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ORIGINAL ARTICLE

Correlating rodent community structure with ecological integrity, Tussen-die-Riviere Nature Reserve, Free State province, South Africa

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Abstract

Rodents form a vital component of Free State ecosystems and monitoring them may be a relatively quick and inexpensive method of indicating healthy or unhealthy ecosystem functioning. Using removal trapping, we have studied rodent seasonal abundance, species richness, Shannon diversity, and evenness of rodents in four habitats in the Tussen-die-Riviere Nature Reserve, inspected the most successful sampling method for these habitats, and report on their community structure and how it is related to an Ecological Index (≈ EI value of grassland). Both species richness and Shannon diversity increased significantly with EI value. The indicator species *Mastomys coucha* occurred at all plots, but contributed the largest proportion of the total captures (*ca.* 80%) at the plot with lowest EI value. Other results important for small mammal monitoring and collecting are that trap success and species richness was highest in autumn. This study also confirms that four days and nights continuous trapping is essential for the effective sampling of rodent communities in Free State grasslands. Our results partially support expectations that the number of specialist species increases with succession, *M. coucha* dominance acts as an indicator of habitat disturbance, rodent species richness conforms to Tilman's hump-shaped curve model, and adds to a baseline of diversity indices in a variety of grassland habitats.

Key words: community structure, diversity, ecological integrity, rodents, species richness.

INTRODUCTION

Rodents form a vital component of Free State ecosystems. They are not only important in nutrient cycling, habitat modification, as consumers of plants, dispersers of seed (and sometimes even predators of invertebrates), but also constitute the primary link between primary producers and secondary consumers. However, the mechanisms of these relationships are extremely complex. Among others, rodent community structure and species richness have been related to habitat structure and complexity, area, productivity, predation, trampling and grazing, surrounding landscape and the distance between similar habitats, maturity of the habitat / succession of the vegetation, and the presence of exotics (see Avenant 2000a). In general, changes in rodent habitats are associated with changes in rodent diversity and community structure, and ecological disturbance of these habitats is associated with the presence or absence of indicator species and decreases in rodent species richness. As such they have been identified as valuable

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indicators of habitat integrity in grassland habitats, and rodent sampling is considered to be a very effective, practical and relatively inexpensive tool for wildlife managers and environmental consultants to study, describe and monitor ecosystem or habitat integrity (Avenant 2000a,b, 2003a, 2005). Rodents react fast to habitat change and, due to clear and easy to observe reproductive seasons and consequent fluctuations in densities, studying this major prey group is ideal for indicating short term dynamics (connected to e.g. "fat & lean periods") in an ecosystem. They make out a fairly large percentage of all mammal species (>40%), are found in comparatively large numbers (a single species up to 200/ha), contribute largely (estimated at up to >10%) to total mammalian biomass and, due to their relatively high metabolism, are responsible for an even larger percentage of total mammalian consumption. As primary and sometimes secondary users they, therefore, have an important direct and indirect influence on a number of levels in ecosystems. Rodents are also specialized and adapted for survival in "smaller" habitats and are, therefore, suited as indicators of ecosystem integrity in smaller areas. They are relatively easy to handle, mark and it is simple to monitor their movements. We already know detailed information regarding the biology and natural histories of most small mammal species. They reproduce fast (important if you sample by removal trapping, currently the most effective method for sampling species diversity in Free State grasslands) and, compared to plants and invertebrates, are fairly easy to identify (which means that you can teach field personnel to continue monitoring according to a fixed program and standard method).

