decreased during this time.

Male number 73 at site 1 was recaptured 8 times, the furthest distance between recapture sites was 40m, he was captured at 5 different nests. For the most widely ranging female at the same site (no. 18) the maximum distance was 38 metres. At site 2 the movements were in general more restricted, with maximum distances of 15m for a male and 22m for a female.

Behaviour:

Feeding:
Foraging areas were dependant on the availability of adequate plant cover. When suitable food plants were depleted close to the lodges, the rats moved greater distances to forage. The availability of a particular food plant close to a lodge was not necessarily an advantage as food plant selection varied from feeding session to feeding session.

The direct observation showed that the observed *Otomys unisulcatus* at site 1 spent on average twice as long feeding than the individuals at site 2. At both sites the main basking and feeding took place in the morning and later afternoon hours, barely any activity at all was observed between 11:00 and 14:00. The first emergence was closely related to sunrise.

Runways, radiating from and between lodges, were used to travel to and from feeding grounds, usually with "safe havens" located at several points along the runways. The "safe havens" were located under bushes and food was frequently seen to be stored and consumed at such sites. Use of "safe havens" increased with greater distances from the home lodge. No lodge swap took place. Individuals came close to neighbouring lodges only.

Ground creeping plants, such as *Tribulus*, were often eaten at foraging sites. When feeding on the taller (25cm) *Pentzia* species *Otomys* would climb into the shrubs or eat whilst standing on their hind legs. On occasion, the front paws were used to pull twigs and stems closer to the mouth. Stems of taller plants such as *Psilocaulon absimile* (80cm) and alfalfa, were snipped off with the incisors into manageable lengths (up to 42 cm) and dragged back to the lodge or "safe haven" along a pathway (see image of dragmarks right). These stems were dragged, or carried in the mouth crossways and then later nipped into manageable pieces at the "safe havens" or lodges. Stems were held in the forepaws in an upright position, the rat sitting on its haunches.

Much foraging took place in taller bushes, such as the *Lycium* species and *Atriplex nummularia*. The *Otomys* climbed up to two metres into these bushes, where leaves and new shoots were nipped off with the incisors and eaten directly, or dropped to the ground to be eaten later. Other *Otomys* foraging on the ground, especially juveniles, often made use of food dropped in this way.

Feeding at times was observed to be communal. This was observed most frequently in the alfalfa fields, where the food source was uniform and abundant. All *Otomys unisulcatus* occupying a lodge would leave at the same time and head in single file down a pathway to the selected feeding ground. They would feed in relatively tight clusters for brief periods. This would be followed by frequent travel while carrying harvested alfalfa stems between the feeding grounds, and the lodges, or "safe

havens" along the pathway. Feeding bouts usually ended abruptly, when all the *Otomys* returned to the lodge together. Foraging patterns were observed to be eratic on a day to day basis. Feeding levels were not necessarily constant from all occupied lodges at the same time of the day. On some days there would be considerable feeding and harvesting from all observed lodges, at other times harvesting levels were limited. At this time feeding at the lodges was concentrated on material that had been harvested previously. Food selection was also variable, on some days only alfalfa was eaten, whilst on other days no alfalfa was taken, even though it was available.

Foraging took up a comparatively small part of the day, usually peaking after sunrise for a period of under one hour and again before sunset for less than one hour. Juvenile *Otomys* were observed to remain in close proximity to the lodge and did not move along the pathways to principle feeding grounds. The young fed on plant parts brought to the lodges by adults and sub-adults, or material dropped by feeding *Otomys* in the bush forming the canopy over the lodge.

During February and March 2000 some 145.5 mm of rain fell and many of the lodges under observation were surrounded by flood waters for several days, cutting the *Otomys* off from their feeding grounds. Prior to the flooding and at the onset of the rains large quantities of food plants were transported to, and stored on top of, the lodges.

Gnawing on dried twigs and larger branches, used in the lodge construction was presumed to be more of a tooth sharpening function than of food value. Some lodges had a single large branch used by all occupants for gnawing purposes. Table 8 shows observation periods and activities at nest 22, in table 9 the same for nest 10.

