Sustainability and Biodiversity Conservation

Assessment of rodents and insectivores' diversity and abundance, Unguja, Zanzibar, Tanzania

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Abstract

This study was conducted in Zanzibar Island aiming to provide baseline data on the abundance and diversity of rodents and shrews in that area, cross-section survey was conducted involving five selected habitats (farm, domestic, peridomestic, forest, and grazing area) in every six districts and Shehia, a total of 100 Sherman live traps were placed per site in 10 lines each with 10 trapping stations, 10m apart in each station and each line for four consecutive nights; traps were daily baited by using a mixture of peanut butter and maize brans. A total of 324 individual rodents and insectivores were captured from five different habitats. Individuals belonging to eight species were captured out of 4200 trap nights. Rodents species and insectivores which were identified and recorded were: *Mastomys natalensis, Mus muscularis, Rattus rattus, Rattus norvegicus, Cricetomy gambianus, Crocidura spp, Arvicanthis spp and Lophuromys spp,* the overall trap success was ranging from 2.4% to 15%, *Mastomy natalensis* was the most abundant species, accounting for 82 (25.3 %) individuals of all the rodents collected in different habitats, this was followed by *Rattus rattus* comprised of 77(23.8%) of individuals captured, *Rattus norvegicus* comprised of 72 (22.2%) , *Mus muscularis* comprised of 63(19.4%), *Cricetomy gambianus* comprised of 13(4%), *Shrew (Crocidura spp)* comprised of 12(3.7%), *Lophuromys spp* comprised of 3(0.9%) and *Arvicanthis spp* comprised of 2(0.6%) individuals captured respectively. Analysis showed that there was a statistically significant difference (P<0.05), in the diversity of rodents across the farm habitat with forest habitat, farm habitat across the domestic habitat, and the Peridomestic habitat as well as the diversity of rodents in the grazing habitat across the domestic habitat during the wet season.

Keywords: Diversity, habitat, Rodents, Shrews, zoonotic disease

Introduction

The presence of diastema, the constant growth of their long incisor teeth, and continual gnawing distinguish rats from other small mammals (Kingdon, 1997). Rodents seem to be the major damaging invader species to agricultural products in many parts of the world (Singleton, Hinds, Leirs, & Zhang, 1999; Leirs, 2003; Stenseth *et al*., 2003). They are extremely successful mammals, as they are the largest recorded vertebrate order, with 2277 known individuals pertaining to 33 families accounting for approximately 42% of worldwide mammalian richness and a nearly universal dispersal (apart from Antarctica and a few islands) (Happold, 2013; Dahmana *et al*., 2020). Rodents are the most diverse group of mammals (Vaughan *et al*., 2000, Yihune & Bekele, 2012). They are well adapted to a wide range of habitats (Nowak, 1999), and they show great species richness in their ecology, life history strategies, behavior, morphology, and physiology (Nebdbal *et al*., 1996: kingdon, 1996). They are a widespread invasive rodent species that has been demonstrated as (Adler & Moctezuma, 2009: Levett, 2001: Vinetz, 2001), over 60 zoonotic illnesses have been linked to rodents as reservoir hosts (Taylor, 2008), whereby the *Rattus norvegicus, Mastomys natalensis, Cricetomys sp and Crocidura sp.* are known to be carriers for *Leptospira* interrogans of the serogroup Icterohaemorrhagiae*,* but the domestic mouse is a carrier for *leptospira* borgpetersenii of the serogroup Ballum. (Levett, 2001; Adler and Moctezuma, 2009; Himsworth *et al*., 2013; Ellis *et al*., 2015; Mgode *et al*., 2015; Mgode *et al*., 2021).

Rodent distribution, composition, diversity, and abundance are influenced by environmental components such as plant communities and density, weather factors, disease, and predation (Johnson and Horns, 2008). The number of individualrodents in a given area is mostly determined by the availability of food and ground cover (Rubio *et al*., 2014), but also rodents and shrew habitat quality has been linked to the presence of ungulates (wild or domestic), which reduces the availability of food and shelter for these small mammals (Keesing *et al*.,1998: Caro, 2001 and Afonso *et al*., 2021). On the other hand, the loss of ground cover and food sources for small mammals reduces rodent diversity but increases the risk of predation (Hoffmann and Zeller, 2005). Species composition in distinct habitat types is affected by habitat structure and predation risk (Massawe *et al*., 2007). Rodents serve the ecology by providing food for other animals and dispersing seeds (Fischer and Turkey, 2016) and aiding in bio-control by devouring weed seeds (Davies, 2000; Daedlow *et al*., 2014). In Tanzania, rodents have been reported as the one of reservours of zoonotic diseases (Machang'u *et al*., 2003: Zavitsanou & Babatsikou, 2008), as well as dispersion abundance and richness (Sabuni *et al*., 2015; Stanley and Kihaule, 2016; Mulungu *et al*., 2008), although ecological studies on rodents have been conducted in various parts of Tanzania's mainland, there is little information on the diversity and abundance of rodents in many areas of Zanzibar island, this study was conducted in Zanzibar island with the goal of providing baseline data on the abundance and diversity of rodents and shrew in that area.

Zanzibar Island is the largest of the 'continental islands in Africa (kingdon, 1977), the island is rich in biodiversity and provides several habitats for different kind of species (Pakenham,1984; Musser & Carleton, 1993; Kingdon 1974), due to its higher diversity , different studies focusing on large mammals have been done (Goldman & Walsh, 2002; Goldman & Winther-Hansen 2003; Kingdon, 1982; Archer & Mwinyi, 1995) and few studies were focused on small mammals (Pakenham, 1984; Swynnerton & Hayman, 1950; Swai, 1983).

Small mammals like rodents and shrews may act as carriers of a number of zoonotic diseases, such as leptospirosis, which is brought on by the *Leptospira* bacteria and is thought to be the most significant source of infection in both domesticated and wild animals, as well as humans (Jones *et al*., 2001, Taylor *et al*., 2015). Leptospirosis is among the neglected zoonosis disease despite being common in Tanzania and other developing countries (Motto *et al*., 2021), these small animals have received relatively little attention on Zanzibar Island. Therefore, there is little information that exists about the role of small mammals in disseminating pathogens to other animals based on their abundance and diversity in their ecology, also the information on prevalence and distribution of leptospirosis is scarce although there is the fragmented report on infections in both domestic animals, wild animals and rodents sharing same habitats which raises the possibility that humans could contract leptospirosis, presumably leading to morbidities and larger economic losses in the human and livestock sectors (Mgode *et al*., 2021). The current study was the first to be carried out in Zanzibar Islands.