Several studies have addressed the relationship between species richness and primary productivity (Rosenzweig 1995). Tilman's hump-shaped curve model states that species richness increase with productivity, but then decrease after a point of climax is reached (Tilman 1982). This model has since been confirmed for several animal taxa (Rosenzweig 1995), including rodents (Abramsky & Rosenzweig 1984; Abramsky 1988; Owen 1988; Rosenzweig 1995; Wang *et al.* 1999). Rodents (specifically the Muridae) can therefore, be good indicators of habitat integrity. Avenant (2005) asked the question what murid community characteristics other than species richness can be used for this cause because the number of species in any specific habitat in Free State grasslands is only between two and seven (e.g. Avenant 1997, 2000a,b; Kuyler 2000; Avenant & Watson 2002; Kaiser 2006). Interpreting the data of a number of relatively short-term studies (see references above; also Nel *et al.* 1996; Avenant 1998, 2002, 2003b, 2004; Avenant & Kuyler 2002), Avenant (2005) proposed a hypothesis whereby "species richness increases with succession (Tilman's model) up to a point of climax, and then decreases to a point where equilibrium is reached. Species number fluctuates around this point until disturbance takes place. Depending on the measure and speed of disturbance the number of species for the specific animal group may follow the curve backwards, with highest species numbers found at intermediary disturbance, and lowest species number found immediately after extreme disturbance. The number of microhabitats and primary productivity is also high at the point of climax, and able to sustain a number of individuals from different species. Shannon diversity and Evenness (E_{var}) are also good indicators of ecosystem integrity, as it increases with succession. Generalist species dominate small mammal numbers on the lower part of the curve, with the opposite true for specialist species, which increase in number towards the end of the curve. This model also predicts that some species appear or drop out at specific stages in succession, or when the habitat reaches a specific level of integrity. This hypothesis is also strengthened in some ways by the results of a number of longer term rodent studies in southern Africa (e.g. Rowe-Rowe & Lowry 1982; Rowe-Rowe 1995; Ferreira & Van Aarde 1999, 2000). However, it has not been tested. While a longer term, multi-dimensional project in one habitat is in progress, this contribution discusses a one year project where murid community variables were correlated with an Ecological Index (≈ EI value of veld) in the Tussen-die-Riviere Nature Reserve (TdR), Free State Province, South Africa. The determination of an EI value is the leading method used to interpret habitat integrity in Free State nature reserves, and a useful tool driving management decisions (E. Schulze personal communication). It also reports on the seasonal abundance of rodents present in these habitats, and aims to contribute towards a most successful sampling method for rodents in South African grasslands.

Study area

The Tussen-die-Riviere Nature Reserve (30°30'S, 26°15'E), situated on and around the peninsula at the confluence of the Orange and Caledon Rivers, has been established as a game farm in 1967 and declared a provincial Nature Reserve in 1972. More than 13 large antelope, buffalo and rhinoceros species have since been re-introduced, and the small to medium size carnivores are considered to be relatively untouched. This reserve is essential in conserving *ca.* 23 000 ha of the "Eastern Mixed Nama Karoo" vegetation type (no. 52 – Hoffman 1996), a vegetation type where the conservation status has been described as "poor"; Acocks (1988) considered this the most degraded of all the vegetation types in South Africa. Altitude ranges between *ca*. 1 250m and 1 400m. Mean annual rainfall in this summer rainfall area is 444 mm (Weather Bureau 1986). Mean daily maximum and minimum temperatures ranges from *ca.* 31.2°C and 14.4°C in January to *ca*. 16.8°C and 0.0°C in July; absolute maximum and minimum temperatures are 38.3°C and –9.3°C, respectively. Both the years before and during the study were considered "normal" with respect to the rainfall and temperature, and none of the study areas has burnt during the periods of fieldwork or during the 36 months prior to the study.

MATERIALS AND METHODS

Rodents were surveyed over four successive seasons, in the middle of the season using snap traps in four homogenous (see Avenant 2000b) grassland plots (≈ habitats). The substrate was loamy, well drained soil and other geographical features of three of these plots (Plots 2, 3 and 4) were considered to be identical. The plots were, therefore, assumed to be of similar habitat features, but in different stages of succession. Plot 1 (clay/loamy soil, with a higher water-holding capacity) was considered to be the possible outlier. Two hundred traps, spaced 5 m, were set on four trap-lines spaced 10 m apart in each plot. Trap-lines were moved at least 350 m every season, and in such a way that they were never closer than 150 m to any previous lines in the same habitat. Traps were left open for *ca*. 10 days and checked and rebaited with a mixture of peanut butter, rolled oats, sunflower oil and marmite at sunrise and just before sunset. Dead specimens were included in the National Museum collection.

The three measures of abundance used in this study were trap success, species richness (or variety), and diversity calculated using the Shannon-Weiner information index (Magurran 2004). The relative abundance or evenness of the component species was determined as E_{var} (Smith & Wilson 1996). The term "trap night" was used to describe one trap that was set for a 24 h-period (Rowe-Rowe & Meester 1982), and trap success (or percentage success) is the number of small mammals captured/100 trap nights. Species richness (variety) is the number of species collected, and the Shannon diversity index ($H' = -\Sigma p_i \ln p_i$) is a measure of both the number of species and equality of representation of the individuals of all species.

In autumn the percentage crown cover and the contribution of individual plant species were recorded within a 2.5 m radius around each of the 200 small mammal traps in each of the four habitats. These species were divided into ecological groups according to their ecological or grazing value (*viz.* Decreaser species, Increaser I species, Increaser IIa species, Increaser IIb species, and Increaser IIc species – Van Oudtshoorn, 1994). Ecological Index (EI) values, established by E. Schulze (2004, unpublished data) for TdR, were given to each ecological grouping: Decreaser = 10; Increaser I = 7; Increaser IIa = 7; Increaser IIb = 4; Increaser IIc = 1; Herb = 4; Shrub = EI value of the nearest plant; and, Bare ground = -2. The EI value of each plot was determined using the sum of these values, divided by two (in order to yield a maximum EI value of 1000 for the specific plot).

