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Impacts of Recreational Infrastructure on Rodent Communities and their Associated Haemoparasites in Serengeti National Park, Tanzania

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ABSTRACT

Rodents are a vital component of ecosystems as they play an important role in community structure, stability, and diversity. Recreational infrastructure constructed in Protected Areas to support leisure and recreation activities for tourists, may disrupt the rodents' natural environment and influence dynamism in their communities and in turn their associated haemoparasites. This may lead to transmission of the haemoparasites to the humans. Capture-Mark- Release was used to collect data where four transect lines of 100 meters; set 10 meters apart were used for setting traps in selected trapping sites; and capillary tubes were used to collect blood samples for assessment of haemoparasites' prevalence. A total of 128 rodents belonging to 9 species were captured, of which *Mastomys natalensis* was the dominant species (53.1%). Generally, areas with less active infrastructure had higher diversity, but lower breeding patterns. *Bacillus spp* was the only haemoparasite observed to prevail in 24% of all captured rodents. The study concludes that the recreational infrastructure, does not directly impact rodent communities; but rather the communities are influenced by the general nature of their surrounding environment. Thus, we recommend further studies be done on rodents in relation to potential zoonotic haemoparasites around recreational infrastructure within protected areas.

Keywords: Abundance – Diversity - Community Structure - Recreational Infrastructure-Haemoparasites - Protected Areas - Serengeti National Park.

INTRODUCTION

Recreational infrastructure such as, walking trails, airstrips, hotels, roads, lodges and campsites, are manmade facilities that are designed to support leisure and recreation activities for tourists visiting Protected Areas (PAs). These facilities have been developed within PAs over the years (Zhong *et al.* 2015), and have been known to play an important role in the tourism industry by accommodating and catering for tourists' needs.

Apart from being helpful in accommodating tourists' needs, recreational infrastructure may also have negative impacts on the environment (Erdogan and Tosun 2009). For instance, during construction of roads and hotels, wildlife is directly affected by habitat destruction through fragmentation of food patches and restriction of wild animals' movement, hence denies the wildlife access to resources (Bennet *et al.* 2011). Similarly, after construction, roads can affect wildlife population through road mortality (Clark *et al.* 2010). Moreover, the construction of recreational infrastructure in PAs may alter patterns of wildlife's natural behaviour, more specifically feeding behaviour and their contact with humans (Orams 2002). These impacts in turn may significantly affect the flora and fauna in different ecosystems.

Small mammals, particularly rodents are a vital component of ecosystems influencing various ecological aspects such as community structure, stability, and diversity (Dunstan and Fox 1996). Because of their sensitivity to adverse conditions, rodents can act as indicators of environmental suitability in their respective ecosystems (Addessi *et al.* 2011). Rodents have also been known to be carriers of agents of diseases; some of the diseases can be transmitted from animals to humans and vice versa, (Nyirenda *et al.* 2017). Human disturbance has been known to facilitate interaction between humans and rodents, and through such interactions, diseases which can be harmful and even fatal to both humans and rodents can easily be transmitted (Katakweba *et al.* 2012).

Thus, understanding the link between rodent communities and the impacts imposed by development of recreational infrastructure is important because these interactions may have an effect on both sides (Buzan *et al.* 2016). Moreover, ecological impacts of these infrastructures within PAs are often extended far beyond the surface covered by the infrastructure itself. There has been an increase in development of recreational infrastructure within the Serengeti National Park (SENAPA 2016) which in turn affects the wildlife communities. Different studies have been done on rodent community structure within SENAPA including (Senzota 1982, Magige and Senzota 2006, Byrom *et al.* 2010), these studies mainly focused on the habitats, feeding habits and even population dynamics of the small mammals in SENAPA at large. Despite this vast body of knowledge, there is still a knowledge gap on the influence that recreational infrastructure built within PAs have on small mammals' community structures, specifically rodents, given the fact that rodents are potential agents of transmitting diseases of economic importance to human beings. Addressing this gap is crucial to our understanding on the ecology of rodents.

Therefore, this study seeks to assess if and how the presence of recreational infrastructure in the national park affects rodent communities. Information from this study will be useful in shedding light on possible risk factors imposed to both the humans and rodents, around recreational infrastructure within the PAs so as to lessen interaction between the two.

