Habitat associations and impact of habitat degradation on small mammals in the Heritage Park, North West Province, South Africa

by

K.L. Bullock*, F. Viljoen & J.J. Kotze

Department of Nature Conservation, Tshwane University of Technology, Private Bag X680, Pretoria 0001, South Africa
Email: kerrynbullock@gmail.com
*Corresponding author

ABSTRACT

Bullock, K.L., Viljoen, F. & Kotze, J.J. 2014. Habitat associations and impact of habitat degradation on small mammals in the Heritage Park, North West Province, South Africa. Navor. nas. Mus., Bloemfontein 30(1): 1–17. The association between small mammals and their surrounding habitat features were investigated during the growing seasons of 2008 and 2009 in the 90 333 ha proposed Heritage Park corridor between Pilanesberg National Park and Madikwe Game Reserve, North West Province, South Africa. Ninety-six sites were surveyed using live capture traps. Habitat associations of the five most abundant species were analysed using Multivariate Community Analysis Techniques. *Mastomys coucha* showed varying degrees of association with the different habitat features. This species was associated with areas of lower altitude and varying soil clay content, and was most abundant in areas with slight or no overgrazing. *Aethomys chrysophilis* preferred lower-lying habitat with varying clay content, no surface rock, little overgrazing and no bush encroachment; *Tatera leucogaster* had a strong association with habitats at lower altitude, sandy soil, low surface rock and varying tree density; *Saccostomus campestris* was strongly associated with areas at lower altitude, sandy soils, no surface rock and varying tree density; *Crocidura* sp. strongly preferred areas with no surface rock and low or no overgrazing. Such clear understanding of habitat selection criteria of small mammal species in diverse landscapes can suggest conservation and management strategies valuable to land managers.

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INTRODUCTION

Small mammals comprise a large percentage (>60%) of all terrestrial mammal species in southern Africa (Skinner & Chimimba 2005). These mammals, especially rodents, are widely dispersed, often abundant, and important components of nearly all terrestrial ecosystems (Brown et al. 1986; Price & Jenkins 1986; Kerley & Erasmus 1992). Small mammal species become adapted to certain habitat types where their temporal and spatial needs are satisfied, theoretically allowing more species to co-exist (Smith et al. 1975). This occurs on an adaptive basis (Martin 1998) and ultimately results in a species being more abundant in certain habitats rather than others in order to maximise their lifetime reproductive success (Cramer & Willig 2002). Rodents specifically are specialised and adapted for survival in “smaller” habitats and are, therefore, functional indicators of ecosystem integrity in smaller areas (Avenant & Cavallini 2007).

In recent times the field of landscape ecology has grown, emphasising relationships between animal species and habitat, and land use patterns (Francl et al. 2004). Habitat factors have pervasive effects on the spatial organisation and behaviour of organisms (Wrangham et al. 1993) and are believed to be critical factors determining richness of small mammal communities and abundance of certain species (Reed & Fleagle 1995). Several factors such as food quality and availability, predator abundance, inter- and intra-specific competition, and cover for nesting sites (Caro 2001) may be responsible for the degree of this species richness and abundance. Silva et al. (2005) classifies landscape features as important determinants of small mammal variables at all levels, but especially at community level. Environmental factors interacting to produce different habitats and high species diversity include altitude, topography, grazing, trampling, ploughing, fire, geology, soil types and climate (see Avenant 2003). The absence of vegetation and soil (microhabitat) variables from a trapping site results in difficulty in determining possible environmental correlates of community structure in variable small mammal communities sampled (Taylor et al. 2007). Therefore, every habitat offers distinctive abiotic and biotic features, which may or may not be suitable for specific species.

In this study the main aim was to ascertain the presence of small mammal species based on specific landscape characteristics or habitat features of each sample site.
MATERIALS AND METHODS

The proposed North West Heritage Park is situated in the northern part of North West Province, South Africa (within the co-ordinates: 24° 44’ S to 25° 03’ S and 26° 37’ E to 27° 03’ E). The surveyed portion of the proposed Heritage Park was approximately 89 833 ha in size. Altitude ranged from 1 000 to 1 299 m a.s.l. From data obtained from the South African Weather Services (2007) the average rainfall for the area could be approximated to 543 mm per annum, with the majority of rain falling in the summer months. There is a definite dry period during the winter months. Temperatures peak during December and January, reaching average maximum temperatures of 31.1°C and 32.1°C respectively (Mucina & Rutherford 2006). During the winter months of June and July the average minimum temperatures plummet to 2.6°C and 2.4°C respectively. Frost occurs fairly frequently in winter (Mucina & Rutherford 2006).