This study aimed at providing baseline information about Leptospira infection status in the region and to raise awareness of the disease in general public and health care, the results from this study are hoped be communicated to Tanzania and the Zanzibar Ministry of Health to be attention to prevention and control of leptospirosis in the area. Also, knowledge and awareness being used in planning for rodents' control and to reduce the burden of pests in the agriculture sector as well as zoonotic management

Materials and methods

Study Area

This study was carried out on the island on Unguja, Zanzibar (figure 1). Zanzibar is primarily comprised of two large Islands, Unguja and Pemba. Unguja covers an area of 1,666 square kilometers and 988 square kilometers in Pemba. They lie in the Indian Ocean off the coast of Eastern Africa and situated about 30 kilometers from the Tanzania mainland. Tourism activities are main source of revenue in Zanzibar, also fishing and agriculture activities are importance in local economy (OCGS, 2020), characterized by equatorial and humid climate, it is between -

6°18'S and 39°30'E, maximum temperatures are 30°C during the hot season (December to March) and minimum temperatures are 20°C during the cool season (June to November). There are two rainy seasons: the long rains (Masika) last from March to June and the short rains (Vuli) fall from October to December. The humidity is high ranging from 900 -1000 mm during heavy rain season and 400 – 500 mm during short rainy period. Altitude is ranging from 0 to 195 meters above sea level (URT, 2021). Unguja island consists three regions; Kusini, Kaskazini and Mjini Magharibi and seven districts; Kaskazini A, Kaskazini B, Magharibi A, Magharibi B, Mjini, Kati and Kusini. The reason for selecting the Zanzibar Islands for the study is that it is essential for three things: firstly, presence of environmental conditions favorable for *leptospira* to survive includes: high humidity and favorable temperature. Secondly the main live hoods and economic activities such fishing activities, slaughtering activities, hunting, farming production such as sugarcane and paddy plantation and recreational activities that are potential risk for leptospirosis as well as presence of farmers raising variety of domestic animals in Zanzibar (Tambi *et al*., 1999) and lastly abundant of rat species (Pakenham, 1984; Martin, 2006). The Sampling sites (Farms and Households) were selected and our visits were arranged through the Department of Livestock Development. Sites were spread across the entire island to include the Kaskazini, Kati, Kusini, Mjini and Magharibi districts to ensure a representative sample population.

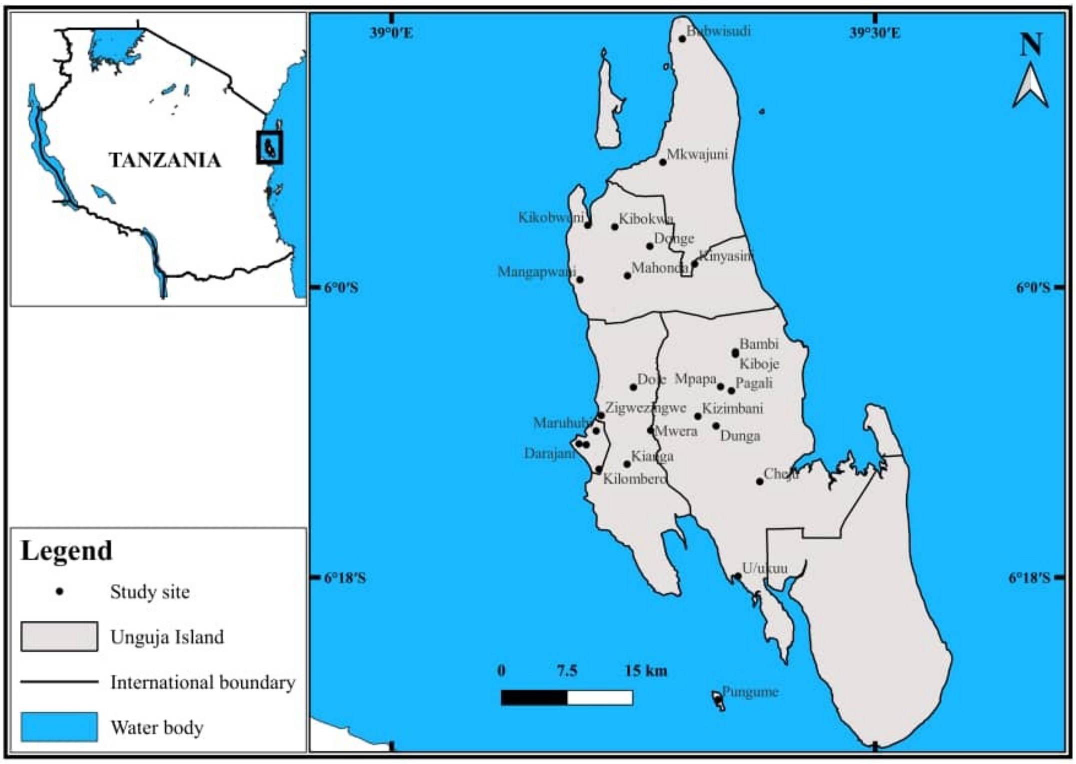

Figure 1. Map Showing study Sites in Unguja Island

Administration of the survey

The cross-sectional survey took place from January to March 2022. Sampling locations from each of the island's six districts were determined by the Zanzibar Livestock Research Institute (ZALIRI). Department of Livestock and Development veterinarians, then meeting were held with extension workers by building capacity on the disease and to arrange the sites for sample collection, The extension worker was able to arrange meeting with farmers by raising awareness of the disease and request permit to take blood sample from their animals, the animals were selected based on which farmers were willing to have their animals to be examined also farmers were given local traps and Sherman live traps for trapping of rodents. Study site was randomly selected by considering habitat types and distance from one habitat to another. The suggested distance from one habitat to another was greater than 500m. Five different habitats in each shehia were selected, which were farm, domestic, peridomestic, plantation forest and grazing habitats.

Sample size estimation

Sample size was estimated by using the equation which were developed by Cochran (1963, 1975) $n=\frac{Z^2PQ}{d^2}$ whereby n = sample size, Z=1.96 (Desired confidence level was 95%), P= Previous proportional factor (proportional of leptospirosis in domestic animals and rodents). Q=1-p, d=desired level of precision, the previous prevalence of Leptospirosis in rodents was 17% according to Mgode et al. (2015), Therefore, the estimation was as follow; 1.96^2 X 0.17 (1 – 0.17)/ 0.05^2 = 216.82, total of 217 rodents, were required in this study.

Rodents trapping

Rodents trapping were carried out in domestic habitat, peridomestic habitat and farms (cultivated, fallow lands), forest habitat and grazing lands habitat by using Sherman live traps (7.5 × 9.0 × 23.0 cm), Glue trap and locally made live traps with wooden box wire mesh window (12 ×15 ×20cm).Total of 100 Sherman live traps were placed per site in 10 lines each with 10 trapping stations, 10m apart in each station and each line for four consecutive nights; traps were daily baited using a mixture of peanut butter and maize brans (Mulungu *et al*., 2008).