In this study, we assess the impacts of recreational infrastructure on rodent communities and their associated haemoparasites in Serengeti National Park. Specifically, the study aims (i) To determine rodents' species richness, diversity and abundance around recreational infrastructure areas in Serengeti National Park. (ii) To assess the population structure and distribution of rodents around recreational infrastructure within Serengeti National Park. (iii) To estimate prevalence of potential haemoparasites in rodents around recreational infrastructure areas in Serengeti National Park.

MATERIAL AND METHODS

Study site

The study was conducted in Serengeti National Park from July to October 2020. SENAPA is the third largest national park in Tanzania after Nyerere and Ruaha National Parks respectively**.** It is found in the North-western part of Tanzania, within Mara and Simiyu regions. According to SENAPA (2010), the park covers 14,763 square kilometres and is located 2°20'S 34° 34'E of Tanzania, elevation ranging from 920m to 1850 m above sea level, with a mean temperature varying from 13 to 28°C. The Park is bordered to the north by Maasai Mara

National Reserve in Kenya, to the south-east by the Ngorongoro Conservation Area, to the south-west by Maswa Game Reserve, to the east by Loliondo Game Controlled Area and to the west by Ikorongo and Grumeti Game Reserves. The vegetation in the park includes; grassland plains, savannah, riverine forests and woodlands. Data was collected from the central part of SENAPA called Seronera (Figure 1). SENAPA was chosen as a study area because it is the most visited Park in Tanzania, receiving about 350,000 visitors annually, correspondingly SENAPA has a larger and more diverse number of recreational infrastructures to accommodate such visitors.

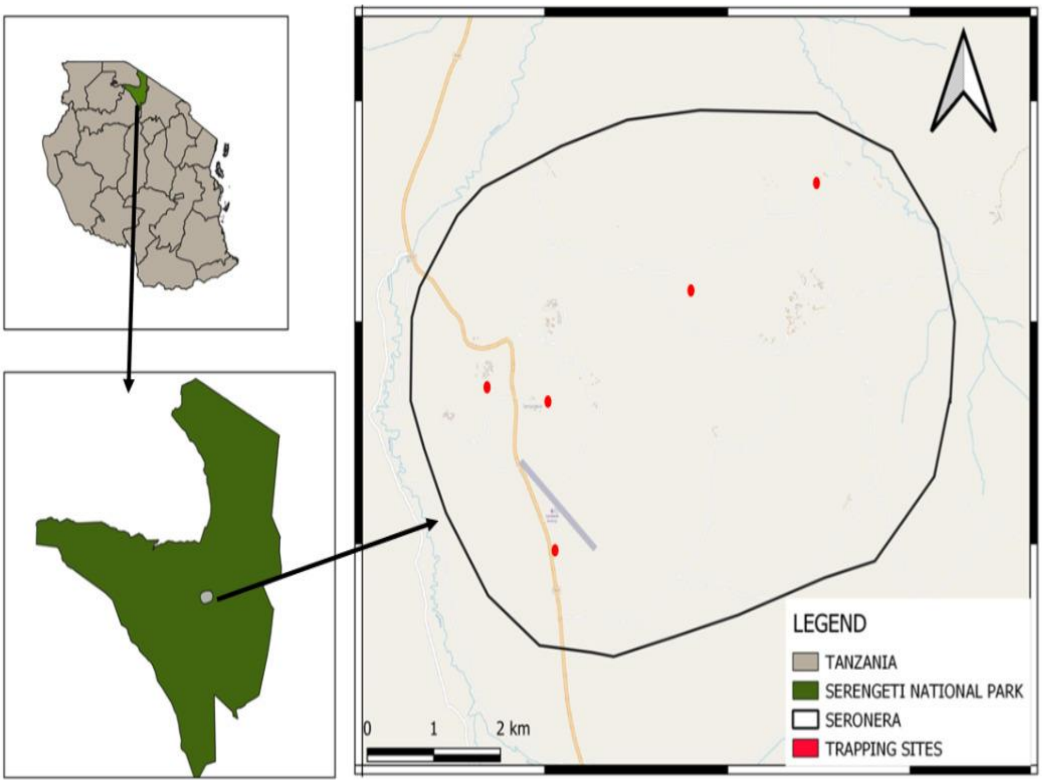

Figure 1: Map of the Serengeti National Park showing the trapping sites (red dots) at Seronera: an insert is the map of Tanzania indicating the location of SENAPA

