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Features of Rodent Species Diversity in Wuyi Mountain National Nature Reserve, Jiangxi Province, China

Peng Xu[1], Yankuo Li[2]*, Shusong Zhang[1] and Bin Liu[3]

[1]*Jiangsu Key Laboratory for Bioresources of Saline Soils, Jiangsu Provincial Key Laboratory of Coastal Wetland Bioresources and Environmental Protection, Jiangsu Synthetic Innovation Center for Coastal Bio-Agriculture, School of wetland, Yancheng Teachers University, Yancheng, 224007, China*

[2]*College of Life Sciences, Jiangxi Normal University, Nanchang, 330022, China*

[3]*Dafeng Père David's deer National Nature Reserve, Yancheng 224136, China*

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Authors' Contribution
YL and PX conceived and designed the study. PX and YL conducted field survey. SZ performed the satellite image interpretation. YL, PX and BL analyzed the data and drafted this manuscript.

Key words
Wuyi mountain area, Rodents, Diversity index, Similarity index, Live traps method

ABSTRACT

Rodents are important components of animal communities in forest ecosystems. This study investigated rodent species diversity in Jiangxi Wuyi Mountain National Nature Reserve of China in 2014-2015. Rodents were trapped at nine selected sampling sites varying in altitude for evaluating their diversity. Consequently, 16 rodent species belonging to eight families were recorded. Out of 376 individuals of rodent species trapped (capture rate = 4.7%), *Apodemus agrarius*, *Eothenomys melanogaster, Niviventer fulvescens* and *N. confucicianus* were identified as dominant species with relative abundances over 10%, in which *N. fulvescens* and *N. confucicianus* were trapped in eight and seven habitat types, respectively, indicating a larger altitude span of their distribution ranges. Bamboo planting areas were found to possess more rodent species than other habitats. *Crocidura Dracula, Micromys minutus*, *Lepus sinensis*, *A. agrarius*, *Rattus nitidu*, *Tamiops swinhoei* and *R. norvegicus* were each trapped in only one habitat. Among habitats, bamboo planting areas showed the highest diversity index and richness index of rodent community, while farmland harbored the highest dominance index and lowest diversity index. Rodent communities were classified into three categories, namely meadow type, forest type, and farmland type. The present study provides a comprehensive inventory of rodent species diversity of the reserve, and is of great significance in the protection and construction of biodiversity in the forest ecosystem of Wuyi Mountain area.

INTRODUCTION

Understanding distribution patterns of animal community relating to species diversity is the fundamental and challenging task for zoologists and ecologists, which is considered as the premise of local biodiversity conservation (Brown, 2001; McCain, 2005). Mountains are an important landscape because they occupy relatively large land surface showing a strip distribution of forests with different plants along the altitudinal gradient, and often possess high biodiversity by acting as powerful natural experimental systems (Körner, 2007; Shuai *et al*., 2017).

As a major group of small mammal community, rodents occupy a wide range of habitats from lowland swamps to high-altitude montane grasslands (Monadjem *et al*., 2015; Mwasapi and Rija, 2021). They often represent a significant amount of the animal biomass in forests and other natural habitats, and provide ecosystem services (Xie *et al*., 2014). They also play an important role in the food web structure and nutrient cycle in forests ecosystems as primary and secondary consumers, acting as important seed dispersers in forest ecosystems (Aleksandra and Rafał, 2017). On the other hand, rodents are very sensitive to environmental changes and can be used as an indicator of environmental health at a local to ecozone level for biodiversity detection and evaluation (Zhang *et al*., 1997). Studies have identified several rodent species that are important and responsible for crop yield loss and in lowering of crop qualities (Stenseth *et al*., 2003; Raja and Iqra, 2019). Additionally, a high diversity of rodent species in any ecosystem provides an opportunity to identify them and study their populations (Khan *et al*., 2017). Reasonably, rodent species diversity of forest ecosystems in different range regions has always been one of the hotspots of biodiversity research.

