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Abundance and distribution of small mammals relative to human activities in the wildlife management areas of Ruvuma landscape, southern Tanzania

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Abstract
The overall objective of this study was to understand the influence of anthropogenic disturbance on the abundance, diversity, richness and distributionof small mammals, and in Wildlife Management Areas of the Ruvuma landscape: Mbarang'andu, Kimbanda, Kisungule in Namtumbo District and Nalika and Chingoli in Tunduru District. The survey was conducted using standard live Sherman trap (23 x 8 x 9 cm) andplastic bucket pitfall traps (33.3cm high x 30cm diameter). A total of 187 individual small mammals were captured, including 17 species in 16 genera and five families. Chingoli had the least number of species with five species while Kimbanda accommodated the highest number of species (with 10), closely followed by Kisungule with 9 species. Species diversity was significantly different between areas of high and low anthropogenic disturbance. Therefore we suggest that human resources and funds should be available to safe guard from any environmental degradation for the benefit of present and future generation.

Keywords: small mammals, conservation, human activities, habitat, wildlife management Areas, Ruvuma landscape

1. Introduction
An understanding of ecological situations in any system can be achieved through assessments of richness, diversity, and abundance of species [1]. The advantage to this is that at least some variables remain constant or can be controlled. In Africa however, small mammal populations, especially in Africa, exist in human disturbed environments [2]. In many cases, disturbed habitats provide living conditions suitable to most small mammals. Encroachment to protected areas is a worldwide human disturbance problem which contribute to the decline and extinction of wildlife [3, 4]. This has occurred as a result of human population increase in areas adjacent to protected areas; leading to increased demands of land for settlement, economic related activities, agriculture and other natural resources to improve livelihoods [5]. This has been recorded as a major factor to the global depletion of natural resources [6], due to habitat degradation, and loss or local extinction of fauna species including rodents and shrews. The small mammals we refer in this study are rats, shrews and elephant shrew.

In the Africa ecosystems, small mammals are important and they contribute to biodiversity by saving as food for birds of prey, reptiles and mammalian predators [7, 8]. They are primary consumers of seeds and herbage, they also serve as sources of human protein in areas where livestock is rarely kept [9]. However, small mammals are likely to be adversely impacted by frequent burning, cultivation as well as over use of either domestic herbivore mammal in agricultural land or wildlife of large mammals in protected areas. Research showed a decline of small mammals in areas adjacent to protected areas in the Serengeti-Mara ecosystem, due to human activities and which resulted into a decline of rodent-eating birds as well as some carnivore species [7].

Studies conducted in tropical savannah have been focused at understanding the influence of habitat disturbance on small mammal species diversity and distribution [7, 10]. These studies show greater association between species diversity and human pressure. In the five Wildlife Management Areas (WMAs) across of the Ruvuma landscape, increases in human activities have been reported [11]. These human activities include rice cultivation, cattle grazing, deforestation, mining, increased poaching and high incidences of bush fires [12].

However, the influence of these human induced factors on the abundance and distribution of small mammals in the WMAs of Ruvuma landscape is still not well known. This study was aimed at understanding the current status of small mammal communities with emphasis on the influence of anthropogenic disturbance on abundance, evenness, species diversity and richness. Specifically, the study aimed at obtaining answers to two main questions: First, what is the diversity and abundance of small mammals in the WMAs across the Ruvuma landscape? Second, how does human disturbance (burning, grazing and cultivation) influence the abundance, evenness and diversity in the study area? We predicted that small mammal species richness, diversity and abundance should be higher in low grazed and cultivated areas than in intensively grazed and heavily cultivated areas.

