

Article

Small Mammal Diversity in Response to Land Transformation and Seasonal Variation in South Africa

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Abstract: Anthropogenic land transformation is a consequence of human population growth and the associated agricultural, residential, and industrial needs. This study aimed to investigate the effects of anthropogenic activity and human-mediated land transformation on capture/recapture frequencies, species richness, and diversity of native small mammal community assemblages in the Magaliesberg Biosphere, North West province, South Africa. Five anthropogenically transformed land-use types were investigated: an animal rehabilitation and ecotourism center, an agricultural farmstead, a residential farmstead, a mine-adjacent agricultural farmstead, and a protected nature conservancy. We used live traps to sample small mammals during the dry and wet seasons over three consecutive years and compared population numbers and species composition across study sites and seasons. Capture/recapture frequencies differed significantly between sites and seasons, with the highest capture frequencies recorded at the agricultural and residential farmsteads. Species richness and diversity were highest at the residential and mine-adjacent farmsteads, both of which experienced intermediate levels of anthropogenic disturbance throughout the sampling period. The study shows that while natural and protected landscapes with low levels of disturbance are preferred, transformed landscapes can also be managed effectively to benefit native small mammal populations by regulating the frequency and intensity of human-mediated activities.

Keywords: abundance; agriculture; anthropogenic activity; community assemblage; industrial activities; intermediate disturbance; rodents; species richness



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1. Introduction

Due to the rapidly increasing human population and the far-reaching impacts of anthropogenic activities such as agriculture, industrialization and urbanization, fewer ecosystems remain untransformed and undisturbed [1–3]). Monitoring threats to biodiversity that stem from anthropogenic activities is vital in mitigating and managing their effects [4–6]. Ecosystem health is often monitored using several environmental variables, and any one of these variables can be a proxy for health. In the past, similarities in terms of species richness, distribution, and community assemblage in small mammals were investigated across transformed and untransformed landscapes to assess ecosystem health [1,4]. Whereas some studies focus on the impact of one variable at a time, an integrated investigation of several variables can give a more insightful view of the state of both biotic and abiotic components within the system [7,8]. The investigation of the presence of land-use-based species can inform on the impact of various alterations to landscapes and which human activities are most impactful to the ecosystem and resident species [9,10].

Diversity refers to the range and abundance of species in an area and is also a reliable indicator of ecosystem health [7,11,12]. Along with the presence and number of species, it is essential to record the diversity of a region over time, as this further demonstrates how

impactful anthropogenic activities are on natural environments [1,4]. Reduced community evenness can indicate species and diversity declines, resulting in the homogenization of formerly diverse landscapes and the extinction of local species [11,13]. The presence of invasive species in a landscape can also indicate land disturbance, displacement of indigenous species, and most likely declines in biodiversity [8,14].

It is essential to research species prone to population fluctuations in response to landscape changes, as these species are the most vulnerable to environmental and anthropogenic threats [15,16]. To improve the identification of vulnerable species, the IUCN [5] has identified several relevant biological traits that make species more at risk. These include the use of specialized habitats or microhabitats, a narrow environmental tolerance, dependence on environmental cues, a dependence on relationships and interactions with other species, and a poor ability to disperse from low-quality habitats and establish in landscapes with more favorable conditions.

Similarly, it is also important to investigate those taxonomic groups that occur on the other end of the spectrum and do not generally operate within the ecological constraints of at-risk species [17]. However, it can be assumed that environmental changes that affect these tolerant taxonomic groups may have devastating consequences for at-risk species that are dependent on specific ecological and climatic cues [17–19]. Small mammals, such as rodents, are a reliable model for shorter-lived species that can be easily studied, as they have relatively short generation times that can be observed over a human lifetime [20,21]. The use of these adaptive and resilient species in research allows us to investigate the likelihood of wildlife populations and ecosystems recovering from human-induced disturbances. It can also help to improve the management strategies of threatened species in disturbed landscapes.