* Corresponding author: liyankuo@126.com
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Jiangxi Wuyi Mountain National Nature Reserve (JWNNR) retains main area of primitive forests in Jiangxi Province, which is considered to have high value in preserving perfect and balanced forest ecosystem (Chen, 1999). Known as a hot spot of biodiversity in China, the subtropical mid-mountain forest ecosystem is the main protection object of JWNNR. As altitude increases, the vegetation shows an obvious vertical stratification, making it an ideal area to study the diversity of rodents in forest ecosystems with different vegetation types (Qiao *et al*., 2009). Since the establishment of the reserve, a lot of work has been done in the investigation of biodiversity resources, involving endangered plants, birds, fishes, amphibians, reptiles and large mammals (Qiao *et al*., 2009; Cheng *et al*., 2014; Chen *et al*., 2018). However, previous researches of rodents in JWNNR were mostly based on local investigations or species records. To date, no in-depth studies have been carried out to assess the species diversity of rodents in this area, and little is known about rodent communities in this forest ecosystems.

In this study, a systematic field survey was conducted to explore a comprehensive inventory of rodent community in the JWNNR. It clarified the community composition, diversity characteristics and similarity among different habitat types of rodent species in forest ecosystem. This study therefore contributes to local mammal research by providing basic data of the rodent diversity. This information is of great significance in biodiversity protection, relating to the understanding of the health and function of forest ecosystem in the whole reserve of Wuyi Mountain.

MATERIALS AND METHODS

Study site

The JWNNR (27°48′11″-28°00′35″N, 117°39′30″-117°55′47″E) is located in the eastern Jiangxi Province, China, and occupies the north section of Wuyi Mountains (Fig. 1). The altitude of the reserve ranges from 300 to 2160 m. Huanggang mountain, the main peak of the JWNNR, is the highest peak in Jiangxi Province. With a total area of 16007 hm^2, the reserve borders Fujian Wuyi Mountain National Nature Reserve on the south, forming a complete subtropical mid-mountain forest ecosystem. This area belongs to a subtropical central monsoon humid climate zone, with an average annual temperature of 14.2 °C and average annual precipitation of 2583 mm. The average slope of the mountain in the reserve is greater than 40°C, which is characterized by tall mountains and many valleys. Affected by terrain, temperature, precipitation, soil and other factors, there is an obvious vertical band spectrum of vegetation with diverse understory plants (Cheng *et al*., 2014; Chen *et al*., 2018).

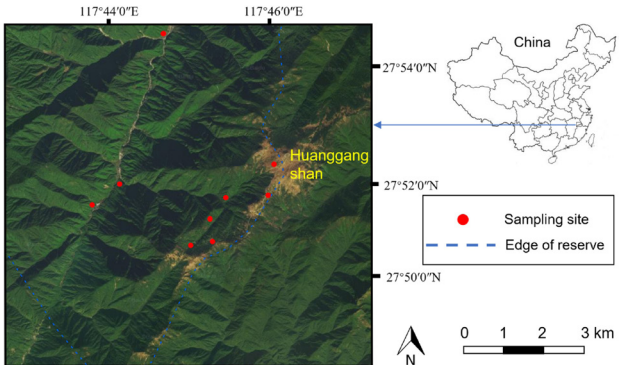

Fig. 1. Map showing the study area and the sampling sites.

Methods

This study had been approved by the Administration of the JWNNR. In May, 2014, we made a preliminary field survey to assess the vegetation types, degree of human disturbance and functional zones (the experimental, buffer and core zone) at different altitudes spanning the edge of the reserve and the top of Huanggang mountain. A total of nine sampling sites were selected for rodent diversity investigation within the reserve (Fig. 1). The sampling sites transited from low to high altitude to cover different habitat types. The nine habitat types were numbered from habitat I to habitat IX (Table I), and the average altitude of our sampling sites were also measured and recorded.