2. Methods and Materials

2.1. Study Area

This study was conducted in the Ruvuma landscape which encompasses five Wildlife Management Areas (WMAs) namely; Mbarang'andu, Kimbanda, Kisungule in Namtumbo District; Nalika and Chingoli in Tunduru District. The Ruvuma landscape is an extensive trans-frontier area of approximately 278,950 km^2, flanking the Ruvuma River, spanning Tanzania's southern regions (Coast, Lindi, Mtwara, Morogoro and Ruvuma), to Mozambique's northern provinces of Niassa and Cabo Delgado, forming the largest wilderness area of unfragmented miombo woodland, coastal forests and associated ecosystems remaining in Africa. The study area was comprised of 10 villages located between latitude -9° 52' 8" to -11° 45' 36" South and longitude 35° 41' 42" to 37° 19' 43" East (Figure 1). The Ruvuma landscape borders with Selous Game Reserve in the north and the Niassa Game Reserve (Mozambique) to the south. The Ruvuma River forms the international boundary between Tanzania and Mozambique within Namtumbo as well as Tunduru districts [13]. The landscape is also fragmented by a succession of west-east flowing rivers which cross the landscape till the Mozambique border and are associated with permanent swamp regions.The landscape is dominated by tree species of *Brachystegia* spp, *Julbernardia* spp., *Isoberlinia* spp, *Afzelia quanzensis*, *Pterocarpus angolensis*, rare and threatened *Dalbergia melanoxylon*. Other vegetation types include wooded grasslands, open savannahs, granite inselbergs, seasonal and permanent wetlands and Riverine forests along numerous perennial and seasonal streams [14]. The area is dominated by small hills which are slightly undulated to flat isolated hills [14]. The rainfall pattern is unimodal spanning from late November to May with a mean annual rainfall of 800-1200 mm in a north-south gradient, and the mean annual temperature is about 21°C following the Köppen system [15].

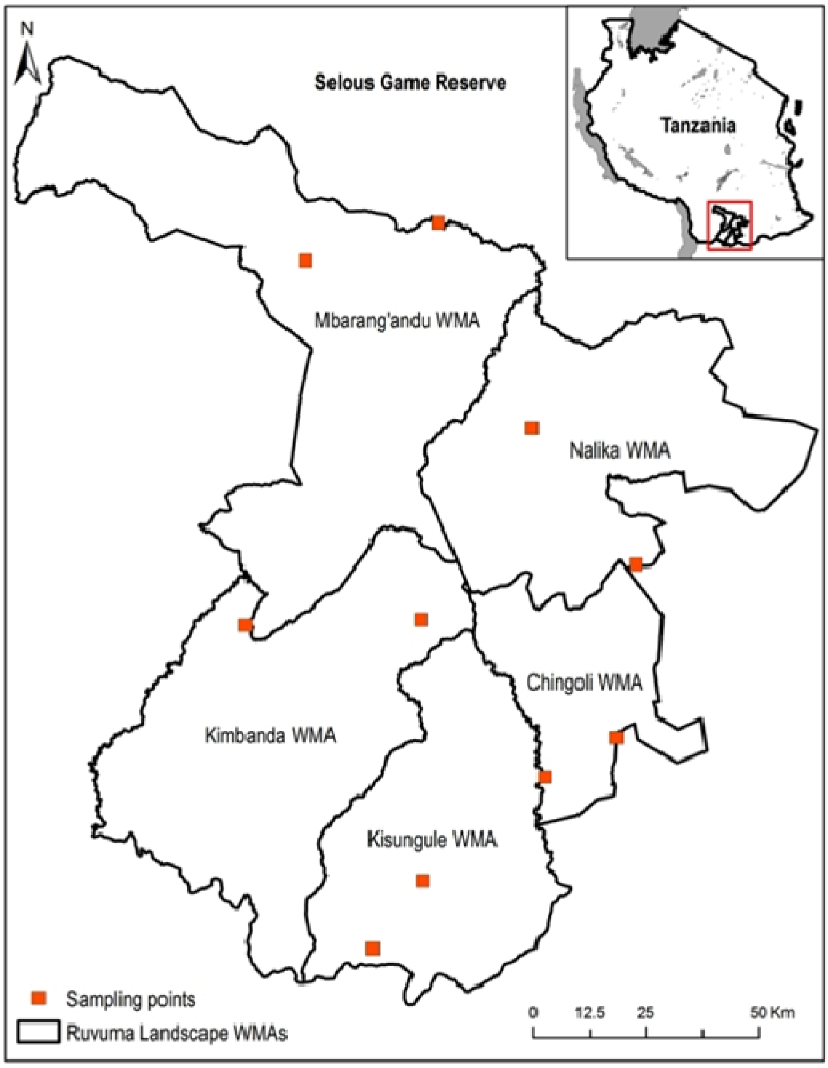

Fig 1: Map of Ruvuma landscape showing the five WMAs and the location of sampling sites

2.2. Trapping design

A total of 10 separate sites each covering a total area of approximately 10,000 m^2 were established in the five WMAs. We selected two main habitat/vegetation types namely miombo woodland and Riverine forest because these were the main types in the area. Disturbances such as level of grazing by livestock, wild fires burning and cultivation were recorded in two category; low (when just traces of disturbance were found) and high (when the whole plot sampled was either grazed or farmed or both). Burned areas were categorized into recently burned (when ash was present in the plot) and resprout (when grasses/herbs were regenerating). Each site was sampled for three consecutive days from 20th September to 25th November 2014 in the dry season of the year.