Most rodents are not on the IUCN Red Data List of Threatened Species and are classified as ‘least concern’, with only a handful being assessed as threatened or endangered [22]. When assessed using the IUCN-identified biological traits, they are shown to be capable of either adapting to most environmental changes or finding more favorable conditions [23,24]. Although rodents can use microhabitats, they are not restricted by their macrohabitat and can thus persist in a wide range of landscapes [25]. Successful establishment of rodents in a landscape does not require interspecific interactions with other taxonomic groups. They, themselves, are ecosystem drivers who cycle nutrients through the soil, disperse seeds to aid in plant growth, and provide food for predators [23,26]. With increased human expansion and subsequently transformed landscapes, favorable conditions prove more challenging to maintain [27,28]. In addition to an increase in land transformations due to more significant anthropogenic needs, climate change may exaggerate disruptions to ecosystem health, and thus, seasonal variation should be included in diversity-based research [7,29]. Due to the resilient characteristics displayed by rodents, it is essential to monitor them in both natural and transformed landscapes to gauge the critical limit of their tolerance for environmental changes brought about by climate change and anthropogenic activities.

Additionally, due to the heavy reliance of small mammals on resources and shelter in their environments, it is important to monitor any external factors that may influence these environments. Seasonal variation is one such variable, as it can have immediate and delayed effects on natural landscapes. In terms of immediate effects, wet season climatic conditions may lead to physical alterations in the landscapes, such as softer soil substrates, whereas dry season climates can harden said substrates [27]. Many habitats found in southern Africa can be adversely affected by climatic conditions but can also be renewed by wet season rains and produce vegetation that small mammals use for cover and food [28]. Conversely, the dry season may mean that food and cover are limited, often leading to inter- and intraspecific competitive interactions for these resources [18,19]. This study aimed to investigate the effects of land transformation and seasonal variation on small mammal biodiversity in the Magaliesberg Biosphere of South Africa by examining the impacts of season and land transformation on (a) capture frequency; (b) species richness; and (c) community diversity, evenness, and similarity. We predicted that an increase in landscape disturbance would

be inversely proportional to population health and community diversity. Furthermore, we anticipated that seasonal variation would reduce community diversity during the dry season and increase population abundance in the wet season.

2. Materials and Methods

2.1. Study Area

The Magaliesberg mountain range (25°41′00.1″ S 27°57′51.8″ E) expands through the Gauteng and North West provinces, South Africa. The mountain range spans a length of approximately 140 km, with a maximum elevation of 1852 m.a.s.l. The Magaliesberg is primarily characterized by the Savanna Biome, which covers the Gold Reef Mountain Bushveld vegetation type at higher altitudes and Marikana Thornveld and Moot Plains Bushveld in lower-lying areas [30]. The vegetation in these bioregions is woody and consists of a predominantly grassy herbaceous layer. Thorny *Vachellia* species and semi-open thickets dominate the region. The region comprises igneous rocks from the Rustenberg Layered Suite and the Rooiberg Group [30].

Trapping localities were in the De Wildt (25°40′05.5″ S 27°55′23.1″ E) and Zilkaatsnek (25°39′25.8″ S 27°56′34.9″ E) areas, with land-use types such as agriculture, residential, tourism, conservation, and mining (Figure 1). We named the sites as follows: the animal breeding, rehabilitation, and ecotourism center (ABR); the agricultural and residential farmstead (ARF); the residential farmstead (RFS); the industrial and agricultural farmstead (IAR); and the nature conservancy and residential site (NCR). The climate is characterized by hot, wet summers and cold, dry winters, with April until October referred to as the dry season and November to March typically referred to as the wet season [31]. However, the start and patterns of annual rainfall are unpredictable each year. We used five closely located study sites (the maximum distance between sites is 15 km) to discount climatic variability and determine whether the size of study sites and their proximity to each other allows for species turnover (Table 1). All five sites shared similar natural vegetation structures [30], apart from additional cultivation of commercial vegetation in some areas (Table 1). The savanna vegetation composition differs across land-use types, with the level of clearing increasing with an increase in anthropogenic activity. This means that land-use types in the same region with similar vegetation differ in plant species assemblages due to human-mediated land development, clearing, and burning, among other factors. Study sites with infrequent human activity therefore experience less vegetation clearing, resulting in high richness of plant species, with a few examples of cleared areas being roads and footpaths for occasional tourists. Despite the differences in composition, however, the effects of seasonal variation influence the different study sites in similar ways. In the dry season, the area experiences low rainfall conditions, which leaves habitats dry with little green vegetation for animals to use. The soil is dry and compacted, making burrowing more arduous for some species [30]. Due to the dry climate and grass, locals around the area practice controlled burning and slashing techniques to ensure that the areas do not experience uncontrollable and dangerous veld fires. This alters the landscape and may influence natural vegetation and wildlife in various ways. In the wet season, rainfall experienced in the region results in green vegetation and softer soil, which makes burrowing easier for small mammals [31,32]. Additionally, the increase in vegetation can result in increased grazing activity by livestock in the surrounding areas [32].