To investigate the rodent species diversity, we conducted field surveys in July, August and September, 2014, and January, February, May and June, 2015. Rodents were sampled in the nine selected sampling sites. Habitats distributed at the altitude from 1000 to 1500 m were not sampled due to low accessibility. Live cage traps were used for sampling. At each site, we placed wire cages (25cm × 10cm × 10cm, and 5 m intervals between two neighboring cages) along one transect according to topography. The total length of each transect was more than 3.5 km, which meant that there were at least 700 trapping days for each site. Sliced ham sausages, which are highly attractive to most rodents, were used as bait. Cages were placed from 1 p.m. to 5 p.m., and checked in the morning of the next day. Trapping at each site lasted at least two days. All captured rodent individuals were identified to species and then released (Li *et al*., 2003a; Shuai *et al*., 2006). Rodent communities in each habitat were numbered from community I to IX accordingly.

Data analysis

The proportion of captured rodent individuals to the trapping days was defined as the capture rate, and its proportion in the total captured individuals was considered as the relative abundance for each species in different habitats. The following indices were used to

statistically analyze the diversity characteristics of rodent communities, comprising Shannon-Wiener diversity index (H, $H = -\Sigma P_i \ln P_i$), Pielou evenness index (J, $J=H/H_{max}$, $H_{max}= \ln S$), Simpson dominance index (D, $D= {}_{max}\Sigma(P_i)^2$) and richness index (R, $R= (S-1)/\ln N$)), where $P_i= N_i/N$, with n_i representing the number of species *i*, N representing the total number of individuals, and S representing species number of the community (Margalef, 1958; Sun, 2001).

Community similarity index (I, $I = 1-0.5(\Sigma |a_i-b_i|)$), where a_i and b_i represent proportion of species *i* in community and community b (%), was employed to evaluate the differences and correlations of species composition of communities among habitats, using the minimum distance discriminant method (Li *et al*., 2003a; Mwasapi and Rija, 2021). SPSS 19.0 was used to analyze the data in our study.

RESULTS

Rodent community composition

A total of 16 rodent species belonging to eight families were recorded with 8046 effective trapping days (Table II). Out of 376 individuals of rodent species trapped (capture rate= 4.7%, capture rate in different habitats ranging from 0.6% to 10.8%), *Apodemus agrarius* and *Eothenomys melanogaster* each accounted for 26.9% (101 individuals), followed by *Niviventer fulvescens* (20.2%) and *N. confucicianus* (10.4%). These four rodent species (relative abundance= 84.3%) were considered as dominant species with relative abundances over 10%. On the other hand, *A. draco* (relative abundance= 5.6%) was regarded as common species, while the other species were considered as rare species due to their low relative abundance (less than 5%).

Table I. Different habitat types along altitude in the Jiangxi Wuyi Mountain National Nature Reserve.