Small mammals were trapped with either standard live Sherman trap (23 x 8 x 9 cm) or plastic bucket pitfall traps (33.3cm high x 30cm diameter). On all trapping sites, 100 Sherman traps were placed per site in 10 lines, each with 10 trapping points at 10m apart. Sherman traps were baited with standard sized toasted coconut, sardines, sorghum grains and peanut butter baits every evening (around 16:00hr) and checked early the following morning (around 07:00hr). In a line 20 pitfall traps were placed per site, one to another pitfall trap was positioned at 5m intervals. A sheet of plastic (approximately 0.5m high) was erected as a "drift fence" so that animals moving into the area from either side are channeled along the plastic sheet towards the pitfall traps and were checked twice a day, early in the morning (07:00hr) and in the evening (16:00hr). Captured animals were placed in a zip-lock plastic bag and weighed using a spring balance and the animal weight was obtained by taking the difference between plastic bag and the captured animal. Measurements of body and tail length were taken with a transparent plastic ruler. Weight, length and overall appearance were used to identify animals to the generic to species level using a field guide book of [16].

2.3 Data analysis

2.3.1. Diversity and abundance of small mammal species in Wildlife Management Areas

Species richness estimates was obtained following [17]. This index uses three biodiversity indices including, diversity (the ability for species differences to coexist together), species richness was described as the number of different species in each area and evenness of species to see how close in numbers each species in an environment is in each of the five WMAs.

2.3.2. Small mammal species across disturbance levels

We compared areas of high and low cultivation, grazing and burning using Exact Wilcoxon-Mann-Whitney Rank sum tests with bonferroni correction in order to understand the effect of these factors on species number, diversity and evenness in the miombo and forest sites. Only in areas with both recent burn and sprouting after burning had sufficient data for comparison while comparison were done between high and low levels of cultivation, grazing and fire in Riverine forest. We calculated p-values and effect size *r*and used both of them to interpret our results. The effect size *r* indicates the likelihood that any effect we saw in our data, such a difference in means between groups, may have occurred by chance [18]. It is used to precisely measure the sizes of associations or the sizes of differences. The rules of thumb for interpreting these effect sizes, have been suggested that an *r* of |.1| represents a 'small' effect size, |.3| represents a 'medium' effect size and |.5| represents a 'large' effect size [18]. The *Z* values obtained from Mann-Whitney tests were used for calculation of the effect size *r*.

$$r = Z/\sqrt{N}$$

where *N* is the total number of the samples**.**

3. Results

3.1. Diversity and abundance of small mammal species in Wildlife Management Areas

A total of 187 small mammals were captured (Table 1), including seventeen species in three orders, five families and sixteen genera from 3000 trap- and 600 bucket nights. All the animals were first-time captures. The families recorded were Soricidae (with 1 species), Muridae (with 11), Sciuridae (2), Nesomyidae (1), Macroscelididae (2). Chingoli had the least number of species with five species while Kimbanda accommodated the highest number of species (10) closely followed by Kisungule (9). Mbarang'andu and Nalika had seven species each.

The overall diversity for five WMAs generally was less than 2.0. The result showed that Kisungule (H' = 1.934) has the highest species diversity of small mammal followed by Mbarang'andu (H' = 1.864) and Nalika (H' = 1.769, while species diversity calculated in Kimbanda (H' = 0.840) and Chingoli (H' = 0.631) did not exceed 1. The evenness of the communities was high in Mbarang'andu (E_H = 0.921) and Nalika WMA (E_H = 0.838) almost reaching complete evenness. The evenness of small mammals in other WMAs was relatively low ranging from E_H = 0.279 in Kimbanda to E_H= 0.408 in Chingoli which did not reach complete evenness.