In farms, forest and grazing, traps (Sherman and locally made wire) were placed close to irrigation canals, near holes, on trees and putative rodent trails. Inside houses traps were placed in kitchens and on top of shelves where food was stored as well as in living places, for the bigger rodents found in peridomestic areas the large locally made wire traps (DEMA) were used. GPS coordinates on each trapping site were taken and later used to map the distribution of rodents in different district.

Trap inspection and maintenance

The traps were inspected early in the morning (06:00 and 07:00h) and late in the evening (18:00h), then traps were washed with water to remove any old feces, food and smell that may discourage other species from entering example shrew, the bait was replaced new one after every trap inspection for three consecutive night per month probably due to inactive of rodent at day and active in night time (Magige, 2016).

Handling of captured animals and species identification

The collected rodents were shipped in ventilated plastic buckets to the Department of Livestock and Development laboratory (Maruhubi), anaesthetized with di-ethyl ether preserved with ethanol and identified to species level using the established taxonomic nomenclature guide book (Kingdon 1997; Wilson and Reeder; 2005), rodent morphometric data including weight, total length, tail length, hind foot length and ear length were also recorded, female and male were identified based on vagina (closed or perforated) position, also shorter the distance from genital papilla to the anus and position of the testes (scrotal or abdominal) longer the distance from papilla to the anus respectively. Furthermore, they were classified in different age such as adult, sub-adult and juvenile whereby individuals weighing from 21-24g were classified as sub adults, ≤ 20 g were classified as juveniles and > 24 g were classified as adult

Data analysis

The relative abundance was analysed as trap success percentage relative abundance of each species per habitat type was estimated using the ratio of total individual species to the total rodents captured.the ratio of total individual species to the total rodents captured. The trap success was determined by ratio total counting of captured individuals per habitat type to the trap nights

%Trap success (Relative abundance) $=\frac{\text{Captured individual}}{\text{Trap nights}}$ x100%Species Diversity

Shannon–Wiener diversity index (Shannon and Wiener, 1948) was used to measure diversity in the different habitats and this was also used to compare between habitats using the Student's *t*-test (Hutcheson,1970). Where by the Shannon-Wiener diversity index is defined as:

H*'* is the diversity index, *pi* is the proportion of the total sample belonging to each species *i*

$$H' = -\sum_{i=1}^{S}(p_i)(\ln p_i)$$

Data entering and coding

Data that was generated from the field was coded, entered and stored using Microsoft excel spread sheet, then Microsoft Office Excel® 2013 was used to calculate the percentage relative abundance, Paleontological Statistics software (PAST) were used to calculate the diversity of rodents and shrew, a correlation test and Student's *t*-test and Mann-Whitney U test for difference in means and to determine if there was a significant difference in diversity between habitat type but also species similarity, evenness and dominance were calculated (Campbell & Swinscow, 2009).

Inclusion and exclusion criteria for rodents and shrew selection

The study included live and dead rodents and shrew captured individual in the traps, ranged from adult, sub-adult and juvenile, to determine their abundance and diversity. However, the dead rodents and shrew were excluded from the study in the next step of blood sampling.The research clearance and ethical protocols of this study were approved by Sokoine University of Agriculture (Ref. No. SUA/ADM/R.1/8/779) and (Ref. No.DPRT/SUA/R/186/F.7) respectively and a permission to conduct this study in Zanzibar was granted by the Office of the Second Vice President of Zanzibar (Ref. No. OMPR/M.95/C.6/2/VOL.XVIII/187) prior to the start of data collection**.**

Results

Rodents and insectivores abundance

Total of 324, individual rodents (312) and insectivores (12) were captured from five different habitats. Individuals belonging to eight species were captured out of 4200 trap nights. Rodents species and insectivores which were identified and recorded were: *Mastomys natalensis, Mus muscularis, Rattus rattus, Rattus norvegicus, Cricetomy gambianus, Crocidura spp, Arvicanthis spp and Lophuromys spp.* Rodent's species and insectivores captured and the associated habitats are shown in table 1 below. But also, the overall trap success was ranging from 2.4% to 15% are shown in Table 2. *Mastomy natalensis* was the most abundant species, accounting for 82 (25.3 %) individuals of all the rodents collected in different habitats, this was followed by *Rattus rattus* comprised of 77(23.8%) of individuals captured, *Rattus norvegicus* comprised of 72 (22.2%) , *Mus muscularis* comprised of 63(19.4%), *Cricetomy gambianus* comprised of 13(4%), *Shrew (Crocidura spp)* comprised of 12(3.7%), *Lophuromys spp* comprised of 3(0.9%) and *Arvicanthis spp* comprised of 2(0.6%) individuals captured respectively.

Table 1. Number of Rodents and Insectivores and their Relative Abundance in Zanzibar Island

Species	**Total No.**	**Relative abundance (%)**
Mastomy natalensis	82	25.3
Rattus rattus	77	23.8
Rattus norvegicus	72	22.2
Mus muscularis	63	19.4
Cricetomy gambianus	13	4
Shrew (Crocidura spp)	12	3.7
Arvicanthis spp	2	0.6
Lophuromys spp	3	0.9
Total	324	100

The number of individuals captured varied with different habitat type, from the results shows that more individuals were captured in domestic habitat (15%). Trap success as compared with other habitats, followed by peridomestic habitat comprises of 10.5% and farm comprises 6.9% respectively. However, trap success was rare in forest comprises of 2.4% and grazing comprises of 2.4% of individual captured.

Table 2. Trap Success of rodents and shrew abundance in different Habitat Type

Habitat Type	Captured individuals	Trap nights	Trap success (%)
Farm	74	1080	6.9
Forest	52	960	5.4
Grazing	20	840	2.4
Domestic	90	600	15
Peridomestic	88	720	10.5
Total	**324**	**4200**	**12.2**

Number of rodent's species and insectivores captured in different habitats and their relative abundance are shown in the Table 3. In domestic habitat was the most abundant common species, accounting for 90 (27.8%) individuals of all the rodents and insectivores collected, this was followed by peridomestic habitat comprised of 88 (27.2%) of individuals captured and farm habitat comprised of 74 (22.8%) respectively. However, the species was rarely collected in forest habitat comprised of 52 (16%) and grazing habitat comprised of 20 (6.2%) respectively.