2.2. Data Collection

For this study, we sampled five study sites during four consecutive seasons (two dry and two wet seasons) for 16,000 trap nights between 2018 and 2021. At each site, we deployed 40 Enviro-Care live traps (imported from Cangzhou Jinglong Technology Co., Ltd., Hebei Province, China), for a total of 3200 trap nights per site. The traps were made of galvanized sheet metal and had the following dimensions (length × height × width): 255 × 78 × 80 mm. We baited each trap with a mixture of oats and peanut butter and placed them 10 m apart in a 5 × 8 trapping grid, following standard procedures [33]. All traps

remained open during the day and night to ensure diurnal and nocturnal species trapping. We checked all traps in the morning from 05:30 until 10:00 and again from 15:00 until 17:00 every day. All captured animals were identified and sexed where possible [23,24,34]. We weighed individuals using a spring scale (PESOLA Präzisionswaagen AG, Schindellegi, Switzerland) and marked them using numbered clipping of toenails to identify recaptured individuals [33]. As many small mammals contain blood vessels in their toenails, which may become damaged if clipped, we treated toenail-clipped individuals with antiseptic Mercurochrome (Barrs Pharmaceutical Industries, Cape Town, South Africa) to prevent infection and ensure that the nails would heal with minimal contamination [35]. Toenail clipping had a dual function of marking individuals and providing keratinized materials to be analyzed in a separate diet-related study. Additionally, we collected <1 mm ear clips by clipping the upper right ear using sterilized dissecting scissors. These ear clips were used as genetic material for resolving individuals from cryptic genera, namely *Aethomys* and *Mastomys*, into their respective species [33]. After processing, we released individuals at their respective capture sites [32,36]. We emptied the traps of all contents, rebaited, and returned them to their original positions in the trapping grid [33]. This study was performed with the approval of the Animal Ethics Committee of the University of Pretoria, Pretoria, South Africa (Ethics clearance number EC044-18).