Normality of data has been checked with Shapiro-Wilk's W test. For non-normally distributed data, standard nonparametric tests were used. All statistical analyses have been done with the computer program Statistica for Windows (Statsoft Inc., 1995). All tests were two-tailed, and the 95% level ($p<0.05$) was regarded as statistically significant for all tests.

RESULTS

The most obvious difference between the four grassland plots can be found in their substrate: Plots 2, 3 and 4 loamy and well drained soil, Plot 1 with clay/loamy soil. This difference is especially evident when pools would only form at Plot 1 and last for days after rains. This difference in soil characteristics found expression in the vegetation. Although all four plots shared grass species, Plots 2, 3 & 4 (called "similar" plots) clearly grouped together, sharing 55% of the total number of grass species (Plots 2 & 3 shared 45%; Plots 3 & 4 and 2 & 4 shared 55% each). Plot 1 (called the "outlier" plot) grouped away from these three, sharing only 25% of grass species with all other plots, only 43% with at least one of the other plots, and 31% of this plot's species were found nowhere else.

EI values increased from Plot 1 (EI = 277) to Plot 4 (EI = 593) ($F_{3,\ 796}$ = 156.72, $p<0.001$), with significant differences observed between all plots (Tukey HSD post hoc test). Percentage crown cover also followed this pattern, ranging from a low 66% (Plots 1 and 2) to 74% (Plot 4) ($F_{3,796}$=2.70; $p<0.05$), with significant differences between Plots 1 and 4 (Tukey HSD post hoc test). The

Table 1 The rodent species trapped at three “similar” grassland plots, compared to the species trapped at an “outlier” plot (Plot 1) at the Tussen-die-Riviere Nature Reserve, Free State Province, South Africa, 2002/3. EV, ecological value

Plot 2 EV = 424	**Plot 3** EV = 491	**Plot 3** EV = 593
Rhabdomys pumilio	*Rhabdomys pumilio*	*Rhabdomys pumilio*
Mus minutoides	*Mastomys coucha*	*Mastomys coucha*
Otomys karoensis	*Mus minutoides*	*Mus minutoides*
Plot 1 EV = 240 *R. pumilio* *M. coucha* (*c.* 80%) *Mystromys albicaudatus* *Saccostomus campestris*	*Otomys karoensis*	*Otomys karoensis*
		Dendromus melanotis
		Tatera leucogaster

relatively low percentage of Increaser I grass species (*i.e.* species that increase in abundance when vegetation is under-utilized, Van Oudtshoorn 1994 - present at only 35% of the eight hundred 19,6 m^2 plots, and contributing less than 10% to total crown cover) further confirmed our notion that the vegetation at all four plots was in a pre-climax state. Our hypothesis was, therefore, that rodent numbers (i.e. trap success), species richness and diversity at the three “similar” plots would increase with EI value, following Tilman’s hump-shaped curve model (Tilman 1982). These were compared with the rodent community variables at the outlier plot (Plot 1).

In total eight rodent species were trapped (Table 1), with a mean of 7 ± 0.8 per season. Two shrew species, *Crocidura cyanea* (Duvernoy, 1838) (n=2, caught in autumn at Plot 1) and *Suncus varilla* (Thomas, 1895) (n=2, caught in autumn and summer at Plots 1 and 4, respectively), and the molerat *Cryptomys hottentotus* (Lesson, 1826) (n=1, caught in autumn at Plot 1) were also trapped. At the three similar plots, the number of rodent species increased with Ecological Index value, but the correlation (Pearson Product-Moment) was not significant. These plots also shared species, with Plot 3 hosting all the species present at Plot 2, and Plot 4 hosting all the species present at Plot 3. The total species richness on the outlier plot (Plot 1) did not fit on the same EI value curve, and also shared ≤ 50% of its species with any of the other plots; these being *Rhabdomys pumilio* (Sparrmann, 1784) and *Mastomys coucha* (A. Smith, 1836). The species *Dendromus melanotis* (A. Smith, 1834) and *Tatera leucogaster* (Peters, 1852) were only found at the plot with highest Ecological Index value, Plot 4.