Table 1: Small mammals identified (based on Kingdon, 2012) and number of individuals of each species trapped in the five WMAs of Ruvuma landscape. ¥ indicates new records for Ruvuma WMAs, LC= Least Concern, NT= Near Threatened

Order and Family	Common name	Status by IUCN	Grand Total	% capture
Order Rodentia				
Family Muridae				
Acomys spinosissimus Peters, 1852	Spiny Mouse	LC	10	5.35
Aethomys chrysophilus de Winton, 1897	Red Rock Rat	LC	12	6.42
Arvicanthis somalicus Thomas, 1903¥	Somali Grass Rat¥	LC	1	0.53
Gerbillus sp Desmarest, 1804			6	3.21
Grammomys dolichurus, Smuts, 1832	Woodland Thicket Rat	LC	2	1.07
Lemniscomys striatus Heuglin, 1864	Zebra mice	LC	6	3.21
Mastomys natalensis Smith, 1834	Multimammate Mouse	LC	117	62.57

Mus minutoides Smith, 1834	African Pygmy Mouse	LC	7	3.74
Myomys fumatus Peters, 1878	Meadow rat	LC	1	0.53
Praomys sp Thomas, 1915			1	0.53
Taterillus harringtoni Thomas, 1906	Emin's Tateril	LC	5	2.67
Family Sciuridae				
Xerus rutilus Cretzschmar, 1828	Unstriped Ground Squirrel	LC	1	0.53
Paraxerus flavovittis Peters, 1852	Striped Bush Squirrel	LC	1	0.53
Family Nesomyidae				
Dendromus mesomelas Brants, 1827	Brant's Climbing Mouse	LC	3	1.6
Order Macroscelidea				
Family Macroscelididae				
Rhynchocyon cirnei Peters, 1847	Chequered Elephant-shrew	NT	1	0.53
Rhynchocyon petersi Bocage, 1880	Black and Rufous Sengi	LC	5	2.67
Order Eulipotyphla				
Family Soricidae				
Crocidura hirta Peters, 1852	Lesser Red Musk Shrew	LC	8	4.28
		Total	187	100

3.2. Small mammal species across disturbance levels

The diversity of rodent species differed between the recently burnt areas and sprouting areas in the miombo woodland (Figure 2C,P = 0.0001, Z = 3.94, r = 0.60). The number of species (Figure 3C) was not significantly different between recently burnt and sprouting areas. In the Riverine forest, the diversity of rodent species differed significantly between areas of high and low cultivation (p = 0.026, Z = 2.22, r = 0.34), similar to the results on species evenness (p = 0.026, Z = -2.077, r = 0.32). `The effect of cultivation revealed similar with grazing. The number of rodents captured did not differ significantly between areas of high and low cultivation.

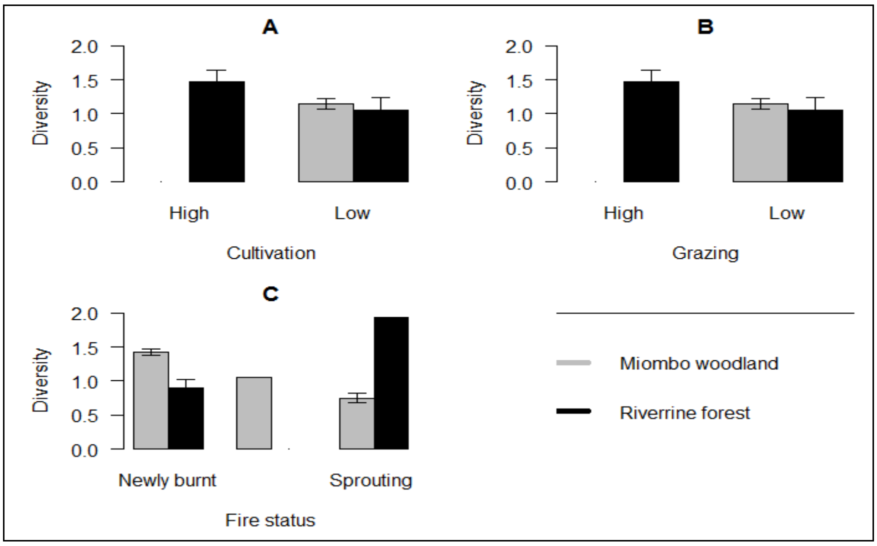

Fig 2: Diversity of rodent species plotted against observed levels of cultivation (A), grazing (B) and fire (C) in the Miombo (grey bar) and Riverine forest (black bar) vegetation of the Ruvuma Landscape in 2015.