Habitat types	Description
Habitat I	Farmland, with the altitude ranges from 300 to 700 m, was located in the experimental zone, and included the adjacent residential countries, farmland and wasteland with high density of herbaceous plants. Human activities brought high degree of disturbance. The altitude of our sampling site was 437m.
Habitat II	Planting area of tea germplasms (*Camellia* spp.), with the altitude ranges from 600 to 900 m, was located in the experimental zone. Tea germplasms were planted and harvested as economic crops to maintain the income of residents. The activities of tea leaves collection in spring and summer brought relatively low degree of human disturbance. The altitude of our sampling site was 860m.
Habitat III	Planting area of bamboos (*Phyllostachys pubescens*), with the altitude ranges from 500 to 1000 m, was located in the experimental zone. Relatively low degree of human disturbance was brought by cutting bamboo and digging shoots. The altitude of our sampling site was 909 m.
Habitat IV	Evergreen broad-leaved forest, with the altitude ranges from 1500 to 1700 m, was located in the buffer zone. The degree of human disturbance was low in this area. The altitude of our sampling site was 1675 m.
Habitat V	Forest of *Tsuga chinensis*, with the altitude ranges from 1650 to 1800 m, was located in the buffer zone. The *Tsuga chinensis* was a rare gymnosperm endemic to China. The degree of human disturbance was also low in this area. The altitude was 1774 m of our sampling site, which showed a steep terrain with an average gradient of more than 60°C.
Habitat VI	Deciduous broad-leaved forest, with the altitude ranges from 1800 to 2000 m, was located in the buffer zone. The sampling site was set up near the monitoring station with low human interference. The altitude of our sampling site was 1830 m.
Habitat VII	Mid-mountain moss dwarf forest showed a gentle terrain in the buffer with the altitude ranges from 1800 to 2000 m. The undergrowth and trunk were often covered with mosses, and plant height was relatively low. There was no human interference in this area. Our sampling site was at the altitude of 1873 m.
Habitat VIII	Forest of Taiwan pine (*Pinus taiwanensis* Hayata), located in the core area, was at the altitude from 1900 to 2000m with relatively gentle terrain and little surface water. No human disturbance was recorded. Our sampling site was at the altitude of 1966 m.
Habitat IX	Alpine meadow, located in the core zone, with a large number of herbaceous plants, large rocks and small debris on the surface, was at the altitude from 2000 to 2160 m. The altitude of our sampling site was 2140 m. No human activities were recorded in this area.

Table II. Communities composition and relative abundance (%) of rodents in different habitats in Jiangxi Wuyi Mountain National Nature Reserve, China.

Habitat tupe/ Trapping days	I 1000	II 1186	III 1260	IV 700	V 700	VI 850	VII 750	VIII 750	IX 850
Niviventer fulvescens	2[a] (1.9)	29(54.7)	15(34.1)	2(33.3)	1(25.0)	12(44.4)	4(50.0)		11(13.9)
Apodemus draco	2(1.9)	4(7.6)	7(15.9)	3(50.0)			2(25.0)		3(3.8)
Rhizomys pruinosus			1(2.3)			1(3.7)			
Rattus losea		1(1.9)	1(2.3)			2(7.4)			
N. confucicianus		11(20.8)	12(27.3)	1(16.7)	3(75.0)	6(22.2)	1(12.5)		5(6.3)
Leopoldamys edwardsi			4(9.1)			1(3.7)		1(2.1)	
Crocidura dracula									2(2.5)
C. attenuate	1(0.9)	3(5.7)	2(4.6)			1(3.7)			
Eothenomys melanogaster						4(14.8)	1(12.5)	41(87.2)	55(69.6)
Micromys minutus								3(6.4)	
Lepus sinensis								1(2.1)	
A. agrarius	101(93.5)								
R. nitidu			1(2.3)						
Tamiops swinhoei	1(0.9)								
R. flavipectus		5(9.4)	1(2.3)						
R. norvegicus	1(0.9)								
Species number	6	6	9	3	2	7	4	4	5
Total number	108	53	44	6	4	27	8	47	79

Note: I, farmland and residential area; II, planting area of tea germplasms (*Camellia* spp.); III, planting area of bamboos (*Phyllostachys pubescens*); IV, evergreen broad-leaved forest; V, forest of *Tsuga chinensis*; VI, deciduous broad-leaved forest; VII, mid-mountain moss dwarf forest; VIII, forest of Taiwan pine (*Pinus taiwanensis* Hayata); IX, alpine meadow; a: captured number.

Habitat distribution and diversity characteristics of rodent community

Among all habitats, habitat III possessed the highest rodent species (9 species), followed by habitat VI (7 species), and I and II (6 species each), whereas habitat V possessed only 2 species. In terms of individual numbers, habitat I possessed the highest number of individuals (108), habitat II, III, VIII shared similar individual numbers, and fewer individuals were trapped in IV, V and VII (Table II). Two species of Niviventer, *N. fulvescens* and *N. confucicianus* were trapped in eight and seven habitats, respectively. *Crocidura Dracula, Micromys minutus*, *Lepus sinensis*, *A. agrarius*, *Rattus nitidu*, *Tamiops swinhoei* and *R. norvegicus* were each trapped in only one habitat.