The study area falls within Rutherford & Westfall’s (1986) Savanna Biome, exhibiting typical savanna characteristics, namely a well-developed grassy layer and a conspicuous upper layer of dense to sparse shrubs or trees (Van Rooyen 2002). Acocks (1988) further categorises the research area into three different Veld Types: Turf Thornveld (no. 13), Mixed Bushveld (18) and Sourish Mixed Bushveld (19). More recently, Mucina & Rutherford (2006) classified the area as Central Bushveld Bioregion, with three vegetation units: Dwaalboom Bushveld (Scb 1), Madikwe Dolomite Bushveld (Scb 2) and Dwarsberg-Swartruggens Mountain Bushveld (Scb 4). Dwaalboom Bushveld is characterised by plains with an almost continuous herbaceous layer dominated by grass species, and a layer of scattered low to medium high deciduous microphyllus trees and shrubs; a few broadleaf species may also occur (Mucina & Rutherford 2006). Madikwe Dolomite Bushveld has a continuous herbaceous layer dominated by grass species. The woody layer is dominated by deciduous trees. This vegetation unit is found on low hills and gentle ridges up to about 100 to 150 m above the surrounding plains (Mucina & Rutherford 2006). Finally, the Dwarsberg-Swartruggens Mountain Bushveld consists of rocky low to medium high hills or ridges, with some steep ridges occurring in places (Mucina & Rutherford 2006). The farms constituting the study area were private, state or community-owned, used for a variety of different purposes, mainly agriculture, stock farming and game farming.

Ninety-six sample sites were identified within the study area, and sampled during the growing season of 2008 and 2009 (February to April during both years). These sites were positioned, based on strata defined by the Land Types map 2426 Thabazimbi (1984; 1:250 000), to adequately cover each Land Type unit. The Land Type map itself delineates areas with a marked degree of uniformity regarding terrain form, geology, soil and climate (Macvicar 1984). At each sample site small mammal species composition and abundance data were recorded together with habitat features. These habitat features included altitude, soil clay content, surface substrate (ζ the visible percentage of surface rock), overgrazing, and woody bush encroachment. Baited Poly-Vinyl-Chloride (PVC) live traps were used to capture the small mammals. The bait comprised rolled oats, peanut butter, sunflower oil, syrup and polony. Cotton wool was used as insulation inside each trap. Twenty PVC live traps (Willan 1986; Benedek 2006) were set in a trap line, spaced 10 m apart (Avenant 1997) for the duration of two nights and days (c. 48 hours). Trap line technique was utilised as it has been found to be effective in detecting the presence of species and is useful in covering a large area with a large variety of habitats (Herbert 2008). Due to logistical constraints, trapping was limited to two nights per transect. All small mammals captured
were individually marked by dorsally-shaved patches of fur (Ansara 2004; Benedek 2006; Gurnell & Flowerdew 2006).

Specimens were identified in the field using Stuart & Stuart (1991), and released at the capture site. The *Crocidura* specimens could not be identified to species level in the field, as positive identification is often possible only by microscopic examination of cranial features (Skinner & Chimimba 2005).

Along the same transect of the small mammal traps a 200 point nearest plant method survey (Foran et al. 1978; Mentis 1981) of the herbaceous layer was carried out, as well as a 200 m² belt transect (Mueller-Dombois & Ellenberg 1974) to record woody plant species. This 200 m² belt transect overlapped the first 100 m of the set traps and herbaceous survey, further covering 1 m to either side. The altitude of each site was obtained from 1:50 000 topographical maps of the area (2426DC Dwarsberg 1984; 2426DD Drieviersboom 1984; 2427CC Middelwit 1984; 2526BA Khayakhulu 1996; 2526BB Mabeskraal 1996).

The soil clay content was calculated from three holes augered 100 m apart (start, mid-point and end of the herbaceous survey line). The mean percentage clay, using the ‘sausage test’, was calculated following Brady (1984). Percentage surface rock was estimated subjectively on a visual basis. Relative overgrazing was estimated subjectively, using the ecological value of the dominant species recorded in the herbaceous survey. The relative bush encroachment was also estimated subjectively in conjunction with tree density from each belt transect.