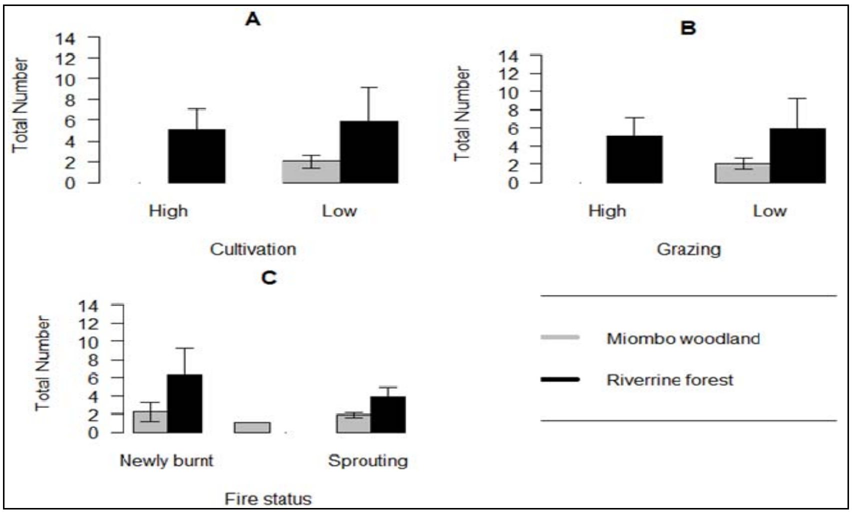

Fig 3: Bar graph of total number of rodents captured plotted against observed levels of cultivation (A), grazing (B) and fire (C) in the Miombo(grey bar) and Riverine forest (black bar)vegetation of the Ruvuma Landscape in 2015.

4. Discussion

4.1. Diversity and abundance of small mammal species in Wildlife Management Areas

In order to compare the results with the prediction from the questions laid out in the introduction. We proposed that small mammals' abundance, diversity and richness should change with cultivation, grazing and burning levels due to habitat degradation. The results obtained, indicated decline of small mammal species when compared to other protected area such as Katavi *Brachystegia* woodlands [19] and the savanna of Serengeti ecosystem [2, 20], the five WMAs situated in Ruvuma landscape is among the least rich areas in small mammal species composition. [19] recorded twenty three genera of small mammals in the Katavi ecosystem; [20] recorded eighteen species in the kopjes of the Serengeti National Park while [2] recorded forty species in the Serengeti ecosystem. Only seventeen species was recorded in the five WMAs, the Kimbanda and Kisungule WMAs supported higher species richness than most others in the landscape, presumably due to their varied microhabitats provided by the thick undergrowth Riverine forest. Undergrowth is particularly crucial which provided habitat heterogeneity of the area. However, it is possible that some animals were missed at other habitats as we selected two main habitat/vegetation types namely miombo woodland and Riverine forest due to constraint of our budget being small to establish more sites in the whole Ruvuma landscape. The low in species diversity in Chingoli and Kimbanda probably was due to different and low in habitat suitability within the areas, which attracts fewer species to move in.

In terms of distribution and abundance, the most common small mammals recorded include, rats, shrews and elephant shrew. Most of the small mammals trapped belong to the family Muridae, having 11 species (table 1) with the *Mastomys natalensis* being highly the most commonly found species, accounting for 62.57% of captures and was the most abundant in the five WMAs, followed by other members in the same family, in proportions (between 0.53 to 6.42%) but representing high diversity including *Aethomy schrysophilus* (6.42%), *Acomys spinosissimus* (5.35%), *Grammomys dolichurus* (1.07%), *Lemniscomys striatus* (3.21%), *Mus minutoides* (3.74%), *Gerbillussp* (3.21%) and *Taterillus harringtoni* (2.67%). The *Crocidura hirta* was recorded and represented 4.28% of the captured small mammals in the five WMA's (Table 1). Somali grass rat (*A. somalicus*) was trapped and recorded for the first time in the Ruvuma landscape represented 0.53% of the trapped rodent at Kimbanda WMA. [21] Explained distribution of *A. somalicus* to occur in two areas: one in Somalia and Ethiopia and a second in northern Tanzania and have not indicated whether the species occurs in Southern Tanzania. *Rhynchocyon cirnei* this species was listed by IUCN in 2008 as Near Threatened-NT [22], the species was found in fragmented forest patches present in Kimbanda WMA in southern Tanzania. The *R. cirnei* is threatened by alteration, fragmentation and loss of closed forest habitat. The *R. petersi* was also recorded and faced with threats similar to those for *R. cirnei.*