Data collection

Recreational sites considered in this study included campsites, lodges and roadways. Within Serengeti National Park there are around 22 camping sites, which include seasonal/ special tented campsites, public campsites and permanent tented campsites, six lodges, and main roadways leading to the four main gates (Naabi Hill, Fort Ikoma, Bologonja and Ndabaka) (SENAPA 2016). The Park also has gates that are seldom used which are; Klein's gate and Handajega gate. Selection of recreational infrastructure for data collection was first done by randomly choosing four types of infrastructure: lodge, campsite, hostel and roadway, and thereafter by systematically picking the largest and busiest lodge and hostel, a permanent and public campsite, a roadway and a site without any infrastructure (control area). From these criteria, data were then collected at the infrastructure around Seronera area including Seronera Wildlife Lodge, Pimbi Campsite, Youth Hostel, Nyani Campsite, A roadway connecting Seronera Airstrip to Seronera shopping centre and a control area without any infrastructure.

Capture- Mark- Release technique was used to collect data, where by Sherman traps were set on transect lines. Four transect lines of 100m length were set at a 10m distance apart in each recreational infrastructure. In each transect line 10 Sherman traps of size (8*9*23 cm) were set 10 meters apart, making a total of 40 traps per site. Traps were baited with peanut butter mixed with maize flour, and were set early in the morning and in the evening and were re- baited after capture was been done and data had been recorded. Checking of the traps was also done during these hours before re-baiting. To avoid misplacing of traps by other animals, traps were camouflaged by hiding them in bushes or covered by grass. The captured rodents were marked by shaving their fur using a pair of scissors on their backs near the tail for easy visibility of the mark. Data recorded included, sex, body weight and length, tail length, hind foot and ear length were measured using digital calliper. In addition, further identification was done by experts from Sokoine University (Pest Management Centre), field guide books were used for species identification (Happold *et al.* 2013 and Kingdon 2015). Moreover, Leirs and Verheyen (1995) guidelines for rodents' age structure were used to categorize captured individuals into different age and sex classes. The age was categorised as juveniles (<20g), sub-adults/immature (21g-23g), Adults (>24g) and sex as female and male. The distribution of the rodent species was recorded by considering the presence or absence of the captured rodents in the particular habitat.

Blood samples were collected from the captured rodents by placing a capillary tube at the corner of the eye, where blood was drawn into the tube and thereafter the rodent's eye was wiped using cotton wool to avoid the blood affecting the eye. Thick and thin smears were made on glass slides, for each blood sample drawn from the rodents and labelled. The blood smear was fixed using 100% methanol concentration for two minutes, then left to air dry and preserved in a slide box.

The preserved dry smears were stained with 10% Giemsa for 30 minutes at the laboratory, where they turned from red to purple colour, and the stained samples were examined using 100× objectives under ordinary light microscope. Examining the stained smear helped in identifying different haemoparasites that were carried within the captured rodents' blood.

Data Analysis

Rodents' abundance was calculated as the minimum number alive (MNA) index in each capture. MNA in Capture-Mark-Recapture is defined as the number of individuals caught in that capture session in each habitat and those that were caught both previously and subsequently (Krebs 1966).

Species diversity (number of species and numerical contribution of each to the community) were calculated using the Shannon-Wiener diversity index (Krebs 1999), as it also accounts for species evenness and richness in distribution of a sample in a number of sites.

$$H_i = -\sum_{i=1}^{s} PiLnp_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where pi = S / N

H_i = species diversity index,
S = number of individuals of one species,
N = total number of individuals in the sample,
Pi = is the relative abundance (proportion) of the ith species in the community,
Ln Pi = natural logarithm of Pi.

Kruskal Wallis test was used for comparing species richness and abundance between the recreational infrastructures.

Sex ratio was calculated in each recreational infrastructure as the number of females divides by the number of females plus the number of males i.e., $\frac{F}{F+M}$.

Breeding pattern was grouped as active and inactive individuals, where active individuals were perforated or pregnant females and active males had visible scrotum, while inactive females had small nipples and not perforated and inactive males had no visible scrotum. In each recreational infrastructure age was categorised as juveniles (<20g), sub-adults/immature (21g-23g), Adults (>24g)) and sex (female and male) of the individuals. To test the significant difference of recreational infrastructure on sex, breeding pattern, Kruskal Wallis test was used while in age ANOVA test was used. The distribution of the rodent species was recorded by considering the presence or absence of the captured rodents in the particular habitat. The prevalence of haemoparasites in rodents was estimated in percentage (Okeke *et al.* 2013), between species, and the recreational infrastructures.