Community III showed higher diversity index (1.7162) and richness index (2.1141) than others while having the lowest dominance index (0.2283) (Table III). Community II, VI and VII were similar in three indexes, all having relatively higher diversity index and richness index but lower dominance index. Community VIII and IX, located in the core zone of JWNNR, had lower evenness index than all communities in the buffer and experimental zones, except for community I. With the lowest diversity index (0.2538) and evenness index (0.1416), community I had higher dominance index (0.8753) than the other communities.

Table III. Diversity characteristics of rodent communities in different habitat types.

Commu-nity	Diversity index	Evenness index	Dominance index	Richness index
I	0.2538	0.1416	0.8753	1.0679
II	1.3115	0.7320	0.3606	1.2594
III	1.7162	0.7811	0.2283	2.1141
IV	1.0114	0.9206	0.3889	1.1162
V	0.5623	0.8113	0.6250	0.7213
VI	1.5365	0.7896	0.2785	1.8205
VII	1.2130	0.8750	0.3438	1.4427
VIII	0.4586	0.2849	0.7660	1.0389
IX	0.9186	0.5127	0.5102	1.1443

Table IV. Similarity index of rodent communities in different habitat types.

Community	I	II	III	IV	V	VI	VII	VIII	IX
I	—								
II	0.0463	—							
III	0.0463	0.7110	—						
IV	0.0370	0.5755	0.6592	—					
V	0.0185	0.4575	0.5228	0.4167	—				
VI	0.0279	0.7079	0.6827	0.5001	0.4723	—			
VII	0.0370	0.7005	0.6251	0.7083	0.3750	0.6945	—		
VIII	0.0106	0.0106	0.0320	0.0107	0.0106	0.1802	0.1357	—	
IX	0.0560	0.2595	0.2596	0.2595	0.2215	0.3697	0.3845	0.7259	—

Rodent community similarity

With the highest similarity index of 0.7259, community VIII and IX were considered in same group (Table IV). Community II, III, VI and VII were also displayed in same group with similarity indexes higher than 0.6. Community IV and V both had high similarity indexes with community III, which, therefore, were regarded as the same group. By contrast, community I displayed relatively low similarity index with all of the other communities, thus, it was disassociated from all the others (Fig. 2). According to the similarity cluster tree of nine communities, they were divided into three categories, namely meadow type (community VIII and IX), forest type (community II, III, IV, V, VI, VII), and farmland type (community I).

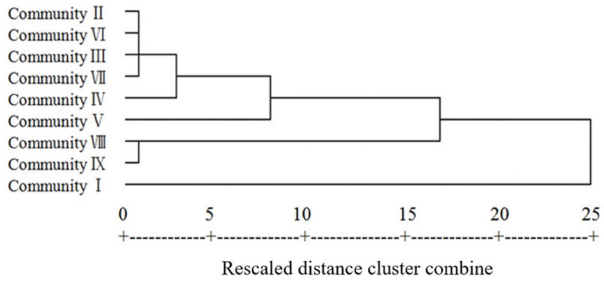

Fig. 2. Similarity cluster tree of rodent communities in different habitats.

DISCUSSION

Animal community refers to a complex composed of different animal species, which is formed with the interaction with the environment and plants in a specific ecosystem. Previously, a total of 33 rodent species were identified in a study investigating the composition and geographical distribution of mammals in national nature reserves in Jiangxi Province (Tu *et al*., 2015). The current research indicated that the JWNNR harbored 16 rodent species, which accounted for over 48% of the total number of species in national nature reserves in Jiangxi Province. On the other hand, despite our efforts, it was unlikely to trap all the rodent species due to space limitation and habitat accessibility (Shuai *et al*., 2017). For future field surveys of rodent species, more trapping days are required. Visual observation and infrared-triggered camera technology need to be conducted and applied at sampling sites to enhance survey efforts (Wu *et al*., 2013; Zhang *et al*., 2013). Capture rate is known to be affected by a number of factors, such as abundance of food resource in certain habitats, bait types, weather conditions (Jaksic *et al*., 1999). In this aspect, specific researches are also needed to improve the coverage and accuracy of the results. In this study, cages were applied for live sampling of rodent species, which brought lower disturbance to ecosystems than traditional mousetraps. Therefore, our method is widely applicable to field surveys aiming at assessing rodent population density and scope of activities (Li *et al*., 2003a, b; Shuai *et al*., 2006).