Table 3. Number of Rodents and Insectivores in different habitats and their Relative Abundance

Habitats	Total No	Relative Abundance (%)
Farm	74	22.84
Forest	52	16.05
Grazing	20	6.17
Domestic	90	27.78
Peridomestic	88	27.16
Total	**324**	**100**

Relative abundance of rodents and insectivores in each habitat are shown in table 4 below: whereby in farm habitat, *Mastomy natalensis* was abundant common' accounting for 34 (45.9%) individuals of all the rodents and insectivores collected, this was followed by *Rattus norvegicus* comprised of 13 (17.6%) of individuals captured, *Mus muscularis* comprised of 9 (12.2%), *Rattus rattus* comprised of 7 (9.5%) of individuals captured, but also was rarely collected in *Shrew (Crocidura spp)* comprised of 5 (6.8%) and in *Cricetomy gambianus, Arvicanthis spp* and *Lophuromys spp* comprised of 2 (2.7%) of individuals captured. In forest habitat: *Mastomy natalensis* was abundant common' accounting for 26 (50%) individuals of all the rodents and insectivores collected, this was followed by *Rattus norvegicus* comprised of 14 (26.9%) of individuals captured, *Shrew (Crocidura spp)* comprised of 6 (12%) and *Mus muscularis* comprised of 5 (9.6%) respectively, however the abundant was very low in *Rattus rattus* comprised of 1 (1.9%) and absent in *Cricetomy gambianus, Arvicanthis spp* and *Lophuromys spp* comprised of 0 (0%) of individual captured.

In grazing habitat: *Mastomy natalensis* was abundant common' accounting for 8 (40%) individuals of all the rodents and insectivores collected, this was followed by *Rattus norvegicus* comprised of 4 (20%) of individuals captured, *Rattus rattus* comprised of 3 (15%) and *Mus muscularis* comprised of (10%) respectively. However, the abundant was very low in *Cricetomy gambianus, Shrew (Crocidura spp)* and *Lophuromys spp* comprised of 1(5%) of individual captured and absent in *Arvicanthis spp* comprised of 0(0%) of individual captured *Shrew (Crocidura spp)* comprised of 6 (12%) and *Mus muscularis* comprised of 2 (9.6%) respectively. However, the abundant was very low in *Cricetomy gambianus, Arvicanthis spp* and *Lophuromys spp* comprised of 0 (0%) of individual captured. In domestic habitat: *Mus muscularis* was abundant common' accounting for 41 (45.6%) individuals of all the rodents and insectivores collected, this was followed by *Rattus rattus* comprised of 38 (42.2%). However, the abundance was low in Cricetomy *gambianus* comprised of 5 (5.6%), Rattus *norvegicus* comprised of 4 (4.4%) and *Mastomy natalensis* comprised of 2(2.2%) individuals captured respectively, but also was absent in *Shrew (Crocidura spp*, *Arvicanthis spp* and *Lophuromys spp* comprised of 0 (0%) of individual captured.

In peridomestic habitat: *Rattus norvegicus* was abundant common' accounting for 37 (42%) individuals of all the rodents and insectivores collected, this was followed by *Rattus rattus* comprised of 28 (31.8%) and *Mastomy natalensis* comprised of 12 (13.6%) respectively. However, the abundance was low in Mus *muscularis* comprised of 6 (6.8%), *Cricetomy gambianus* comprised of 5 (5.7%) respectively, but also was absent in *Shrew (Crocidura spp*, *Arvicanthis spp* and *Lophuromys spp* comprised of 0 (0%) of individual captured.

Relative abundance of rodents and shrew at district and Shehia level

The results show that total of 324 rodent and shrew were captured, whereby in North A was the most common abundant species were collected at variety habitat type, accounting for 80 (24.7), this was followed by North B comprised of 65 (20.1%) of individuals captured, West A comprised of 60 (18.5%) , Central comprised of 48 (14.8%), urban comprised of 36 (11%) and south comprise of 35 (10.8%) respectively. The results show that total of 80 rodents and shrews were captured in North A, whereby more abundant of species were observed in kinyasini accounting for 26 (32.5%), this was followed by kikobweni comprised of 24 (30%), kibokwa comprised of 17 (21.25%) and Donge comprises of 13 (16.25%) individual captured respectively. In North B, total of 65 were collected slightly more abundant of species were observed in Mahonda accounting for 18 (27.7%), this was followed by kilombero comprised of 15 (23.1%), Mangapwani comprised of 12 (18.5%), Zigwezingwe comprised of 11 (16.9%) and Mkadini comprised of 9 (13.8%) respectively. In west

A, total of 60 species were collected, common more abundant of species were observed in Kizimbani, accounting for 17 (28.3%), this was followed by Dole comprised of 15 (21.6%), Kianga comprised of 10 (16.7%), Mwera comprised of 9 (15%), Bubwisudi comprised of (11.7%) and Mkwajuni comprised of 4 (6.7%) respectively. In central, total of 48 species were collected, slightly more abundance was observed in Dunga, accounting for 11 (22.9%), this was followed by Mpapa and Bambi comprises of 9 (18.75%) at each, Cheju comprises of 8 (16.7%), Kiboje comprises of 6 (12.5%) and Pagali comprises of 5 (10.4%) respectively. In Urban, total of 36 species were collected, slightly more abundance was observed in Maruhubi, accounting for 14 (38.9%), this was followed by Darajani comprises of 12 (33.3%) and Mwemberadu comprises of 10 (27.8%) total individual captured respectively. In south, total of 35 species were collected, commonly more abundance was observed in Pungume, accounting for 20 (57.1%), compared to U/ukuu comprises of 15 (42.9%) of individuals captured.

Table 4. Relative abundance of Rodents and Shrew at district level

District	Total No Species	Relative abundance (%)
North A	80	24.69
North B	65	20.06
West A	60	18.52
Central	48	14.81
urban	36	11.11
South	35	10.80
Total	324	100

Age and Sex of common Rodents Species and Insectivores Abundance

Most of individuals captured were ranged from adult, sub-adult and juvenile, the results show that the adult was most high relative abundance as compared to other species age, whereby adult accounting for 197 (60.8%), was followed by sub-adult comprises 98 (30.2%) and juvenile comprises of 29 (9%) individuals captured respectively. Furthermore, age ratio of common rodents' species and insectivores are shown in the table 6.

Table 5. Age ratio of common Rodents Species and Insectivores

Age	No of individuals	Relative abundance (%)
Adult	197	60.80
sub-adult	98	30.25
Juvenile	29	8.95
Total	**324**	**100**

Sex of common Rodents Species and Insectivores Abundance

Most of individuals captured were further sub-divided into male and female, the results show that female was more abundant common than male, whereby female accounting for 171 (52.8%) and male comprises of 153 (47.2%) of individuals captured. However, the abundance of female in adult and sub-adult comprise of 110 (55.83%) and 51 (52.04%) respectively was higher compared to abundance in male in adult and sub-adult comprises of 87 (44.16%) and 47(47.96%) individual captured, but also abundance of male in Juvenile was more abundant than female comprises of 19 (65.52%) and 10 (34.48%) individual captured respectively, therefore, male and female in adults was more abundant than other ages (sub-adult and Juvenile). The results of sex of common rodents and shrew are shown in the Table 6 and figure 2.