4.2. Small mammal species across disturbance levels

The distribution of small mammal species in the WMAs in Ruvuma landscape was influenced by the level of anthropogenic disturbance. Cultivation and grazing revealed significant influence on distribution of small mammals in the five WMAs. Both the increase in cultivation and intensive grazing lowered the richness of small mammal species in the Riverine vegetation, which is in agreement with hypothesis we laid down in the introduction. There is increasing evidence that disturbance has an impact on biodiversity. Many studies including [23-26] have shown that different types and scales of disturbance have different effects and that different mammal's type including rodents and shrews respond to the same form of disturbance in different ways. The higher species records of small mammals in burned and grazed areas was due to new vegetation (sprouting) presumably provided better nutrition for small mammal species and the requirements for breeding, growth and survival of the young. Being an r-selected species [27], *M. natalensis* are perhaps better adapted to colonize disturbed Savannah land in Sub-Saharan Africa, where disturbances are common. Being a generalist in feeding habits [28], it is therefore better adapted for colonizing areas such as the miombo and Riverine disturbed field. Therefore, it has been suggested that regenerating vegetation creates an attractive food resource for species such as *M. natalensis* [29].

Anthropogenic disturbances have different effects on small mammals' distribution in the five WMAs. The response of small mammal species to habitat disturbance depends in varying degrees on physical modification, isolation and habitat area [30]. Habitat specific species including rare species are important to monitor, as they are particularly vulnerable to environmental change. With this study, it was difficult to draw convincing general conclusions about the effects of anthropogenic disturbances on small mammal species richness, diversity and abundance as such conclusions require extensive research study. It is worth noting that the data we analyzed were obtained from a short term survey conducted in one season. This could have an influence on the results we have presented and we think that long term survey data could give us more realistic results. Future research, however, should focus on quantifying the impact of the many forms of disturbance on mammal fauna this will give us a much better understanding of the environmental health of the WMAs and so that we will be able to suggest better management decisions on land use for the good sake of both the natives and the biodiversity

The overall results have suggested that small mammal species richness, diversity, evenness and abundance was significantly influenced by human disturbance, in line with findings by [31] who observed human disturbance had a negative effect on the abundance and diversity of small mammals, and also reported the effects to be increased with intensity of disturbance. Although, Kimbanda and Kisungule WMAs supported higher species richness than most others in the landscape, small mammal species richness was still greatly affected by the intensity of disturbance. Less diversity of small mammal species was recorded in areas where human activities are intensively operated in Kimbanda and Kisungule WMAs, which is in agreement with hypothesis we laid down in the introduction. Rice cultivation was very intensive in Kimbanda and Kisungule WMAs and had affected diversity, indicating that land clearance for rice farms influenced the species diversity, because some species are prone to disturbance and could therefore have shifted to other habitats for breeding and foraging.

5. Implications for conservation in the five WMAs of Ruvuma landscape

Small mammal species richness, diversity, evenness and abundance in the five WMAs were influenced by human pressure in miombo woodlands of southern Tanzania. Finding from this study indicates that the five WMAs are under great threat due to anthropogenic activities. While recently there has been a widespread operation to convert Riverine flooded forest for the cultivation of rice in turn affecting the forest-dependent small mammal species, land conversion of flooded grassland and miombo woodland will induce a marked loss in small mammal richness and diversity in areas lacking protection within the next decade. It is true that small mammals play a wide range of elusive and indirect roles in the function of miombo ecosystems [32]. For example, small mammals prey on seeds and seedlings of tree species and disperse seeds, thereby influencing tree establishment and woodland dynamics. Therefore, the loss of particular functional groups, such as granivores, may alter ecosystem processes, such as shrub encroachment through reduced levels of seed predation [33] or could alter plant community composition in the Ruvuma landscape. It is possible that both changing climate and increased anthropogenic disturbances are acting upon the Ruvuma landscape thereby influencing biodiversity existence. Therefore, we propose conservation measures to be undertaken to enhance resilience at a landscape scale in order to prevent irreversible loss of species diversity in response to sudden regime shifts. In this case, it is suggested that the adjacent community be involved in conservation of biodiversity in the WMAs. Land use planning should be encouraged and implemented among local communities in order to put aside land for biodiversity conservation. Most importantly, would be a 're-wilding approach', we advise to incorporate multiple trophic levels [34] in the mentioned WMAs by aiming at protecting trophic processes rather than individual species. WMAs should act as buffers of remnant habitat around natural areas of Selous Game Reserve and Niassa Reserve in order to accommodate both gradual change and or sudden stochastic disturbance events. Protected natural ecosystem should be runs up against an agricultural-ecological barrier, such measures would enhance the resilience of protected areas and would complement the goals of community based conservation measures [3, 35], but we still worried with the proposed intervention measures possibly will be challenged with increasing human pressure as well as a rapidly changing climate to intensify agricultural land for food production.

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