Many factors can influence species diversity in habitats. To elucidate these influential factors, several theories have been put forward by scholars, including the theories of evolutionary time, spatial heterogeneity, climate stability, competition, predation, and productivity (Pianka, 1973; Taylor and Green, 1976; Gill *et al*., 1996). Predation and competition are prevalent in ecosystems, but owing to spatial heterogeneity, habitats differ in the status of food resources. Consequently, these factors collectively contribute to the species diversity of communities (Makundi *et al*., 2010). In our study, the habitats of community I consisted of farmland and wasteland with high density of herbaceous plants in the experimental zone of the JWNNR, with the lowest elevation and high intensity of anthropogenic disturbance. Among all communities,

community I had the highest dominance index (0.8753), with *A. agrarius* being the dominated species, which was closely related to its feeding habits and food resources availability in the habitat. The sampling site contained a large size of abandoned farmlands with rich herbaceous plants. In an earlier study of the food composition of the *A. agrarius* distributed in Dongting Lake area, Yong *et al.* (2012) and found that the seeds of plants were its main food resource. Seeds occupied 48%-64% of the food composition of *A. agrarius* in different seasons, while the stems, leaves and roots accounted for relatively lower proportions, indicating a large proportion of phytophagy in its diet. Moreover, two species of Niviventer, *N. fulvescens* and *N. confucicianus*, were found to widespread in the reserve, which were also the dominant species in planting areas of tea germplasms and bamboos, the forest of *Tsuga chinensis*, evergreen broadleaf forests, and deciduous broadleaf forests. Niviventer in the Shennongjia Nature Reserve was confirmed as the dominant species because of its high proportion in all habitats (Li *et al*., 2003b), which is consistent with the results of this study. The *E. melanogaster* became the dominant species in high-altitude habitats, suggesting that different species vary in environmental adaptability.

Similar to our research, other studies also classified animal communities into different types which varied in dominant species with specific ecological requirements across landscapes (Li *et al*., 2003a; Shuai *et al*., 2006; Amori and Luiselli, 2011). For example, in Xiao Xing'an Ling Forest region, similarity index was used as a main classification standard to classify small mammal communities present in seven habitat types into three categories (Li *et al*., 2003a). In a study of small mammal communities in the desert oasis landscape, communities were divided into desert type and oasis type (Shuai *et al*., 2006). These researches classified the communities in various habitats based on the characteristics of community structure while not taking account of vegetation type because of a shorter altitude span of their sampling sites compared to our study. By comparison, the field sampling sites in this study consisted of a larger number of habitat types varying in vegetation cover and human disturbance degree. Each community was classified by taking account of its similarity index. Community types also showed correlations and differences of rodent community composition at different altitudes. Monitoring of community composition of rodents at different altitudes based on their ecological requirements were needed in the future.

In conclusion, the diversity of rodent species is remarkable in the JWNNR. By providing basic data of rodent diversity features, this study can contribute to the study of local small mammal resources, and is of great significance in the protection and construction of biodiversity in the whole reserve.