During all seasons the total number of rodent species was reached between 2-4 days (mean = 3 ± 0.8 days) of trapping, while immigration started to have a significant effect from the sixth day of trapping. During all seasons Shannon diversity index reached a high after day 3 and dropped after day 5). It was, therefore, decided to only use the data accrued during the first four days and nights for any further comparisons or correlations. Both species richness (Table 1) and Shannon diversity (Fig. 1) increased significantly from Plot 2 to Plot 4 (Kruskal-Wallis, $p < 0.05$), following EI value. Once again the Pearson Product-Moment correlations were not significant. At Plot 1 these variables were intermediary, statistically similar to that of Plot 3. No difference in trap success could, however, be found between plots ($p > 0.1$).

Highest trap success (Fig. 2) and species richness (Fig. 3) was found during autumn, and it is important to note that all the species at each of the plots have been collected between the autumn and winter trap sessions. Lowest trap success and species richness were generally observed during spring.

DISCUSSION

Using an Ecological Index has been the leading method for interpreting veld condition and habitat integrity in the Free State provincial nature reserves, and an important tool driving management decisions. During this study the EI value has increased significantly from Plot 1 to Plot 4 and, seen in the light of our hypothesis, we have expected that differences in rodent community characteristics will follow this curve. However, the difference in substrate between Plot 1 and the other three plots were expected to find expression in plant composition and rodent community characteristics – differences that were indeed found during this study. It was, therefore, clear that Plot 1 should be treated as an outlier and the correlation between rodent community characteristics and Ecological Index value should be seen in perspective.

The three to six murid species collected from the various plots at Tussen-die-Riviere falls within the range detected for Free State grasslands. The increase in species richness with EI value in the three “similar” plots conforms to Tilman’s hump-shape curve model and Avenant’s (2005) hypothesis. When the data from the outlier Plot 1 was included, no pattern was evident. This plot had a fairly unique rodent composition with 50% of its species (n=2) not present at any of the other plots. This becomes more evident when it is realized that the other two species, *Rhabdomys pumilio* and *Mastomys coucha*,

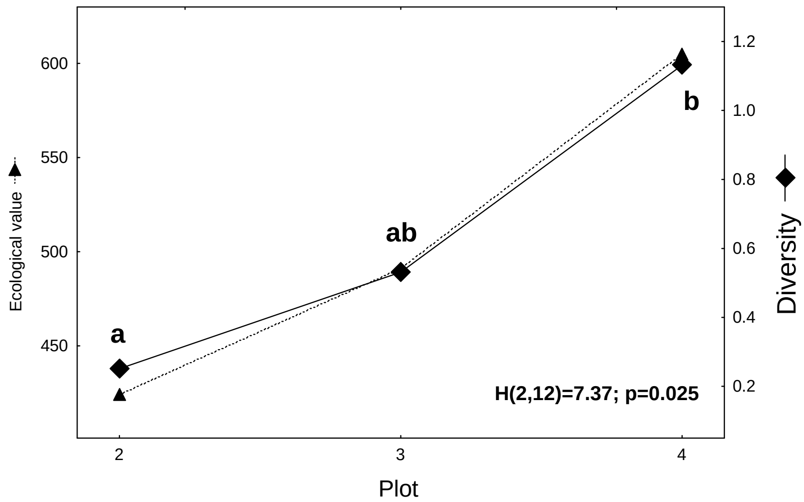

Figure 1 Rodent diversity on three similar grassland sites at the Tussen-die-Riviere Nature Reserve, 2002/3. The homologous groupings are derived from Kruskal-Wallis post hoc comparisons of mean ranks of all pairs of groups.

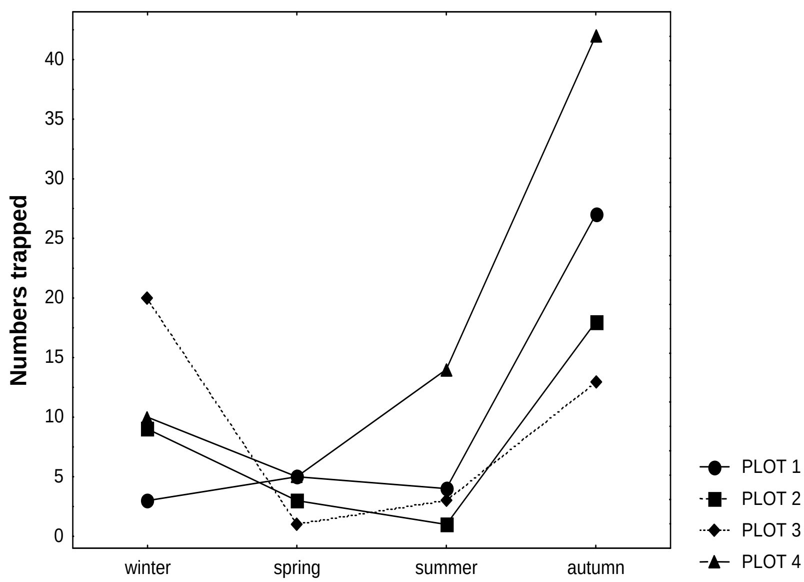

Figure 2 Seasonal rodent trap success on four grassland sites at the Tussen-die-Riviere Nature Reserve, 2002/3.