Table 8: Observation periods and activity at Nest 22 (in minutes):

	Total:	morning:	afternoon:	months in which observed
Number of observations:	20	13	7	
Average observation duration:	157.75	152.69	167.14	
Average basking duration:	73.35	74.27	50.71	
Longest basking duration:	175	175	135	August (winter)
Earliest basking hour:	05:45			January (summer)
Average feeding duration:	27.16	34.92	14.14	
Longest feeding duration:	130	130	41	September
Earliest feeding hour:	05:57			January (summer)

Table 9: Observation periods and activity at Nest 10 (in minutes):

	Total:	morning:	afternoon:	months in which observed
Number of observations:	20	12	8	
Average observation duration:	148.15	140.25	160	
Average basking duration:	71.55	71.83	71.13	
Longest basking duration:	135	135	135	June and May (winter)
Earliest basking hour:	05:40			January (summer)
Average feeding duration:	50.85	55.58	43.75	
Longest feeding duration:	162	162	100	June (winter)

Earliest feeding hour:	05:45			January (summer)

Grooming:
Very little time was observed to be spent on grooming around and away from the lodge. Auto-grooming was observed between periods of basking and lasted for very brief periods (5 – 20 seconds) per session. Self-grooming consisted of face-rubbing using the forepaws, in the manner of a cat, as well as scratching belly and genitalia with mouth and hind paws. Ears are rubbed with the hind feet. Adults occasionally were observed to groom juveniles, mainly using the mouth and incisors to do so. Grooming between adult male and female was observed but always of very short duration.

Nose to nose touching:
This interaction was commonly observed between individuals from the same lodge, involving adults and juveniles. Juvenile to juvenile, adult to juveniles and male to female, whenever they came together. Such interactions were particularly noted between individuals emerging from the lodge to join others basking; returning to and from the lodge from the feeding grounds, and when individuals were moving in opposite directions along the same pathway.

Play:
Juvenile play activity took place on, or in close proximity to, the lodge. It was always initiated by one *Otomys* chasing another at a run. Such chases were not of an aggressive nature and the animals rarely made contact during these chases. Frequently several juveniles would join in the chase but these were usually of short duration, rarely lasting more than a few seconds.

Aggression:
Otomys unisulcatus on the whole appear not to be aggressive towards one another, although occasional fighting was observed between mature males. On each occasion a male would pursue another male and after a short chase contact would be made. They would roll on the ground, biting and scratching each other, after which the loser would submit and run away. At this point the dominant individual made no attempt to pursue the loser. Serious wounds were observed being inflicted during the course of this study. Such injuries included severed tails at different points of their length, pieces of skin and tufts of hair torn from various parts of the body but mainly rump and back. Ear tears were frequently observed, as well as amputated toes and healed scars on the cheeks and forehead. Juvenile *Otomys* at lodges were often chased briefly by adults returning with food from the feeding grounds. After several attempts at removing food from adults they were then usually tolerated and were allowed to settle down and feed.

Male – male, male – female interactions:
Mature males were often seen to bask, feed and sleep on their own. Long periods were spent away from the lodge, particularly when juveniles were present. Adult males were frequently seen to lie up at "safe havens" where they were left undisturbed by other individuals. Some lodges had one adult male *Otomys* in residence, others two. Conflict was never observed between two adult males living in the same lodge. Conflict appeared to be restricted to males occupying different lodges. Some adult males could be indentified on the basis of ear tears and damaged tails. Adult male and female *Otomys* were frequently observed together. They often sun-basked together, touching and not infrequently with one lying across the body of the other. Grooming, although always of short duration, was frequently observed between sexes, and it was common to see male and female "pairs" foraging and feeding together.

Path sweeping:

Path "sweeping" was regularly observed in the wild populations. Debris, such as food waste, sheep droppings and wind-blown leaves, were swept away with a rapid side to side sweeping motion made with the front paws. Pathways were kept scrupulously clear. Sections of exposed runways were often canopied with twigs, especially those bearing thorns and spines. Pathways under the canopy were however kept clear and presented no hindrance to free movement. Path "sweeping" and placement of pathway canopies appeared to be a solely female activity.

Tail-flicking:

Tail-flicking was recorded on more than 100 occasions. It was only observed being executed by one lodge inhabitant at a time, even when several individuals were in sight. It was also commonly heard from inside the lodge when approached by the senior author. Tail-flicking was most frequently observed when a human, or potential predator, was passing within sight of a lodge. Direct observations of tail-flicking were noted when yellow mongoose (*Cynictis penicillata*) , jackal buzzard (*Buteo rufofuscus*) and black-headed heron (*Ardea melanocephala*) were in the vicinity of a lodge, or lodges. *Otomys* showed this behaviour frequently before scurrying into the cover of the lodge. On many occasions tail-flicking was recorded from lone adult males basking away from the lodge.