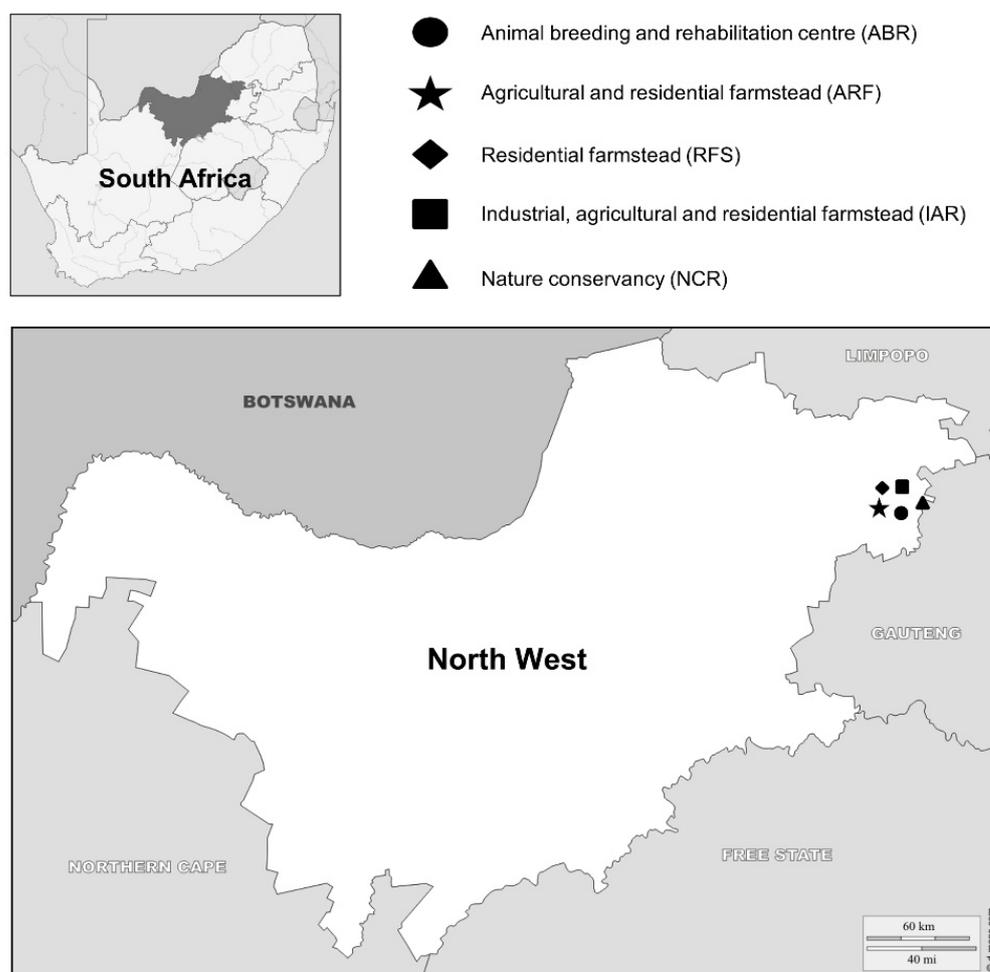


Figure 1. Orientation map of the North West province showing the locations of the five study sites where rodents were captured between 2018 and 2021 in South Africa.

Table 1. Study-area information on the locations and land-use types from which small mammals were sampled in the Magaliesberg Biosphere, North West province, South Africa. The five land-use types were designated as follows: animal breeding and rehabilitation center (ABR); agricultural and residential farmstead (ARF); residential farmstead (RFS); industrial, agricultural, and residential (IAR); and nature conservancy and residential (NCR).

Study Site	Land Use	Abbreviation	GPS Location	Primary Vegetation	Topography
1	Animal breeding and rehabilitation Ecotourism	ABR	25°40'25.2" S 27°55'17.4" E	Thorny, semi-open thickets	Rocky, slight incline near the base of the mountain
2	Agricultural Residential	ARF	25°39'31.3" S 27°55'08.0" E	Grassy herbaceous layer	Flat at the base of the mountain
3	Residential	RFS	25°39'20.3" S 27°55'15.7" E	Herbaceous and semi-open thickets	Flat at the base of the mountain
4	Industrial Agricultural Residential	IAR	25°38'43.3" S 27°55'48.8" E	Herbaceous and semi-open thickets	Flat at the base of the mountain
5	Conservation Residential	NCR	25°40'39.6" S 27°57'48.9" E	Herbaceous and semi-open thickets	Rocky, steep incline along the mountain

2.3. Statistical Analysis

All statistical analyses were done with the software program R 4.1.0 (R Core Team 2021) using the RStudio interface (Version 1.4.1103). For the current study, we only included the first capture of an individual. However, a figure with a summary of capture and recapture numbers is provided in the Results section. Sequence analyses, details on DNA extraction and nucleotide sequencing of the genetic material are included in the Supplementary Materials [37]. Sequence chromatographs were visualized and edited in the Chromas program embedded in MEGA 7 and used to generate contiguous sequences (contigs) [38]. The final aligned database for the cryptic species was used to infer a maximum-likelihood (ML) phylogenetic tree in MEGA 7 [38]. Details on the generation of the database are included in the Supplementary Materials document. The best-of-fit model of sequence evolution was determined under the Bayesian information criteria (BIC), and the Akaike information criteria (AIC) in MEGA 7 were used for the ML analysis, with the nodal support being assessed through 5000 bootstrap replications [38].