To allow for the preferred habitat features to be identified, Canonical Community Ordination (CANOCO) software version 4.5 (Ter Braak 2003) was used to analyse the occurrence of the five most commonly captured species, all captured more than seven times. The specific Ordination technique employed, the Canonical Correspondence Analysis (CCA), was applied to compute ordination inferring relations from the data set of habitat features and small mammal communities. It is a simple technique that analyses and visualises the relationships between species and environmental variables (Ter Braak 1987). The main advantage of this robust technique is that it escapes the assumption of linearity and, therefore, is able to detect unimodal relationships between species and external variables (Ter Braak 1987).

With the use of CCA, five ordination diagrams were computed using a different habitat feature during every computation, while the small mammal abundance data (recaptures excluded) remained constant. The Monte Carlo Permutation Test was used to determine the statistical significance of the relationship between species and the environmental variables (Ter Braak & Šmilauer 1998).

**RESULTS**

In 3 840 trap nights (where 1 trap night = 1 trap set for a 24h period; Rowe-Rowe & Meester 1982) a total of 180 individuals of 11 different taxa were captured (Table 1). Of these, only nine individuals were re-captured. Total trap success (= the number of small mammals captured/100 trap nights; Wandrag et al. 2002) was 4.9%.
<table>
<thead>
<tr>
<th>Family</th>
<th>Subfamily</th>
<th>Scientific name</th>
<th>Common name</th>
<th>Number marked</th>
<th>Number retrapped</th>
<th>Ae57</th>
<th>Ae61</th>
<th>Ae237</th>
<th>Ae251</th>
<th>Ea70</th>
<th>Ea155</th>
<th>Fa293</th>
<th>Fb147</th>
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</thead>
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<tr>
<td>MURIDAE</td>
<td>Deomyinae</td>
<td>Acomys spinosisimus</td>
<td>Spikey Mouse</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>1</td>
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<tr>
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<td>Lenniscornys rosalia</td>
<td>Single-stripped Grass Mouse</td>
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<td>1</td>
<td>0</td>
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<td></td>
<td></td>
<td>Mus minutoides</td>
<td>Pygmy Mouse</td>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>0</td>
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<td>Southern Multimammate Mouse</td>
<td>37</td>
<td>0</td>
<td>8</td>
<td>9</td>
<td>0</td>
<td>7</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>6</td>
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<td></td>
<td></td>
<td>Thallomys paedulus</td>
<td>Acacia Rat</td>
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<td>0</td>
<td>0</td>
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<td>0</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>*Aethomys chrysophilus</td>
<td>Red Veld Rat</td>
<td>88</td>
<td>7</td>
<td>4</td>
<td>14</td>
<td>11</td>
<td>1</td>
<td>14</td>
<td>17</td>
<td>1</td>
<td>26</td>
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<tr>
<td></td>
<td></td>
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<td>Namaqua Rock Mouse</td>
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<td>1</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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<td>Bushveld Gerbil</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>7</td>
<td>3</td>
<td>0</td>
<td>5</td>
<td>2</td>
<td>0</td>
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<td>Cricetomyinae</td>
<td></td>
<td>*Saccostomus campesitis</td>
<td>Pouched Mouse</td>
<td>15</td>
<td>-1</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SORICIDAE</td>
<td>Crocidurina</td>
<td>*Crocidura sp.</td>
<td>Musk Shrew</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Totals: 180, 9, 19, 32, 28, 18, 19, 26, 4, 34
The three most abundant species captured were *Aethomys chrysophilis* (48.9%), *Mastomys coucha* (20.6%) and *Tatera leucogaster* (10.6%), together constituting 80.0% of all individuals trapped. The remaining 20.0% was composed of *Saccostomus campestris* (8.3%), *Crocidura* sp. (4.4%), *Leeniscomys rosalia* (2.2%), *Mus minutoides* (1.7%), *Micaelamys namaquensis* (1.7%), *Acomys spinossimus* (0.6%), *Thallomys paedulcus* (0.6%) and *Mus musculus* (0.6%). The first five species mentioned above were all trapped more than seven times, and their association with landscape and habitat characteristics are discussed below.