Prevalence (N) =N1/N2*100 ……… (2)

Where:

N =percentage prevalence,
N1 =Number of rodents infected,
N2 =Total number of rodents examined for the blood parasites.

In testing for significant difference between recreational infrastructures, ANOVA test was used.

RESULTS

Rodents' specie's richness, diversity and abundance

A total of 128 individuals; 60 males and 68 females were captured between July 2020 and October 2020, belonging to 9 different species (Table 1). Generally, recreational infrastructures with less human activities (less busy sites) had higher abundance, about 60% (77 individuals) of captured individuals as compared to the busiest (infrastructures with more human activities) (Table1). While no rodent was captured in control area (area with no recreational infrastructure) the number of individuals (species abundance) captured was significantly different between recreational infrastructures (Kruskal Wallis: $\chi2 = 3.91$, df = 5, P = 0.03084). Rodents were more abundant at the Youth Hostel which was the busiest recreational infrastructure in terms of human interaction or use, and were less abundant at the Airstrip Road which was another busy recreational infrastructure in terms of movement of vehicles to and from the Airstrip and the Seronera Shopping Centre (Table 1); however, the number of rodents was relatively similar in less busy recreational infrastructures (Table 1). With the relative abundance of 53%, *Mastomys natalensis* was the dominant species in the areas, while *Rhabdomys spp* was the least abundant of all species in all habitats (Table 1).Similarly, species richness was higher in recreational infrastructures with less human activities than busiest infrastructures (Table 1). Further analysis by Kruskal Wallis indicate that the number of species captured were significantly different between infrastructures (Kruskal Wallis test: $\chi2$ = 34.0, df = 5, p = 0.003). Between Infrastructures, less busy (Pimbi Campsite and Seronera Wildlife Lodge) recreational infrastructures had higher species richness as compared to the busiest recreational infrastructures (Table 1).

Table 1: Rodent's species abundance and richness in the study sites

Species	Recreational Infrastructure					Control Site	**Overall number of individuals**
	Busiest Sites		Less Busy Sites				
	Youth Hostel	Airstrip Road	Wildlife Lodge	Pimbi Camp	Nyani Camp	Open Area	
M. natalensis	25	10	16	5	12	0	68
A. niloticus	7	5	5	1	4	0	22
Sacostomys spp	2	0	1	2	0	0	5
Aethomys spp	0	1	1	5	2	0	9
Mus spp	0	1	1	4	6	0	12
Acomys spp	0	0	0	5	0	0	5
Rhabdomys spp	0	0	0	1	0	0	1
Tatera/gb spp	0	0	0	2	0	0	2
Graphiurus spp	0	0	4	0	0	0	4
Total	34	17	28	25	24	0	1128
Richness	3	4	6	8	4	0	

Overall, areas with recreational infrastructure that were less busy or inactive, i.e., Pimbi Campsite, Wildlife Lodge and Nyani Campsite had a more diverse community as compared to the busy sites, Youth Hostel and Airstrip Road (Figure. 2). Moreover, of the six-study sites, Pimbi Campsite had the highest species diversity (H'= 1.921), while the busiest or most active site (Youth Hostel), had the least diverse rodent community (H'= 0.718) (Figure. 2).