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Statement of conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Aleksandra, W. and Rafał Z., 2017. Deciphering the effects of disperser assemblages and seed mass on patterns of seed dispersal in a rodent community. *Integr. Zool.*, **12**: 457-467. https://doi.org/10.1111/1749-4877.12265

Amori, G. and Luiselli, L., 2011. Small mammal community structure in West Africa: Ameta-analysis using null models. *Afr. J. Ecol.*, **49**: 418–430. https://doi.org/10.1111/j.1365-2028.2011.01274.x

Brown, J.H., 2001. Mammals on mountainsides: Elevational patterns of diversity. *Glob. Ecol. Biogeogr.*, **10**: 101–109. https://doi.org/10.1046/j.1466-822x.2001.00228.x

Chen, B., Zhao, J.H., Guan, Q.W., Xue, J.H. and Guo, Y.R., 2018. Community composition and structure of a mid-subtropical coniferous (*Tsuga chinensis var. tchekiangensis*) and broadleaf mixed forest in Jiangxi Wuyishan, China. *Acta Ecol. Sin.*, **38**: 7359-7372. (in Chinese). https://doi.org/10.5846/stxb201709051597

Chen, C.D., 1999. Biodiversity in the Wuyi mountains and its importance in China. *Biodiv. Sci.*, **7**: 320-326. (in Chinese).

Cheng, S.L., Mao, Y.X. and Yuan, R.B., 2014. Jiangxi Wuyishan-research on the diversity of forest breeding birds in the Northwest Slope of Huanggangshan. *Acta Ecol. Sin.*, **34**: 6963-

6974. (in Chinese). https://doi.org/10.5846/stxb201303030333

Gill, J.A., Sutherland, W.J. and Watkinson, A.R., 1996. A method to quantify the effects of human disturbance on animal populations. *J. appl. Ecol.*, **33**: 786–792. https://doi.org/10.2307/2404948

Jaksic, F.M., Torres-Mura, J.C., Cornelius, C. and Marquet, P.A., 1999. Small mammals of the Atacama desert (Chile). *J. Arid Environ.*, **42**: 129-135. https://doi.org/10.1006/jare.1999.0512

Khan, A.A., Khan, W.A. and Khan, N.H., 2017. Abundant distribution of little Indian field mouse, *Mus booduga*, in the wetlands of salt range, Punjab, Pakistan. *Pakistan J. Zool.*, **49**: 449-453. https://doi.org/10.17582/journal.pjz/2017.49.2.449.453

Körner, C., 2007. The use of altitude in ecological research. *Trends Ecol. Evol.*, **22**: 569–574. https://doi.org/10.1016/j.tree.2007.09.006

Li, J.S., Song, Y.L., Xu, C.B., Zeng, Z.G. and Song, Y., 2003a. Studies on bio-diversity of small mammals along different habitat gradients in the Xiao Xing'an Ling Forest Region, China. *Acta Ecol. Sin.*, **23**: 1037-1047. (in Chinese).

Li, Y.M., Xu, L., Ma, Y., Yang, J.Y. and Yang, Y.H., 2003b. The species richness of nonvolant mammals in Shennongjia Nature Reserve, Hubei Province, China: Distribution patterns along elevational gradient. *Biodiv. Sci.*, **11**: 1-9. (in Chinese).

Makundi, R.H., Massawe, A.W., Mulungu, L.S. and Katakweba, A., 2010. Diversity and population dynamics of rodents in farm-fallow mosaic fields in central Tanzania. *Afr. J. Ecol.*, **48**: 313–320. https://doi.org/10.1111/j.1365-2028.2009.01109.x

Margalef, R., 1958. Information theory in ecology. *Gen. Syst.*, **3**: 36-71.

McCain, C.M., 2005. Elevational gradients in diversity of small mammals. *Ecology*, **86**: 366–372. https://doi.org/10.1890/03-3147

Monadjem, A., Taylor, P.J., Denys, C. and Cotterill, F.P., 2015. *Rodents of sub-Saharan Africa: A biogeographic and taxonomic synthesis.* De Gruyter Press, Berlin, Germany. https://doi.org/10.1515/9783110301915

Mwasapi, B.S. and Rija, A.A., 2021. Local habitat characteristics influence abundance and community structure of rodents in a regenerating Lulanda reserved forest, southern Tanzania. *Restor. Ecol.*, pp. e13501. https://doi.org/10.1111/rec.13501

Pianka, E.R., 1973. The structure of lizard communities. *Annu. Rev. Ecol. Syst.*, **4**: 53–74. https://doi.org/10.1146/annurev.es.04.110173.000413

Qiao, S.H., Zhong, Z.Y., Cheng, L., Fang, Y. and Cheng, S.L., 2009. Vertical rule of woody plants diversity of forest communities in Wuyishan Nature Reserve of Jiangxi. *Jiangxi For. Sci. Technol.*, **1**: 6-10. (in Chinese).