The five resulting ordination diagrams generated during the CCA analysis (Figs 1–5) illustrates a pattern of community variation and the major features of the distribution of species along the environmental variables. For visual interpretation of the ordination diagram each dot, representing a site, is given its own co-ordinate consisting of the site scores of two ordination axes (Ter Braak 1994). The site scores are calculated in such a way that sites situated close to one another on the graph are similar in species composition, making distant sites dissimilar (Ter Braak 1994). Further interpretation of the graph in respect of the vector arrows includes the signs of a correlation co-efficient between two variables, inferred from the angle between their arrows. If the angle is obtuse the correlation is negative and if the angle is acute the correlation is positive (Ter Braak & Verdonschot 1995). The direction of the arrow follows the direction in which the value of the small mammal species increases (Lepš & Šmilauer 2003) and the length of the arrow represents the importance of the variable (Ter Braak & Verdonschot 1995). In addition, polygons were inserted to classify samples; the polygons encircled the area on the graph representing a specific habitat feature. If the species fall within this area it confirms a degree of association between that small mammal species and the specific habitat feature (Table 2).

The CCA diagram representing altitude and small mammal abundance data (Fig. 1) resulted in axis 1 explaining 11.3% of the variation among capture rates for different taxa, and axis 2 explaining an additional 6.6% of the variation (17.9% total variation explained by axes 1 and 2). Axis 1 of the soil clay content diagram (Fig. 2) explained 20.1% of the variation among capture rates for different taxa, and axis 2 explained an additional 13.0% of the variation. Therefore, total variation was 33.1%. Axis 1 of the surface substrate diagram (Fig. 3) explained 11.2% of the variation among capture rates for different taxa; axis 2 explained an additional 10.1% of the variation (total variation = 21.3%). The CCA diagram representing overgrazing (Fig. 4) shows axis 1 explaining 10.4% of the variation among capture rates for different taxa, and axis 2 explaining an additional 6.4% (= 16.8% of total variation explained by axes 1 and 2). Axis 1 of the bush encroachment CCA diagram (Fig. 5) explained 10.1% of the variation among capture rates for different taxa, and axis 2 explained an additional 3.9% (total variation 14.0%).
Figure 1: Partial CCA of altitude (six classifications) and ecosystem parameters (small mammal abundance). The points stand for the altitude in meters above sea level of each site, and proximity between points, indicates compositional similarity. Arrows represent significant correlations between ecosystem parameters (small mammal species *Mastomys coucha*, *Aethomys chrysophilis*, *Tatera leucogaster*, *Saccostomus campestris*, *Crocidura* sp.) and canonical axes; they point in the direction of the underlying environmental gradients that differentiate species assemblages; the length of each arrow indicates the strength of interaction. Altitudes of the study area 1000–1049 m a.s.l., 1050–1099 m a.s.l., 1100–1149 m a.s.l., 1150–1199 m a.s.l., 1200–1249 m a.s.l., and 1250–1299 m a.s.l. are indicated by solid grey circles, open grey circles, solid grey squares, open grey squares, solid grey diamonds, and open grey diamonds, respectively.
Figure 2: Partial CCA of percentage clay (five classifications) and ecosystem parameters (small mammal abundance). The points represent the soil clay content of each site, and proximity between points indicates compositional similarity. Arrows represent significant correlations between ecosystem parameters (small mammal species *Mastomys coucha, Aethomys chrysophilis, Tatera leucogaster, Saccostomus campestris, Crocidura sp.*) and canonical axes; they point in the direction of the underlying environmental gradients that differentiate species assemblages; the length of each arrow indicates the strength of interaction. Percentage clay of the study area 0%, 15%, 25%, 35% and 55% are indicated by solid grey circles, open grey circles, solid grey squares, open grey squares, and solid grey diamonds, respectively.