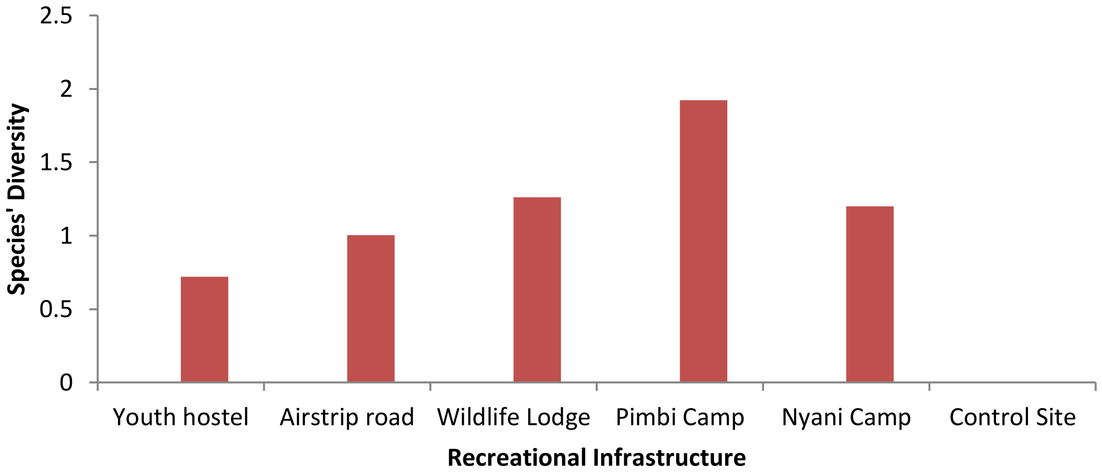

Figure 2: Rodent's species diversity across Infrastructure

Rodent Species' Population Structure and Distribution

Sex ratio

Overall, the population of rodent in the study area was composed of more females than males, with a sex ration of 0.53 (i.e., 53% females and 47% males). However, regardless of the level of activeness, sex ratio varied significantly between recreational infrastructures (χ^2 = 1.317, df = 5, P = 0.02162). The Airstrip Road that leads towards the Seronera shopping centre had the lowest number of females (sex ratio) of *Mastomys spp* which was also observed at Pimbi Campsite, also lower number of females (sex ratio) of *Aetomys spp*, a similar observation was also made at Nyani Campsite and Wildlife Lodge. Nyani Campsite had higher number of females (sex ratio) of *Mastomys spp* and *Avicanthis spp*, a similar situation was observed at Wildlife Lodge and Youth Hostel (Figure. 3). *Graphiurus spp* had no females captured in all recreational infrastructures except in Wildlife Lodge (Figure. 3).

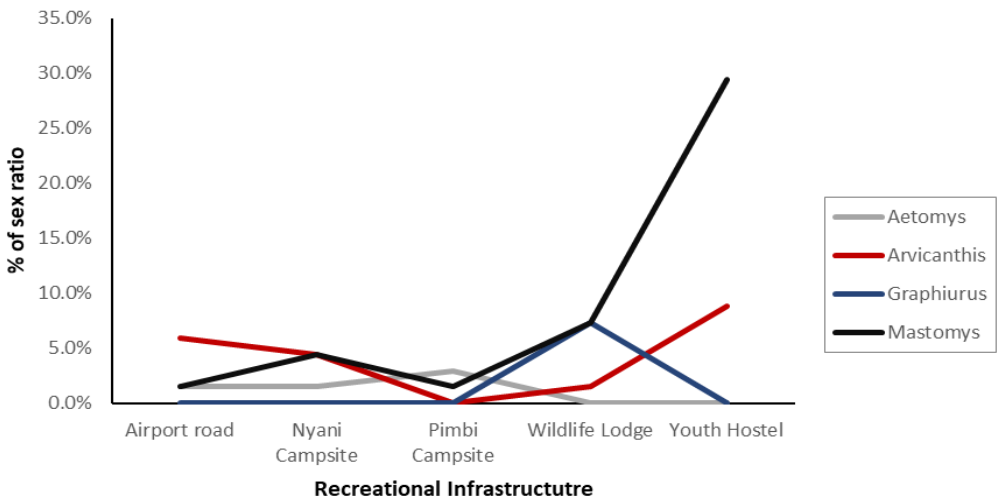

Figure 3: Rodent's species sex ratio across Infrastructure

Breeding pattern

Breeding pattern was categorized into active and inactive individuals. The less busy sites had high occurrence of inactive individuals i.e., Wildlife Lodge and Nyani Campsite and the least was Pimbi Campsite (Figure. 4). While Youth Hostel which was among the busiest recreational infrastructure had the highest number of active individuals, Pimbi Campsite which was among the less active recreational infrastructure had relatively similar number of both active and inactive individuals. This observation was further supported by Kruskal Wallis analysis which indicate that there was a significant difference in number of active individuals across infrastructure (χ^2 =58.6487, df = 5, p = 0.018).