Table 6. Sex ratio of common Rodents Species and Insectivores

Sex	No of individuals	Relative abundance (%)
Male	153	47.22
Female	171	52.78
Total	324	100

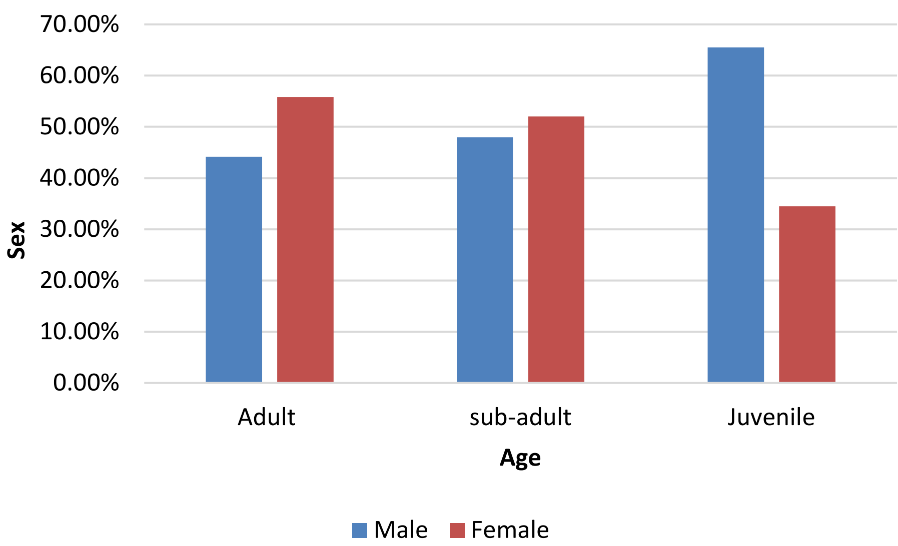

Figure 2. Relative Abundance of Age and Sex of common Rodents Species and shrew

Diversity of rodents and shrew in different habitat types

The result shows that the diversity index of rodents in all five different habitats varies from one habitat to another, The Shannon diversity index in the farm was (1.6), forest (1.25), grazing (1.7), domestic (1.1) and 1.3 in peridomestic respectively, the results show that the higher diversity of rodents species and shrew was shown in the grazing habitat with 1.7 diversity index, followed by farm with 1.6, peridomestic (1.3) respectively, but also the diversity was lower in the forest accounting for 1.25 and domestic with 1.1 diversity index respectively. The results are shown in the Table 7. The coefficient of species similarity between farm, forest, grazing, domestic and peridomestic habitats were 0.77, 0.78, 0.85, 0.69 and 0.84 respectively and average was 0.78. Values in the range between 0.51-0.75 reflect high similarity (Ratliff, 1993). This high similarity indicates that the species diversity was similar across the variety habitat type.

The coefficient of species evenness between farm, forest, grazing, domestic and peridomestic habitats were 0.63, 0.70, 0.74, 0.60 and 0.77 respectively. Values were close to 1 reflect high evenness, the number of species were fairly evenly distributed in all habitat type, within the habitat species were more evenly distributed in peridomestic habitat (0.77), was followed by grazing (0.75), forest (0.7), farm (0.63) and domestic (0.6) respectively.

The coefficient of species dominance between farm, forest, grazing, domestic and peridomestic habitats were 0.27, 0.34, 0.24, 0.39 and 0.30 respectively. Values in the range between 0-0.5 reflect low dominance, generally the species dominance was slightly low in all habitat type. However, species dominance was slightly higher in domestic (0.39), was followed by forest (0.345), peridomestic (0.3), farm (0.27) and grazing (0.24) respectively.

Table 7. Shannon-Winner Species Diversity Index, Simpson, Evenness, equitability J and Dominance values of Rodents and Insectivores

	Habitat Type				
	Farm	**Forest**	**Grazing**	**Domestic**	**Peridomestic**
Individuals	74	52	20	90	88
Dominance_D	0.27	0.34	0.24	0.39	0.30
Simpson_1-D	0.73	0.65	0.76	0.61	0.70
Shannon_H	1.62	1.25	1.65	1.11	1.35
Evenness_e^H/S	0.63	0.7	0.74	0.60	0.78
Equitability_J	0.78	0.78	0.85	0.69	0.84

Diversity of rodent's species and shrew with habitat association

There was higher diversity of rodents and shrew in farm habitat with shannon index (H'=1.6) compared to forest habitat (H'=1.25), There was a statistically significant difference ($P<0.05$), in the diversity of rodents across the farm habitat with forest habitat ($P=0.01$), this results show that there was strong interaction between the rodents and shrew across the two habitats, they can move from farm to forest and vice versa

Farm habitat associated with grazing habitat

There was higher diversity of rodents and shrew in grazing habitat with shannon index (H'=1.65) compared to farm habitat (H'=1.62), but also, there was no statistically significant difference ($P>0.05$) in the diversity of rodents across the two habitat with p-value ($P= 0.87$), this results show that there was less relation between the rodents and shrew across the two habitats.

Farm habitat associated with domestic habitat

There was higher diversity of rodents and shrew in farm habitat with shannon index (H'=1.62) compared to domestic habitat (H'=1.11), but also there was statistically significant difference ($P<0.05$) in the diversity of rodents across the two habitat with p-value ($P= 0.00$), this results show that there was strong interaction between the rodents and shrew across the two habitats, commonly rodents and shrew were found in both habitats

Farm habitat associated with peridomestic habitat

There was higher diversity of rodents and shrew in farm habitat with shannon index (H'=1.62) compared to peridomestic habitat (H'=1.35), but also there was statistically significant difference ($P<0.05$) in the diversity of rodents across the two habitat with p-value ($P= 0.04$), this results show that there was strong interaction between the rodents and shrew across the two habitats, commonly rodents and shrew were found in both habitats.

Forest habitat associated with grazing habitat

There was higher diversity of rodents and shrew in grazing habitat with shannon index (H'=1.65) compared to forest habitat (H'=1.25), but also, there was no statistically significant difference ($P>0.05$) in the diversity of rodents across the two habitats with P-value ($P= 0.07$), this results show that there was less/no interaction between the rodents and shrew across the two habitats, rodents commonly found in forest were rarely or less found in grazing habitat.

Forest habitat associated with domestic habitat

There was higher diversity of rodents and shrew in forest habitat with shannon index (H'=1.25) compared to domestic habitat (H'=1.11), but also, there was no statistically significant difference ($P>0.05$) in the diversity of rodents across the two habitats with p-value ($P= 0.27$), this results show that there was less or rare interaction between the rodents and shrew across the two habitats, rodents commonly found in forest were rarely or less found in domestic habitat.

Forest habitat associated with domestic habitat

There was higher diversity of rodents and shrew in peridomestic habitat with shannon index (H'=1.35 compared to forest habitat (H'=1.35), but also, there was no statistically significant difference ($P>0.05$) in the diversity of rodents across the two habitat with p-value ($P= 0.44$), this results show that there was less interaction between the rodents and shrew across the two habitatsncommonly rodents and shrew found in forest were rarely found in peridomestic habitat.