Figure 3: Partial CCA of percentage surface rock (six classifications) and ecosystem parameters (small mammal abundance). The points stand for the surface substrate of each site, and proximity between points indicates compositional similarity. Arrows represent significant correlations between ecosystem parameters (small mammal species *Mastomys coucha, Aethomys chrysophilis, Tatera leucogaster, Saccostomus campestris, Crocidura sp.*) and canonical axes; they point in the direction of the underlying environmental gradients that differentiate species assemblages; the length of each arrow indicates the strength of interaction. Percentage surface rock of the study area 0%, <2%, 2–10%, 10–25%, 25–60% and >60% are indicated by solid grey circles, open grey circles, solid grey squares, open grey squares, solid grey diamonds, and open grey diamonds, respectively.
Figure 4: Partial CCA of percentage overgrazing (four classifications) and ecosystem parameters (small mammal abundance). The points stand for the percentage overgrazing of each site, and proximity between points indicates compositional similarity. Arrows represent significant correlations between ecosystem parameters (small mammal species *Mastomys coucha*, *Aethomys chrysophilis*, *Tatera leucogaster*, *Saccostomus campestris*, *Crocidura* sp.) and canonical axes; they point in the direction of the underlying environmental gradients that differentiate species assemblages; the length of each arrow indicates the strength of interaction. Percentage overgrazing of the study area described as None (0–24%), Low (25–49%), Moderate (50–74%) and High (75–100%) are indicated by solid grey circles, open grey squares, solid grey diamonds, and open grey rectangle, respectively.

Figure 5: Partial CCA of percentage bush encroachment (four classifications) and ecosystem parameters (small mammal abundance). The points stand for the percentage bush encroachment of each site, and proximity between points indicates compositional similarity. Arrows represent significant correlations between ecosystem parameters (small mammal species *Mastomys coucha*, *Aethomys chrysophilis*, *Tatera leucogaster*, *Saccostomus campestris*, *Crocidura* sp.) and canonical axes; they point in the direction of the underlying environmental gradients that differentiate species assemblages; the length of each arrow indicates the strength of interaction. Percentage bush encroachment of the study area described as None (0–24%), Low (25–49%), Moderate (50–74%) and High (75–100%) are indicated by solid grey circles, open grey squares, solid grey diamonds, and open grey rectangle, respectively.
DISCUSSION

This study aimed to sample small mammals in the families Macroscelididae, Muridae, Myoxidae and Soricidae, whose species would fit through the trap’s door (45 cm²). The trap success rate (4.92%) was consistent with that of a number of other studies done in southern Africa (see e.g. Wandrag et al. 2002; Van Deventer & Nel 2006; Avenant 2011) and elsewhere (Francl et al. 2004; Silva et al. 2005; Vera Y Conde & Rocha 2006).

The low trap success of this study may have resulted from a number of factors (including those listed in Gurnell & Flowerdew 2006). In this study the most likely contributing factors include a genuine low density, traps discharged with nothing or non-target species inside (specifically large invertebrates from the class Diplopoda and others from the order Orthoptera), species showing a reduced activity pattern during trap nights due to non-conducive weather conditions or excessive moonlight (Van Hensbergen & Martin 1993), sensitivity of small mammal species to capture (trap shyness, Gurnell & Flowerdew 2006; Meehan 1984) and the small number of traps set for only two nights. Gurnell & Flowerdew (2006) recommended at least three trap nights and 20 or more traps to carry out systematic sampling and obtain quantitative data. Based on results in Free State grasslands, Avenant (2011) recommended standardising trap effort as 100 traps per transect, spaced 5 m apart, for four continuous days and nights.

Small mammal species richness and community structure have been associated with variables such as habitat structure and complexity, productivity, surrounding landscape, area, rainfall, predation, grazing, trampling, distance between similar habitats, succession of vegetation and the presence of exotics (see Avenant 2000). In this study there was a strong association between the five most frequently caught small mammal species and the sites at lower altitudes. All small mammals occurred within the 1000–1149 m a.s.l. range, while none were associated with the higher-lying areas (polygons at 1150–1299 m a.s.l. do not feature on the diagram). Four species (Mastomys coucha, Aethomys chrysophilis, Tatera leucogaster and Saccostomus campestris) exhibited a strong association with lower altitudes (1050–1149 m a.s.l.). Crocidura sp. showed a wider tolerance to altitude with a fair association to areas ranging from 1000 m to 1149 m a.s.l. Benedek (2006) and Simionescu (1968) also found that small mammal diversity and abundance decreases with an increase in altitude.