Cryptic *Aethomys* species were identified as *A. ineptus*, whereas *Mastomys* species were identified as *M. coucha*. These resolved species were specified in the dataset and included in further analysis. Furthermore, all sequences were deposited in GenBank (*A. ineptus*: OM055762, OM055763, OM055764, OM055772, OM055773, OM055774, OM055775, OM055776, OM055777, OM055778; and *M. coucha*: OM055765, OM055766, OM055767, OM055768, OM055769, OM055770, OM055771). The accession numbers represent unique haplotypes identified in the study and include geographical information. The maximum-likelihood tree is included in the Supplementary Materials file. We investigated nestedness and trap dependency in RStudio using the beta.multi function in the *betapart* package, which computes multiple-site dissimilarities and accounts for the nestedness components of beta diversity [39,40]. The function uses beta diversity to measure site dissimilarity resulting from nestedness patterns in the community [40]. In the event of high nestedness between sites, a linear model was employed to account for inter- and intraspecific trap dependency at spatial and temporal scales:

$$\text{Abundance} \sim \text{Season} + \text{Land Use} + \text{Species} + \text{Trapline}$$

where Abundance is the total number of newly captured individuals within a land-use type, Season refers to the dry and wet sampling periods, Land Use denotes the five sites sampled,

and Trapline refers to the numbered trap in the trapping grid where each individual was captured. A p -value of ≤ 0.05 was defined as significant.

To compare species richness (alpha diversity), we used descriptive statistics, namely the total number of species captured at each site. To compare diversity across sites, we used the *vegan* package to calculate Shannon and Simpson's diversity indices, as well as Pielou's evenness index [41]. Additionally, we used the *betadisper* analytical function in the package to test for homogeneity of groups (or similarity) by calculating Bray–Curtis distances between land-use types [41,42].

3. Results

Both season (dry season, $n = 693$; wet season, $n = 824$; $p < 0.001$; $df = 2$) and land-use type ($p < 0.0001$; $df = 4$) resulted in significantly distinct abundance across study sites (Figure 2). Seasonal abundance fluctuated most at the agricultural farmstead (ARF) and the animal breeding and rehabilitation center (ABR) and least at the residential farmstead (RFS) and industrial and agricultural farmstead (IAR). Small mammal captures were low during the dry season at the transformed sites (ABR and ARF), increasing with a decrease in human-intensive land disturbance. Wet season captures showed an inverse trend, except for RFS, which showed consistent capture numbers overall. During the dry season, 66.7% of all encountered individuals were recaptured animals, while the recapture rate during the wet season was 42.6%.