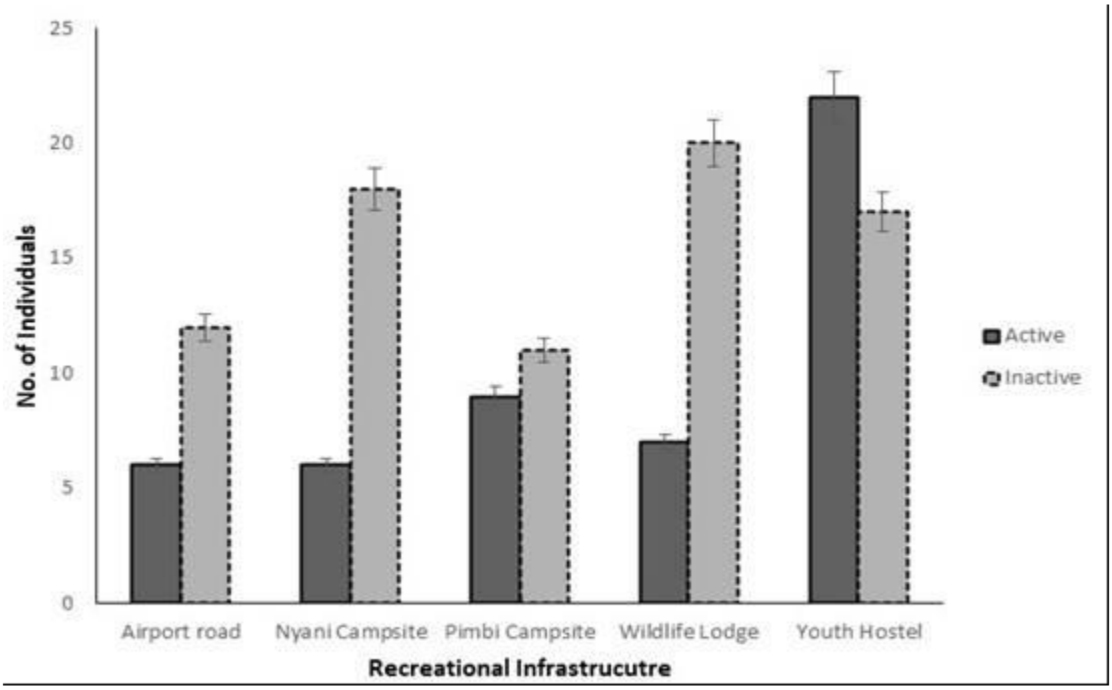

Figure 4: Breeding patterns of captured rodents across infrastructure

Age Structure

The age structure of rodent community was assessed only for *Mastomys natalensis* because so far this is the only rodent species which has the guidelines for determining the age categories. Generally, *M. natalensis* population in the study area was slightly dominated by juveniles (55% of the total captured population). However, there was variation in age structure across recreational infrastructure. Population of *M. natalensis* at Youth Hostel comprised more with adults than juvenile, while that at Wildlife Lodge and Nyani Campsite were comprised of more juveniles than adults, whereas the population at Pimbi Campsite had relatively similar composition of adults and juveniles (Figure. 5). The abundance of adults and juveniles was not significantly different across and within the infrastructure (F_5 = 1.92, p = 0.070).