Four of the small mammal species also showed a strong association with soil clay content. Mastomys coucha and Aethomys chrysophilis have a high affinity for soils with a low (15%) and high (55%) clay percentages respectively. The affinity to sandy soils may be for convenience purposes as the species that excavate their burrows can do so more easily in sandy soils. However, the strong associations with higher clay percentages showed that these two species have a relatively wide tolerance range for the soils they inhabit. Tatera leucogaster and Saccostomus campestris showed a strong preference for soils with a lower (25%) clay content.

Aethomys chrysophilis, Saccostomus campestris and Crocidura sp. are strongly associated with areas with no surface rock, while Tatera leucogaster has a slightly wider tolerance with a strong association to areas with 0–10% surface rock. Mastomys did not show any preference or indifference for surface rock cover.
This study also indicated a strong association between the number of individuals captured and low overgrazing (0% and 25–50%). All the small mammal species’ vectors fell within the two lower overgrazing polygons. *Aethomys chrysophilis*, *Mastomys coucha* and *Crocidura* sp. were strongly associated with areas without overgrazing, while the vectors of the other two species (*Tatera leucogaster* and *Saccostomus campestris*) were not long enough to register as a strong association. Areas with lower grazing pressure have higher plant species richness, taller individual plants with higher seed production, and can therefore promote larger populations of small mammals (O'Farrell 1997; Milton & Dean 1988). It is also well documented that a certain degree of disturbance causes increased environmental heterogeneity which consequently may reduce the effects of inter-specific competition and facilitate co-existence of a larger number of species (Price 1978; Dueser & Shuggart 1979; Fonseca & Robinson 1990; Rosenzweig 1995). Keesing (1998) also suggested that low densities of ungulates serve as a buffer for maintaining small mammal diversity.

Table 2. The associations of the five dominant small mammal species captured in the proposed Heritage Park, with their surrounding habitat features. Strong associations are in bold font.

<table>
<thead>
<tr>
<th>Species</th>
<th>Altitude (m a.s.l.)</th>
<th>Soil clay content (%)</th>
<th>Surface substrate (%)</th>
<th>Overgrazing (%)</th>
<th>Bush encroachment (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Mastomys coucha</em></td>
<td>1050–1149</td>
<td>15–55</td>
<td>0–60</td>
<td>0–49</td>
<td>0–49</td>
</tr>
<tr>
<td><em>Aethomys chrysophilis</em></td>
<td>1050–1149</td>
<td>15–55</td>
<td>0</td>
<td>0–49</td>
<td>0</td>
</tr>
<tr>
<td><em>Tatera leucogaster</em></td>
<td>1050–1149</td>
<td>25</td>
<td>0–10</td>
<td>0–49</td>
<td>0–74</td>
</tr>
<tr>
<td><em>Saccostomus campestris</em></td>
<td>1050–1149</td>
<td>25</td>
<td>0</td>
<td>0–49</td>
<td>0–74</td>
</tr>
<tr>
<td><em>Crocidura</em> sp.</td>
<td>1000–1099</td>
<td>35</td>
<td>0</td>
<td>0–49</td>
<td>0–74</td>
</tr>
</tbody>
</table>

Areas of excessive overgrazing are most likely avoided due to competition for food resources. Muñoz et al. (2009) stated that high densities of ungulates can reduce the diversity, abundance and/or body condition of small mammals, which they have attributed to the reduction of food availability and cover by the ungulates. Areas with selective medium-sized herbivores, like domestic goats or Impala (*Aepyceros melampus*), may have a decreased abundance of high-quality plant species available for herbivorous small mammals (Keesing 1998). In addition to this, trampling and grazing by large herbivores (mainly cattle in the study area) can modify an area by reducing vegetation cover (Bock et al. 1984; Roques et al. 2001; Goheen et al. 2004; Muñoz et al. 2009) to such an extent that it prohibits use by small mammal for fear of predation and the lack of appropriate nesting sites. Trampled soils are more compact and therefore less suitable for constructing and maintaining stable burrows (Torre et al. 2007). Torre et al. (2007) and Hagenah et al.
(2009) also maintained that the absence of large herbivores would lead to increased vegetation height, decreased soil compaction and consequently more protective cover available to small mammals. Hagenah et al. (2009) also found that the number of murid rodents was significantly higher in areas where large herbivores were absent.