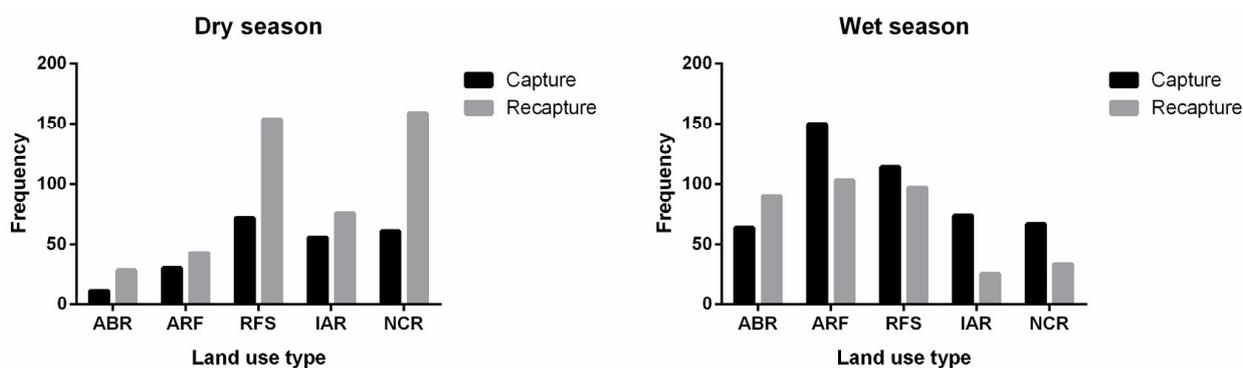


Figure 2. Seasonal capture and recapture numbers for small mammals for a three-year sampling period (2018, 2019, and 2020) across five land-use types: animal breeding and rehabilitation center (ABR); agricultural and residential farmstead (ARF); residential farmstead (RFS); industrial, agricultural, and residential (IAR); and nature conservancy and residential (NCR).

Trap dependency, however, did not have a significant effect on capture and recapture numbers ($n = 1516$; $df = 41$; $p = 0.201$). Species nestedness accounted for a large proportion of the beta diversity in the region ($\beta_{NES} = 0.93$).

All captured species were indigenous to southern Africa. Species richness did not differ significantly across seasons ($p = 0.137$; $df = 1$) or sites ($p = 0.799$; $df = 4$) (Table 2). Shannon's and Simpson's diversity indices, as well as Pielou's evenness index, were not significantly different between seasons or sites. (Table 2). Beta diversity, represented by Bray–Curtis dissimilarity, varied seasonally and across sites (Table 3). Mean dissimilarity was calculated as 0.37 during the dry season and 0.36 during the wet season.

Table 2. Dry and wet season counts of small mammal species and community structure indices across five land-use types in the Magaliesberg Biosphere, North West province, South Africa. Land-use types were designated as follows: animal breeding and rehabilitation center (ABR); agricultural and residential farmstead (ARF); residential farmstead (RFS); industrial, agricultural, and residential (IAR); and nature conservancy and residential (NCR). * Denotes statistically significant differences between sites.

Species Name	ABR		ARF		RFS		IAR		NCR	
	Dry	Wet								
Macroscelidea										
<i>Elephantulus brachyrhynchus/myurus</i> [Elephant shrew]	0	0	0	0	0	0	0	0	1	0
Rodentia										
<i>Aethomys ineptus</i> [Tete veld rat]	3	21	0	0	0	0	0	3	10	17
<i>Dendromus mystacalis</i> [Climbing mouse]	0	0	0	0	0	0	0	0	1	0
<i>Gerbilliscus brantsii/leucogaster</i> [Bushveld/Highveld gerbil]	0	0	0	0	0	0	20	2	0	2
<i>Lemniscomys rosalia</i> [Single-striped mouse]	1	8	3	7	15	14	11	10	9	0
<i>Mastomys coucha</i> [Multimammate mouse]	4	19	20	120	45	70	12	29	14	2
<i>Micaelamys namaquensis</i> [Namaqua rock mouse]	2	16	0	18	0	12	0	21	23	46
<i>Mus minutoides</i> [Pygmy mouse]	2	0	6	1	10	0	8	1	2	0
<i>Otomys irroratus</i> [Vlei rat]	0	0	0	0	2	3	0	2	3	0
<i>Rhabdomys pumilio</i> [Three-striped mouse]	0	0	0	0	0	0	2	0	0	0
<i>Saccostomus campestris</i> [Pouched mouse]	0	0	0	3	0	1	2	6	0	0
<i>Steatomys pratensis</i> [Fat mouse]	0	0	0	1	0	15	2	2	0	0
Captures (N) *	12	64	29	150	72	115	57	76	63	67
Species richness	5	4	3	6	4	6	7	9	8	4
Shannon diversity index (H) *	1.52	1.33	0.82	0.72	0.99	1.20	1.64	1.66	1.66	0.82
Simpson diversity index (D)	0.78	0.73	0.47	0.34	0.55	0.59	0.82	0.75	0.76	0.46
Pielou's evenness index (J)	0.94	0.96	0.74	0.40	0.71	0.67	0.84	0.76	0.80	0.59

Table 3. Bray–Curtis dissimilarity indices between study sites during the dry and wet seasons across five land-use types in the Magaliesberg Biosphere, North West province, South Africa. Land-use types were designated as follows: animal breeding and rehabilitation center (ABR); agricultural and residential farmstead (ARF); residential farmstead (RFS); industrial, agricultural, and residential (IAR); and nature conservancy and residential (NCR).