are the two most common species in virtually all Free State grassland plots (see Avenant 1996, 1997, 2000a,b, 2002, 2004; Kuyler 2000; Avenant & Kuyler 2002; Avenant & Watson 2002). It is also significant to note that the specialist species *Dendromus melanotis* were only found at the plot with highest Ecological Index value, whereas the generalist species *Mastomys coucha* (80% of all specimens) were collected at the plot with the lowest Ecological Index value. Comparable observations for both these species have been made in other southern African grasslands (see previous list of references).

On the similar plots, both species richness and Shannon diversity also increased significantly with EI value, supporting our hypothesis. No difference in trap success could, however, be found and also no evidence that rodent densities increase with the Ecological Index value of grasslands.

Other results important for small mammal collecting and monitoring in Free State grasslands are that the highest species richness, for all plots and seasons, was found after 2-4 days of trapping, with a mean of more than three days. This means that studies that aim to sample the full complement of species should last for four days and nights. This is in agreement with studies done in high rainfall (Avenant 1997, 2000b), low rainfall (Fauresmith & Avenant unpublished data) and intermediate rainfall (Avenant 2000a; Kuyler 2000) areas in the Free State Province. If the aim of the study is to report on community characteristics such as diversity and evenness, trapping should not last longer than five days as immigrants are then beginning to have an effect. We, therefore, advocate a continuous trapping period of four days and nights.

This study has also found greatest sampling success during autumn: both the numbers of specimens and species were highest during this season. Similar results were found at Willem Pretorius Nature Reserve (Avenant 2000a) and at Korannaberg Conservancy (Avenant 2000b), where trap success, species richness and Shannon diversity were highest during the period mid-autumn to early winter. Possible reasons for this phenomenon are that mouse numbers are still high because the breeding season lasts from *ca*. mid-spring to late-autumn while food is declining and energy needs increase fast. The cold, dry winters result in a sudden, massive drop in numbers, annually observed from early to mid-winter. This may force even trap shy animals/species to go for the bait. The worst time to sample is mid-spring to mid-summer. During this period the population numbers are still low while food is available as the plant growing season already starts in early spring.

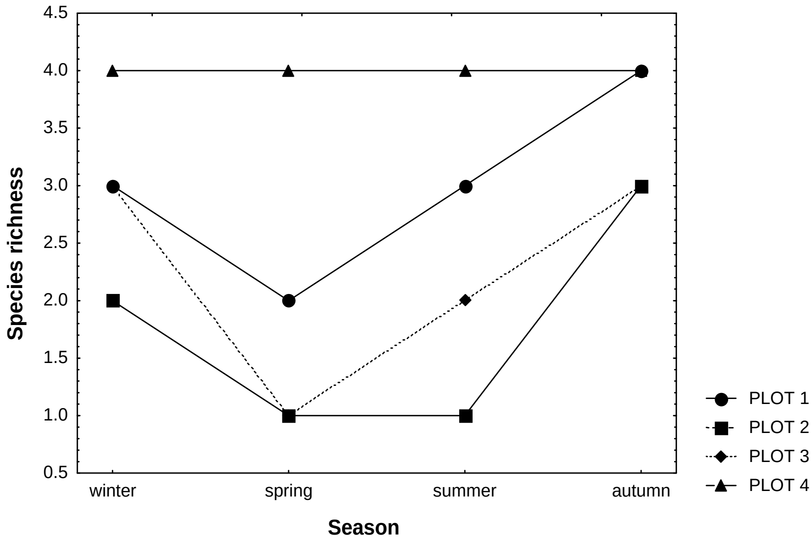

Figure 3 Rodent species richness as observed over seasonss on four grassland sites at the Tussen-die-Riviere Nature Reserve, 2002/3.

In conclusion: our results partially support expectations that the number of specialist species increases with succession and *M. coucha* dominance acts as an indicator of habitat disturbance. Rodent species richness conforms to Tilman's hump-shaped curve model and adds to a baseline of diversity indices in a variety of grassland habitats. This study therefore partly supports, but in no way contradict, our hypothesis.

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