Grazing habitat associated with domestic habitat

There was higher diversity of rodents and shrew in grazing habitat with shannon index (H'=1.65) compared to domestic habitat (H'=1.1), but also, there was a statistically significant difference ($P<0.05$) in the diversity of rodents across the two habitat with p-value ($P = 0.01$), this results show that there was strong interaction between the rodents and shrew across the two habitats, commonly abundant rodents and shrew found grazing habitat were also abundant in domestic habitat.

Grazing habitat associated with peridomestic habitat

There was higher diversity of rodents and shrew in grazing habitat with shannon index (H'=1.65) compared to domestic habitat (H'= 1.35), but also, there was no statistically significant difference ($P>0.05$) in the diversity of rodents across the two habitat with p-value ($P = 0.13$), this results show that there was rare interaction between the rodents and shrew across the two habitats, commonly rodents and shrew found grazing habitat were rarely found in peridomestic habitat

Grazing habitat associated with peridomestic habitat

There was higher diversity of rodents and shrew in peridomestic habitat with shannon index (H'= 1.35) compared to domestic habitat (H'= 1.1), but also, there was a statistically significant difference (P<0.05) in the diversity of rodents across the two habitat with P-value (P = 0.03), this results show that there was strong interaction between the rodents and shrew across the two habitats, commonly abundant rodents and shrew found peridomestic habitat were abundant in peridomestic habitat.

Linear correlation r person's in species with habitat type

The result shows that the correlation of rodents in all five different habitats varies from one habitat to another, domestic and forest habitat was negatively correlated with species but with weak correlation (r = -0.21), strong positive correlation were shown in grazing and farm (r = 0.97) followed with forest and farm (r = 0.96), grazing and domestic (r = 0.95), grazing and forest (r = 0.92) and farm and domestic (r = 0.9) respectively, moderate correlation was shown in forest and domestic (0.62) followed by peridomestic and grazing(r = 0.49), domestic and peridomestic (r = 0.47), farm and peridomestic (r = 0.44) and forest and peridomestic (r = 0.40), peridomestic and forest (r = 0.35) and peridomestic and farm (r = 0.32) respectively, but also, positive correlation but weak were shown in domestic and peridomestic (r = 0.30), grazing and peridomestic (r = 0.21), domestic and farm (r = 0.05), domestic and grazing (r = 0.02), forest and grazing (r = 0.00), farm and forest (r = 0.00) and farm and grazing (r = 0.00) respectively. The results are shown in the Table 8 and figure 3 Table 8**. Linear correlation r person's in Species with Habitat Type**

	Farm	Forest	Grazing	Domestic	Peridomestic
Farm		0.00	0.00	0.90	0.44
Forest	0.96		0.00	0.62	0.40
Grazing	0.97	0.92		0.95	0.21
Domestic	-0.05	-0.21	0.02		0.47
Peridomestic	0.31	0.35	0.49	0.10	

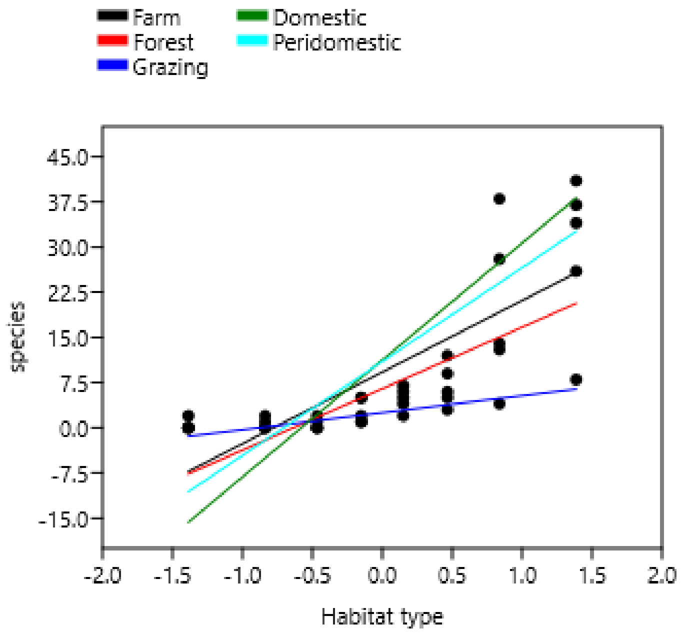

Figure 2. Linear correlation (r) person's in Species with Habitat Type

Age and sex structure in rodents and insectivores

The result shows that the diversity index age of rodents and shrew in all five different habitats were sub-divided into adult, sub-adult and juvenile, the abundance of adult was 197 followed by sub-adult comprises 98 and juvenile (98) captured individual, the shannon diversity index in the adult (H'= 0.68), sub-adult (H'= 0.69) and juvenile (H'= 0.64) respectively, the higher diversity was shown in adult and sub-adult but lower the diversity was shown in juvenile, the results are shown in the Table 9. The coefficient of age similarity between adult, sub-adult and juveniles were; 0.99, 0.99 and 0.93 respectively, Values in the range between 0.51-0.75 reflect high similarity (Ratliff, 1993). This high similarity indicates that the age diversity was similar across the variety habitat type, therefore the age similarity was higher in sub-adult (0.99) followed with adult (0.99) and juvenile (0.93) respectively. The coefficient of age evenness between adult, sub-adult and juveniles were 0.99, 0.99 and 0.95 respectively. Values were close to 1 reflect high evenness, the number of species age were fairly evenly distributed in all habitat type within the habitat sub-adult were more evenly distributed, was followed by adult (0.99) and juvenile (0.93) respectively.

Species dominance

The coefficient of species age dominance between adult, sub-adult and juvenile were 0.51, 0.50 and 0.55 respectively, generally the species age dominance was slightly moderate in all habitat type, however age species dominance was slightly higher in juvenile (0.55), was followed by adult (0.51) and sub-adult (0.5) respectively.

Table 9. Age and Sex Structure in Rodents and Insectivores

	Age		
	Adult	**sub-adult**	**Juvenile**
Individuals	197	98	29
Dominance_D	0.51	0.50	0.55
Simpson_1-D	0.49	0.49	0.45
Shannon_H	0.69	0.69	0.64
Evenness_e^H/S	0.99	0.10	0.95
Equitability_J	0.99	0.10	0.93

Sex structure in rodents and shrew

The result shows that the female (171) was more commonly abundant compared to male (153), the female (0.50) was slightly more dominant than male (0.43), but also, there was higher diversity of male with shannon diversity index (H'=0.94) compared to female (H'=0.81), the male (0.85) was slightly more evenly distributed than female (0.75) individual captured, furthermore there was higher slightly similarity in male (0.86) compared to female (0.74) indicates that the sex diversity was similar across the variety habitat type, there was higher diversity of rodents and shrew in male with shannon index (H'=10.94) compared to female (H'= 0.81). But also, there was a statistically significant difference ($P<0.05$) in the male and female diversity of rodents and shrew across the habitat type with p-value ($P = 0.04$), this results show that there was strong interaction between male and female of the rodents and shrew across the habitats type, the results of sex structure in rodents and shrew are shown in Table 10 and 11 below and figure 4.