	ABR		ARF		RFS		IAR	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
ARF	0.25	0.40	-	-	-	-	-	-
RFS	0.33	0.40	0.14	0.17	-	-	-	-
IAR	0.50	0.38	0.40	0.20	0.45	0.20	-	-
NCR	0.23	0.25	0.45	0.60	0.33	0.60	0.60	0.38

4. Discussion

This study demonstrates that seasonal and land-use-specific variation can influence the abundance of small mammal species to different extents in the Magaliesberg Biosphere, South Africa. Monitored minimally transformed landscapes such as the residential farmstead and the nature conservancy had the highest abundance during the dry season. Conversely, study sites that experienced moderate to high levels of anthropogenic activity, i.e., the animal breeding and rehabilitation center and the agricultural and residential farmstead, had fewer captures during the dry season. This could be due to the high fire risks associated with the region, specifically during the dry season, and the resulting management strategies to prevent or reduce fire damage [31]. Fire risk-management efforts appear to increase with an increase in land-use complexity and associated practices. Activities such as controlled burning, livestock grazing, and mechanical slashing directly impact small mammal populations [42,43]. Additionally, in many areas with a high human presence, humans actively try to reduce the number of small mammals and their pest-related activities in and around their households through live and snap trapping, and poison, as well as biological means, such as pets [44,45]. This may further reduce population numbers in transformed areas with a constant human presence. During the wet season, the abovementioned minimally transformed sites had lower capture numbers, as small mammals were no longer reliant on temporary food sources due to improved plant growth after the rains. Conversely, the more transformed sites had more frequent small mammal captures, possibly due to the resurgence and re-establishment of population numbers following the dry season. Additionally, the breeding season of many observed species coincides with the wet season, which could result in an overall increase in capture numbers [24,35,46]. Species ecology and behavior can also impact seasonal population numbers, as many southern African small mammals are seasonal breeders. For example, *M. namaquensis* reproductive behavior is mainly confined to rainy summer months, which correlates with an abundance of nutrient-rich food resources [47]. Similarly, *M. coucha* has been reported to breed primarily during the wet season, and this behavior has been linked to the growth of new grass shoots [48]. Grass shoot growth can also be seen after fire events, and this could explain the upsurge in *M. coucha* during the dry season months after vegetation-control methods are implemented.

In this study, overall species richness was not significantly different across study sites, although a downward trend was associated with increasing and frequent land-use intensification. These findings align with Flynn et al. [49] and Horváth et al. [50], who showed that intensification of agriculture resulted in reduced species richness. Further, species richness did not differ across seasons and sites, but the highest species richness values were recorded at the intermediately disturbed residential farmstead and mine-adjacent farmstead sites. This may be due to the management strategies employed, which involve alternating between rest and intensive tilling and planting activity [51,52]. Intermediately disturbed landscapes have been linked with increased species richness, as some species can persist and even thrive in these environments [53]. At IAR, species from the genus *Gerbilliscus* were captured almost exclusively, suggesting that this particular landscape and level of disturbance are optimal for their survival [54]. Conversely, *L. rosalia* was mainly found across agricultural landscapes, which correlates with several studies that have reported that the species is commonly found along the fringes of agricultural landscapes [55]. Ecological niche preferences often drive habitat selection, and this is seen with *A. ineptus*, a species that prefers rocky outcrops [24]. These outcrops are found primarily at two study sites (ABR and NCR) that are characterized by a rocky incline near the base of the Magaliesberg. Animal behavior can also drive habitat selection and population numbers, as seen in *E. myurus* and *O. irroratus*. The territorial behavior exhibited by these species may explain the low capture numbers observed in our study [24]. Dietary preference may also explain the disappearance of some species from landscapes, as some small mammal species show seasonal shifts in diet [56]. These shifts may result in a change in food selection or a shift in distributional range in search of favorable food resources [48]. Another potential

behavioral driver of species capture numbers can be adjustments in activity patterns, as some small mammals, such as *S. pratensis*, can reportedly go into torpor [57]. These and other drivers are often linked with seasonal variation.