When tail-flicking the individual *Otomys* was especially alert, and the activity carried out whilst the individual was sitting on its haunches, giving a better view of the surroundings. Tail-flicking was commonly carried out when the *Otomys* is on all fours, especially in very open areas or at the lodge. In 50 observations the number of tail-flicks, although rapid, were counted with a maximum of 35 sideways sweeps per session. It involves a rapid side to side flick of the tail with a momentary pause. It is an intermittent – prrr – pause – prrr, the pause lasting from 0.25 to 1 second. The flicking noise is comparable in volume to the whistle of the closely related Parotomys species. The tail-flicking is more audible when executed in the lodge as the tail frequently strikes twigs and other material. On all occasions when the sex of the individual tail-flicking could be determined it was executed by an adult male.

Sun-basking:

Much of the time spent by *Otomys* outside the lodge was spent sun-basking, or lying up in the shade. As soon as they emerge from the lodge, in the early morning when the sun first strikes the lodge, or the sheltering bush, they bask. Basking takes place before feeding, between bouts of feeding at various times throughout the day and before sunset.

Basking takes place mostly on the top or sides of the lodge, close to the lodge at a "safe-haven", or they clamber into the branches of the lodge bush their with undersides facing the sun. Occasionally, individuals bask at the base of the lodge, or away from the lodge where there is full sunlight. When the ground is warm they will often lie belly down, fully stretched out with chins on the earth. Basking is mainly done whilst sitting on their haunches. Although *Otomys* often bask individaully, several may cluster tightly in a row, juveniles may lie partially over one another.

On cold mornings they cluster together and jostle constantly for the inner positions and basking at these times is of much shorter duration. Adult males often bask alone, some distance from the lodge but close to a "safe haven". Adult males were observed to bask for longer periods than either females or juveniles. Basking periods generally are longer in warmer weather but basking has been

observed when the air temperature was at –6° C and snow was lying on the ground. At such times the basking periods are very short.
DISCUSSION:

Body measurements:
The measurements of head and body, tail, ear and mass of De Graaff (1981) of adult male and female *Otomys unisulcatus* were compared with the measurements of this study, no significant difference was found (T-test, $0.49<p<0.86$).

Incisors:
De Graaff (1981) and Skinner & Smithers (1991) mention that the upper incisors are shallowly grooved but the lower incisors in the majority of specimens are smooth with no grooves. These authors do not attempt to quantify this observation.

Diet:
Vermeulen & Nel (1988) found at their West Coast study site that just three species of plant dominated the diet of Otomys. Du Plessis, *et al* (1991) recorded *Otomys* in their study feeding on 32 species of plant, but of these only 5 species were taken in quantity. In the present study 20 plant species were recorded as being eaten, with a further two seen to be regularly harvested (*Bromus inermis; Aristida congesta)* and carried back to the lodge but not seen to be eaten, these were mainly used to line chambers. Food carried to the lodge was dropped around its perimeter, or laid on the outside surface of the lodge. No efforts were made to measure quantities taken but it became clear through direct observation that for much of the year all parts of *Lycium* species were eaten, and often in quantity. In study site 1 *Medicago sativa* (alfalfa) was very important except during the coldest winter months. Only six plant species made up the bulk of *Otomys* intake during the study period at both sites.

Reproduction:
This is an aspect that has received virtually no attention and is one of the least known part of this species' life history. De Graaff (1981) simply recorded that reproduction unknown, Skinner & Smithers (1991) stated that the meagre information available suggested that the young of *Otomys unisulcatus* were born as late as May. This latter based on the work of Vermeulen & Nel (1987). These authors collected a single female carrying a single late-term foetus in early May as well as trapping a young *Otomys* towards the end of July, and a lactating female caught at the same lodge during that month. What were believed to be young *Otomys* calling from inside lodges were noted in June and July. These data led the authors to suggest that on the Cape West Coast *Otomys unisulcatus* breeds during the winter months, the time of the rainfall regime in that region.

The results of our study show that within the heart of *Otomys unisulcatus* range they probably breed year-round. Pregnant females were recorded in all months with the exception of June, but the sample size in June was only one female. Immature *Otomys* were recorded in all months, with highs in numbers in January and from May through July. During May, 60% of the *Otomys* taken at site 3 were immature animals, 70% in June and 60% in July. During January immature animals made up 58% of all trapped specimens.

Lodge occupancy
Vermeulen & Nel found only an average of 1 *Otomys* occupying a lodge, this contrasting with our observations of an average of 3.6 rats per lodge, with a maximum of 11. The general decline of rats observed per lodge over the study period can probably be explained by the abundant rainfall in the first rainy season compared with that during January to April 2001 at the end of the project.

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Material – including skulls – has been lodged at the Natal Museum, Durban, South Africa.