Finally, varying tolerance limits were shown by small mammals to areas of differing bush encroachment. All the small mammals captured had some affinity to areas with no bush encroachment. *Aethomys chrysophilis* showed a strong affinity to areas with no bush encroachment, while *Tatera leucogaster* and *Saccostomus campestris* showed a wider tolerance, from moderate to no bush encroachment. A moderate percentage of bush encroachment may be favoured by certain species as bushes offer small mammals an additional food source, protection from predators, and suitable cover for nests (Hoffmann & Zeller 2005). However, none of the species studied were associated with high levels (75–100%) of bush encroachment.

*Mastomys coucha* has been described as a generalist species, and its domination in small mammal communities identified as an indicator of disturbance and or low habitat integrity (Avenant 2011). In this study it was associated with soils with varying clay content (15–55%), and more individuals were trapped in areas at lower altitudes (1050–1149 m a.s.l.) and with little to no (0–49%) overgrazing.

The most commonly trapped species in this study, *Aethomys chrysophilis*, had a strong association with all habitat features investigated. It preferred a lower altitude band (1050–1149 m a.s.l.), sandy to moderately clayey soils (15–55%), areas with no surface rock, little to no overgrazing (0 – 49%), and areas of low bush encroachment (0–24%). Its association with low levels of overgrazing and little to no bush encroachment was also noted by Rautenbach (1982) and Linzey & Chimimba (2008), who stated that *A. chrysophilis* is a habitat generalist that achieves higher densities in habitats with abundant ground cover in the form of grass or scrub.

*Tatera leucogaster* preferred areas with sandier soils (0–25% clay content) and little or no surface rock (0–10%), and showed a wide tolerance for different tree densities (0–75%). This is in agreement with De Graaff (1981) and Skinner & Chimimba (2005) who stated that *T. leucogaster* occurs in open woodlands, is generally absent from very rocky areas, and prefers sandy soils for making warrens which are generally scattered around the bases of trees.

*Saccostomus campestris* was strongly associated with areas at lower altitudes (1050–1149 m a.s.l.), sandy soil (25% clay), no rocky surface substrate, and varying degrees of bush encroachment (0–75%). This is supported by the finding of De Graaff (1981) and Skinner & Chimimba (2005) who stated that this species has a wide habitat tolerance on sandy soils, from open veld to dense bush. Rautenbach (1982) specifically stated that *S. campestris* has an apparent dependence on wooded vegetation, which supports our findings that this species also prefers areas of moderate bush encroachment. Rautenbach (1982) presented evidence that this species favours woody plant seeds to the extent that trees can become a prerequisite for habitat choice.
The unidentified *Crocidura* had a strong association with areas without surface rock and with low levels of overgrazing (0–49%).

The kind of testing for habitat associations used in this study provides a useful way to determine how different species respond to environmental heterogeneity. However, the findings may be limited to the study area, or be a result of the conditions being experienced at the time of our survey. Once-off sampling of small mammal populations could potentially bring about misleading results, as numbers of constituent species in a certain community can fluctuate dramatically in response to environmental stimuli, e.g. rainfall (Nel 1983). Long term research in the same area, or further research in a variety of habitats experiencing different environmental conditions, may verify and/or confirm the associations found in this study.

Small mammals play vital and perhaps indispensable roles in ecosystem function (Sieg 1987). They are inter-connected in complex ways with other biotic and abiotic habitat features. The monitoring of small mammals has been described as an effective, relatively inexpensive and quick method of indicating habitat integrity or ecological disturbance (Avenant 2011). Monitoring of small mammals can also add to knowledge of small mammal habitat preferences, and their association with plant communities yield insight about their function as potential indicator species and/or ecosystem engineers (Avenant 2003). Therefore, small mammal monitoring can act as a valuable tool for wildlife managers, and future management efforts need to focus on these relationships to a larger extent than in the past (Sieg 1987). In this study many of the 11 species studied showed significant correlations with one or more habitat features. This reflects their differing physiological, nutritional, social and anti-predator requirements. Conversely, the study of habitat associations of each of the small mammal species in a community improves our understanding of how the presence of different habitats can ultimately affect species diversity. A clear understanding of habitat selection criteria in diverse landscapes will help in the formulation of conservation and management strategies. As such, small mammal studies are crucial for the conservation and regulation of small mammal biodiversity and terrestrial ecosystems (Avenant 2011).

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**REFERENCES**