Table 10. Sex structure in rodents and shrew

	Male	**Female**
Individuals	153	171
Dominance_D	0.43	0.51
Simpson_1-D	0.57	0.49
Shannon_H	0.94	0.81
Evenness_e^H/S	0.85	0.75
Equitability_J	0.86	0.74

Table 11. Sex ratio of common Rodents Species and Insectivores

	Male	**Female**
Shannon index	0.94	0.81
Variance	0.00	0.00
T	2.0915	
Df	322.59	
P (same)	0.037266	

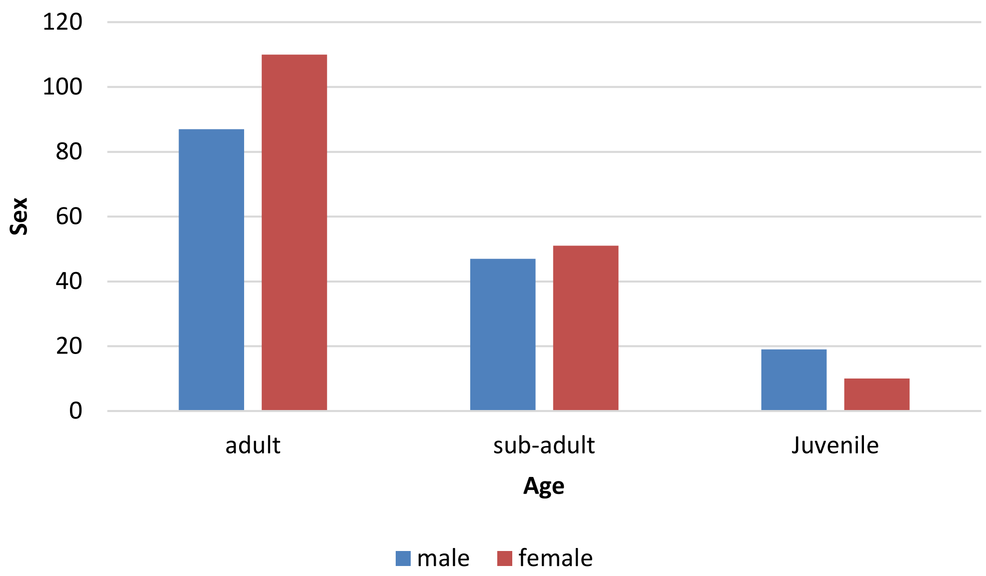

Figure 3. Age and Sex Structure in Rodents and Shrew

Discussion

Rodents and Shrew Species Abundance

In this study, total eight species of rodents were captured, namely *Mastomys natalensis, Mus muscularis, Rattus rattus, Rattus norvegicus, Cricetomy gambianus, Arvicanthis spp and Lophuromys spp.* Also, one non-rodent specie namely Crocidura spp was trapped. The abundance of rodents and shrews were varied across all habitats, the findings of this study show a high number of individuals in domestic and peridomestic habitat type might be due to presence of good quality and quantity of food which were stored in the living place, kitchens, on top of shelves as well barn where the animal feeds were stored (Katakweba *et al*., 2020), followed by farm probably due to these habitat provide good diet, shelter due to their dense vegetation cover, provide wide range of microhabitats and presence of heterogenous plants as well as expansion of agriculture activities favor availability of resources for their survival and high reproductive (Datiko and Bekele, 2014; Massawe *et al.,* 2006; Mulungu *et al.,* 2014). On the other hands, forest and grazing habitats had least number of rodents species compared to the other three habitats, this might be due to poor vegetation cover, insufficient of food, exposure of predators, presence of ungulates (domestic or untamed animals) increase trampling risk for these species lead to reduce the availability of shelter and food, therefore reduce the rodents abundance (Afonso *et al*., 2021**;** Demeke and Afework, 2014).

Abundance of *Mastomy natalensis* was higher as it was found in all habitats and was dominant in farm, forest and grazing with the trap success of 6.9%, 5.4% and 2.4% respectively. This could be due to its capacity to adapt to various settings, ability to live with many rodent species, omnivorous species, generalist dietary preferences, big litter size and maximum conceptive potential (Mulungu *et al*., 2013; Datiko and Bekele, 2013; Mulungu *et al*., 2011; Odhiambo *et al*., 2008; Demeke *et* *al*., 2007; Mulungu *et al*., 2014; Tadesse *et al*., 2008; Mamba *et al*., 2019) followed by *Rattus rattus, Rattus Norvegicus and Mus Muscularis,* abundance of these commensal rodents were associated with availability of foods (grains and fruits) and place especially in storage room, shelves, kitchen, roofs and shops which provides conducive environment for these murids to maintain their population vigor (Khan *et al*., 2020)

On the other hand, among the eight rodent species recorded in this study, four of them (*C. gambianus,* Crocidura sp*,* Arvicanthis sp and Lophuromy sp) were underrepresented compared to the rodent's species listed above, lower abundance being captured during this study was possibly due to distinction in their food preferences and ability to adapt the selected ecology (Assefa and Srinivasulu, 2019) as well as selected habitats were not suitable for them in term of breeding and survival but also expansion of settlements, predators (cats), urbanization and anthropogenic activities affect community composition and demographic pattern of rodents and their ecological disturbances (Kamungo *et al*., 2021; Kingdon *et al*., 2013). But also, habitat specialization such as Arvicanthis spp and Lophuromys spp was absent in Forest, domestic and peridomestic habitat but were few in farm and grazing, therefore depending with preferred habitats some species may be influenced to the habitat (Rubio *et al.,* 2014).

The abundance of rodents and shrews in district level were higher in North A followed by North B, West A*,* Central, urban and south respectively probably due to geographical location, whereby in Zanzibar dominated by peri-urban area, in towns there is no grazing areas as well as grazing activities conducted, while in north, west and central, commonly zero grazing system is practiced as well as semi-intensive system (Khamis *et al*., 2021), due to habitat specification many commensals rodents were commonly captured in domestic and peridomestic areas in town.

Most of individuals trapped were ranged from Juvenile, Sub-adult and Adult and were further sub-divided into male and female, the results show that the adult and female in adult and sub-adult were most high relative abundance as compared to other species probably due to mating behavior, this similar with findings reported by Mulungu *et al.* (2013) as well as Tadesse and Afework (2008).