However, the overall lack of significant variation in species richness across seasons and land-use types is consistent with the findings of Sánchez-Cordero [57]. Contrary to our findings, however, Umetsu and Pardini [1] found that species richness across land-use types varied, leading to strong variation in small mammal community assemblages.

As far as beta-diversity-related nestedness, the five land-use types sampled are similar, and a large portion of this similarity is due to nestedness. The disappearance of some species across land-use types and seasons may therefore be a cause for concern, as this may support the theory that specialist species are being excluded from increasingly transformed landscapes and warmer climates [9,17,43]. In our study, the results obtained for community assemblage diversity, evenness, and similarity highlight the importance of holistic approaches to biodiversity research [4]. At first, the results suggest that the animal rehabilitation and ecotourism site has the most diverse and ecologically ordered community assemblage. However, when incorporating the biodiversity variables mentioned above, it appears to be a skewed view. Due to its low sample size, the findings from this heavily transformed site cannot be resolved into an accurate ecological representation. Community diversity and evenness refer to sample size, and a smaller dataset can lead to a distorted output that is heavily biased [13]. By including different ecosystem health and biodiversity measures, such as diversity, richness, evenness, and composition, the actual state of community assemblages could be more accurately interpreted across all sites [4].

The nature conservancy site showed high diversity and evenness during the dry season, which declined during the wet season. This is contrary to the findings of Sánchez-Cordero [49], who demonstrated that small mammal diversity was higher during the wet season. The residential, as well as the industrial and agricultural farmsteads also showed high diversity. These sites were exposed to intermediate levels of activity throughout the year, as the intensity and frequency of farming and grazing at these sites were well managed. Our findings are consistent with those of Horváth et al. [50] and Sánchez-Cordero [58], who reported that small mammal diversity is associated with habitat complexity. They further show that intensively farmed agricultural landscapes reduce habitat heterogeneity and subsequent declines in diversity and balance in community assemblages, whereas heterogeneously managed sites show high diversity.

5. Conclusions

Our study found that seasonal and land-use variation influences small mammal community assemblages, resulting in fluctuations in population numbers, as well as temporal and spatial differences in species richness. As evidenced by our results, particularly those of the natural and intermediately disturbed landscapes, continuously healthy and diverse wildlife populations in a changing world may rely on an environment that experiences some level of periodic disturbance. Although relatively undisturbed landscapes are preferable, it is possible to manage transformed landscapes to safeguard the species richness and community diversity of the region [59]. Therefore, it is important to carefully manage and monitor the frequency and intensity of anthropogenic disturbance to ensure that native populations can re-establish and stabilize after a disturbance event and continue to do so sustainably for extended periods. Considering the ecology, behavior, and physiology of different species, we can implement careful land-use management strategies to reduce the homogenization of natural landscapes and potentially slow the loss of species in southern African environments that are undergoing anthropogenic transformation.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/d14020138/s1>, Details of molecular methodology, Table S1: Summary information of reference sequences used in the construction of the maximum likelihood tree; Figure S1: Maximum likelihood tree.

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Institutional Review Board Statement: The study was conducted according to the guidelines and approval of the Animal Ethics Committee of the University of Pretoria, Pretoria, South Africa (Ethics clearance number EC044-18; 2018).

Data Availability Statement: The data presented in this study are available on request from the corresponding author or from the DSI-NRF Centre of Excellence for Invasion Biology.

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Conflicts of Interest: The authors declare that they have no other conflict of interest.

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