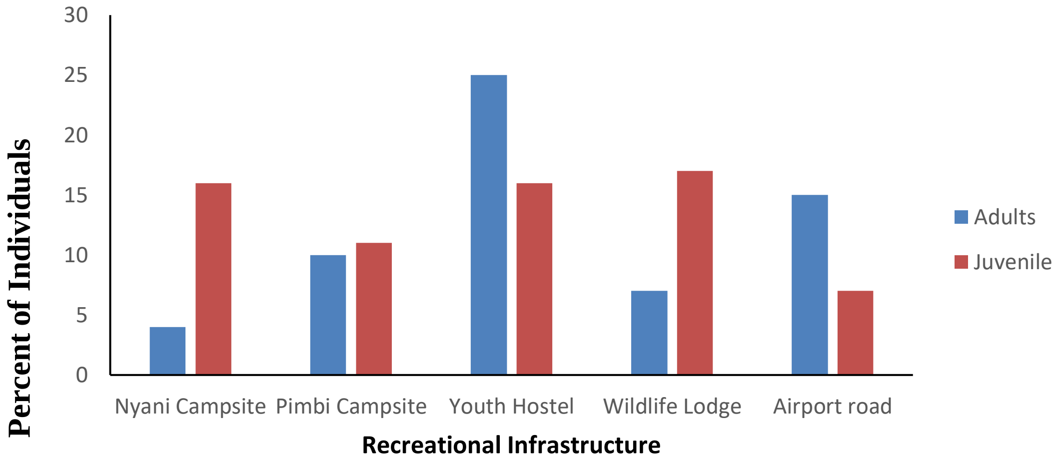

Figure 5: Age structure of captured *M. natalensis* across infrastructure

Prevalence of Haemoparasites

The rodents' species captured were tested for haemoparasites, out of 128 captured rodents, 31 individuals equivalent to 24% (n = 128) showed pleomorphic rods of *Bacillus spp*. The prevalence between infrastructure was significantly different ($F_5 = 4.937$, $p = 0.00014$). It was observed that 57.14% (n = 128) of rodents with *Bacillus spp* haemoparasites were captured at Pimbi Campsite, while 7.14% of the rodents were from Wildlife Lodge, and that Youth Hostel had no rodents with haemoparasites (Table 2). Moreover, the prevalence of parasites also varied between sexes, the parasite was detected in both males and females of *Aetomys spp*, *Mus spp* and *Sacostomys spp*, while in *Mastomys spp* the haemoparasites were observed only in males and in *Acomys spp* it was only recorded in females (Table 2).

Table 2: Percent of haemoparasites positive individuals in specific infrastructure

	Airstrip Road	Nyani Camp	Pimbi Camp	Wildlife Lodge	Total
F	**0**	**7.14**	**35.71**	**0**	**42.85**
Acomys spp	0	0	7.14	0	7.14
Aetomys spp	0	0	14.29	0	14.29
Mus spp	0	7.14	7.14	0	14.28
Sacostomys spp	0	0	7.14	0	7.14
M	**14.29**	**14.29**	**21.43**	**7.14**	**57.15**
Aetomys spp	7.14	0	0	0	7.14
Mastomys spp	7.14	7.14	14.29	7.14	35.71
Mus spp	0	7.14	0	0	7.14
Sacostomys spp	0	0	7.14	0	7.14
Total	**14.29**	**21.43**	**57.14**	**7.14**	

DISCUSSION AND CONCLUSION

This study aimed at assessing the impacts that recreational infrastructure poses on rodents' communities and their associated haemoparasites. The study found a variation in rodent composition between infrastructures i.e., sites where there was no infrastructure built, sites where the infrastructure was barely in use and sites where the infrastructure was occupied by visitors.

During the study, nine rodent species were captured, (*Mastomys natalensis*, *Arvicanthis niloticus*, *Sacostomys spp*, *Mus musculus*, *Aetomys spp*, *Acomys spp*, *Rhabdomys spp*, *Tatera spp*, *Graphiurus spp)*. The most dominant species among these was the *M. natalensis* which was found in five out of the six sites; i.e., Youth Hostel, Seronera Wildlife Lodge, Seronera Airstrip- Seronera Shopping Centre Road, Pimbi Campsite and Nyani Campsite. The least dominant species was the *Rhabdomys spp*, this species was only captured at the Pimbi Campsite.

The six trapping sites had a variation in the rodent communities. In the control area, which was an open area and did not have any infrastructure built, there was no rodent species captured. These differences could be due to the difference on vegetation cover around infrastructures. According to Magige (2013), open plain areas tend to have a lower number of rodents present due to possibility of predation and lack of immediate food sources. This could mean that the areas with recreational infrastructure acted as cover to the rodent communities.

Pimbi Campsite which is rocky in nature with woodland vegetation cover, provided an environment which favours a wide range of species as evidenced by having highest diversity of rodent species.

The number of rodents in an area tends to change from time to time depending on several factors like food availability, environment factors and reproductive potential of rodents (Mulungu *et al.* 2015). In the case of Youth Hostel, the high abundance of rodents might have been facilitated by ease access to food. Orams (2002) also found that presence of human contact in the rodents' environment can alter its feeding behavior, and the hostel was found near a Shopping Center that had two restaurants and three shops, but also human households are within a rodents' home range, i.e., 300 meters. Thus, access to food from leftovers from the kitchens and dumpsters is a contributing factor to the high abundance.

At the Youth Hostel the most dominant species was *M. natalensis* (74%), which is in agreement with Bonwitt *et al.* (2017) assertion that areas with high human activity are associated with factors that draw the *M. natalensis* to the particular environment.