Rodents and Shrew Species Diversity

The results show that the higher diversity of rodent's species and shrew was shown in the grazing habitat followed by farm and peridomestic respectively, probably due to presence of diverse resources such as food and shelter like cover and nesting areas (Kisingo *et al*., 2005; Kingdon, 2014). But also, the diversity was lower in the forest and domestic probably due to habitat specialization and unfavorable habitat within area (Kamungo *et al*., 2020). There was high similarity and evenness of species across all habitats probably indicates that the species diversity was similar across the variety habitat type and the number of species were fairly evenly distributed in all habitat type due to variability of microhabitat type controversial with the study reported by

Mortelliti and Boitani (2006). Generally, the species dominance was slightly low in all habitat type, however species dominance was slightly higher in domestic commonly *M. muscularis* and *R. rattus* were more dominant, followed by forest (*M. natalensis*), peridomestic *(R. norvegicus*), farm and grazing (*M. natalensis*).

There was higher diversity of rodents and shrew in farm habitat compared to forest habitat probably due to presence of different food items, increase human and animal contacts and presence of variety vegetation which support the dispersion of this species .There was a statistically significant difference ($P<0.05$), in the diversity of rodents across the farm habitat with forest habitat, farm habitat across the domestic habitat and the peridomestic habitat as well as diversity of rodents in grazing habitat across the domestic habitat, this result show that there was strong interaction between the rodents and shrew across the farm and forest, domestic and peridomestic and grazing habitat they can move from one habitat to another this study was similar with study reported by Men *et al.* (2015). Furthermore, frequently of seeing rodents in farm habitats was associated with high magnitude seeing rodents cross to the forest habitat, also they move from farm habitat to the kitchen or food store and surrounding compound as well as owing cattle was associated with seeing rodents frequently across food store of animal, kitchen and food store human settlement. In the other hands, there was no statistically significant difference ($P>0.05$) in the diversity of rodents across the forest habitat associated with grazing habitat and domestic habitat as well as grazing habitat associated with peridomestic habitat and farm habitat, there was low magnitude association with seeing rodents frequently in grazing area and shrubland or forest area, but also owning cattle was not associated with seeing frequently rodents in peridomestic and farm area (Maze *et al*., 2018).

The strong positive correlation of rodents and shrews were observed in grazing and farm, forest and farm, grazing and domestic, grazing and forest and farm and domestic respectively, probably due to the distance between the habitats, biological association and habitats conditions favors the species (Bayo, 2019), moderate correlation was shown in forest versus domestic and peridomestic, peridomestic versus grazing, domestic and farm, probably due normal behaviour of this species moving from one habitats to another searching food, social relations and wide home range (Assefa and Srinivasulu, 2019), positive and negative weak correlation were shown in domestic versus forest habitat, peridomestic, farm, grazing and grazing versus peridomestic forest and farm probably due expansion of settlements, ecological disturbance induced by human activities and presence of tamed animals which affects the diversity of rodents (Kingdon *et al*., 2013; Ricardo *et al*., 2020).

Age and sex structure in rodents and insectivores

In this study, sex ratio shows significant difference between males and females, even though more females were captured than males, this is probably be due to that females have more frequencies of movement than males because of their mating behavior similarly with study reported by Mulungu *et al*. (2013). However, there was higher diversity of male than female, male was slightly more evenly distributed and higher similarity compared to female probably due to males can be active, territorial behaviour and ability to impregnate many females at one time while females act as guards to protect others as well as their food supplies (Mulungu *et al*., 2013). More captures were observed in adults and sub-adults than juvenile, according to Assefa and Srinivasulu (2019), this may be because of their extensive home range, frequent migration, and better social status, but also it is similar with findings reported by Kamungo (2021), shows that adults are more frequently captured because they move around a lot during their life, except the time when their protecting their young is when they stop to move in wide range. Generally, there was high diversity similarity across the different habitat type probably due to evenly distribution of food that may indicate the alternation of habitat type thus why frequently of seeing similar rodents in different habitats, but also the similarity and evenness was higher in sub-adult compared to adult and juvenile probably due to ability to detect their enemy, therefore during movement they hide from their predators and also presence of shelters like vegetation cover which help them to protect against their enemy (Bayo, 2019). Furthermore, during this stage they become maturity and they move around to find their own mates and foods.

The finding shows that there was low abundance and diversity of juveniles probably due to limited movements, as they mostly reside inside burrows. Therefore, they depend on their parents for protection, mothering ability and provision of food, according to Mulungu (2013), reported that juvenile might be afraid of heat when they are outside the nest and may decrease because of unfavorable climate condition and harsh environment. Therefore, their home range is smaller due to their parents move far from home range to search for food. This study showed that most of female captured were pregnant, this confirms that the reproductive periods of most rodents occurred during the wet season. Similarly, with results that have been reported by Makundi *et al.* (2006) states that breeding was higher in wet seasons than dry seasons. Therefore, most of juvenile observed in wet seasons whereby the food resources were plenty, for example *A. niloticus* preferred moist habitats and presence of food (Kingdon, 2015), the moist environment is favorable for *Leptospira* bacteria to survive and grow (Wainaina *et al*., 2018)

Our study identifies associations between rodents in the domestic contact with human foods storage such as grains, rodents contact with domestic animals, domestic animals contacts with humans in variety habitat type, linkages between host, pathogen and environment, rodents and shrew provide dozens of microenvironments capable of supporting these parasites, transmit quit number of zoonotic pathogens through their urine, aerosols, ectoparasite, fluids(blood) and feces such as Leptospirosis, this finding suggest that presence of commensal rodents species such as *R. rattus*, *M. muscularis*, wild rodents and domestic animals may be risk factors for animal and human leptospirosis and other zoonotic infection. Therefore, the abundance and diversity of rodents and shrew occurred not only in terms of habitat modification but also due to seasons, disturbance via anthropogenic factors such as livestock grazing, deforestation and environmental factors includes climates, competition, parasitism, disease, and predation. However, this study indicates that modified habitats contribute to the diversity of important commensal and other species, which have the ability to adapt and live in human habitations and peridomestic habitats which is similar with study reported by Assefa and Chelmala (2019).

The limited data availability highlighted as a critical need for further studies to be conducted in Zanzibar due to fact that the data collection period of the present study was of short duration, the limited. Therefore, further studies must be conducted to improve the reliability of the result in the present study. It is recommended that further studies be carried out to assess the community composition, distribution and breeding pattern of rodents in dry season, to characterize the rodent and shrew haemoparasite and establish the potential role of the diverse species of disease transmission. Furthermore, there is a need to involve the local communities in management of rodents and imparting knowledge, skills and techniques to control or reduce the infestation of these species, it will be effective way to reduce the rodents population and zoonotic management (Belmain *et al.* 2008), therefore understanding biology and ecology of rodents, behaviour, local rodents species and kind of zoonoses harboured best solution to eradicate the population of these species.

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