The Seronera Wildlife Lodge was second in high diversity. The lodge is surrounded with woodland vegetation that provides cover for survival of the different rodent species. The lodge pits also provide easy access to food from the remains disposed from the lodge though it did not have high visitor occupancy at the time.

The Seronera Airstrip- Seronera Shopping Centre roadway had low abundance and diversity possibly because it is associated with frequent movement of vehicles. This probably makes the rodents vulnerable to road mortality. It was also observed that the rodents were more abundant on the transect lines further away from the road as compared to the ones that were 10 meters from each side of the road. The road sides were also associated with grassland plains type of vegetation giving the rodents less cover.

The sex ratio was calculated in order to understand the population structure. It was calculated across the different infrastructure sites and among rodent species. The number of females, both across infrastructure and among species in the sites, was found to be slightly higher than that of males. The ratio of males to females having slight variations has been demonstrated in other studies as well showing the differences in behaviour, immune and predation pressure as common characteristics in regulating the balance between sexes in different species of animals (Mulungu *et al.* 2013, Borremans *et al.* 2014). This could imply that the higher number of females was associated with their survival skills and ability to be immune to adverse conditions in the wild.

In the case of breeding patterns, the Youth Hostel had the highest number of reproductively active individuals across species. According to Dantas *et al.* (2021), rodents can withhold from reproducing in case of harsh environment, which relates to findings that rodents can act as indicators of environmental suitability in their respective ecosystems (Addessi *et al.* 2011). Therefore, the easier availability of food at the Youth Hostel might be associated with higher rates of reproductive activities, as found by Waggoner (2000), Connior (2011), the varieties of food preferences to rodents helps them in foraging on a variety of food items such as seeds, invertebrates, plants and fruits.

Therefore, the access to disposed food alongside natural wild food materials, and presence of vegetation cover (as it was surrounded by a rocky and woodland area), might have enhanced the freedom to reproduce.

In the case of age difference across the infrastructures which was based on the *Mastomys Natalensis* species; the Youth Hostel was found to have the highest number of adults and fairly high number of Juveniles as well. Generally, across all infrastructures, the number of adults was higher than the juveniles. The findings of this study are similar to the findings of Assefa and Srinivasulu (2019) who found that adults have large home ranges, active movement, and higher social ranking within rodent communities.

The results show that in terms of population structure of the rodents across infrastructure, the Youth Hostel had the highest activity in terms of age, breeding patterns and sex ratio. This is in line with Dantas *et al.* (2021) findings that showed higher reproductive activity of rodent species in areas where the rodents can have easy access to disposed food materials for some species like *M. natalensis*, but mainly in an environment that is not too harsh for their survival, which according to Mohammadi (2010) and Gomez *et al*. (2012), human activities have a major influence in the rodent's survival alongside other favorable conditions such as vegetation type or environmental condition at large.

The study included examining rodents' blood samples to look for potential haemoparasites that can cause diseases. The haemoparasites found were pleomorphic rods of *Bacillus spp*. According to Gratz (1994) and Katakweba (2018), the presence of the *Bacillus spp* are not completely unexpected as rodents are carriers of various bacterial organisms, and may not impose potential risks of zoonosis in cases where the serological tests on blood from the same animals were found to be negative for antibodies against the antigens of potential pathogens (Katakweba *et al.* 2012), thus making it non conclusive to have a potential risk of diseases in study site (Katakweba 2018).

Based on the results, recreational infrastructure does not highly influence rodent's diversity and abundance within protected areas but rather they are influenced by the vegetation and environment surrounding such infrastructure. This is mainly because infrastructure development in PAs serves as a new environment to the rodent species but the rodents mainly come into contact with the surrounding habitat, and thus we recommend that more detailed studies should be done in relation to potential agents of diseases within PAs especially in relation to areas near recreational infrastructure. This will help in knowing if there are potential risks to tourists and wildlife, and solving them before any outbreak occurs, as the two communities have been found to interact. The lesson of this study to other PAs and the Park's management is to properly manage the future construction or development of recreational infrastructure as the findings show that the facility that was least occupied or had the least human interaction, had a higher diversity compared to the ones with high interaction. This shows only certain species are drawn to factors that are a result of human activities while some prefer their natural cover. And further, recommendation is made to the PA's management on continuing to consider the survival of both large and small mammals, while planning future development of recreational infrastructure within PAs, which includes proper waste disposal systems.

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