Raja, I.H. and Iqra, Y., 2019. Rodents (Muridae) abundance and habitat shift between agricultural, non-agricultural land and human dwellings: A proposed strategy to decrease crop damage. *Pakistan J. Zool.*, **51**: 2051-2056. https://doi.org/10.17582/journal.pjz/2019.51.6.2051.2056

Shuai, L.Y., Ren, C.L., Yan, W.B., Song, Y.L. and Zeng, Z.G., 2017. Different elevational patterns of rodent species richness between the southern and northern slopes of a mountain. *Sci. Rep.*, **7**: 8743. https://doi.org/10.1038/s41598-017-09274-2

Shuai, L.Y., Song, Y.L., Li, J.S., Zeng, Z.G. and Liu, J.Q., 2006. Rodent community structure of desert-oasis in the middle reaches of the Heihe River. *Biodiv. Sci.*, **14**: 525-533. (in Chinese). https://doi.org/10.1360/biodiv.060052

Stenseth, N.C., Leirs, H., Skonhoft, A., Davis, S.A., Pech, R.P., Andreassen, H.P. and Wan, X., 2003. Mice, rats, and people: The bio-economics of agricultural rodent pests. *Front. Ecol. Environ.*, **1**: 367–375. https://doi.org/10.1890/1540-9295(2003)001[0367:MRAPTB]2.0.CO;2

Sun, R.Y., 2001. *Principles of animal ecology (3rd, edition)*. Beijing Normal University Press, Beijing, China.

Taylor, K.D., and Green, M.G., 1976. The influence of rainfall on diet and reproduction in four African rodent species. *J. Zool.*, **180**: 367–389. https://doi.org/10.1111/j.1469-7998.1976.tb04683.x

Tu, F.Y., Tang, S., Liu, X., Huang, X. and Huang, T., 2015. Composition of mammal species and clustering analysis of their geographical distribution in national natural reserves of Jiangxi. *Acta Agric. Jiangxi*, **27**: 117-122. (in Chinese).

Wu, Y., Yang, Q., Wen, Z., Xia, L., Zhang, Q. and Zhou, H., 2013. What drives the species richness patterns of non-volant small mammals along a subtropical elevational gradient? *Ecography*, **36**: 185–196. https://doi.org/10.1111/j.1600-0587.2011.07132.x

Xie, W.H., Yang, X.F., Li, J.N., Tao, S.L. and Xiao, Z.S., 2014. A preliminary study of the biodiversity of ground-dwelling small mammals in Badagongshan National Nature Reserve, Hunan Province. *Biodiv. Sci.*, **22**: 216–222. (in Chinese). https://doi.org/10.3724/SP.J.1003.2014.13151

Yong, Z.Y., Zhang, M.W., Guo, C., Wang, Y., Li, B., Li, J.X., Yang, Y.C. and Xu, Z.G., 2012. Dietary habit of *Apodemus agrarius* in Dongting Lake Area.

Chin. J. Zool., **47**: 115-121. (in Chinese).

Zhang, S.S., Bao, Y.X., Wang, Y.N., Fang, P.F. and Ye, B., 2013. Estimating rodent density using infrared-triggered camera technology. *Acta Ecol. Sin.*, **33**: 3241-3247. (in Chinese). https://doi.org/10.5846/stxb201202290272

Zhang, Z.B., Zhu, Z.Q., Yang, J.Y., Wang, F.S., Hu, Z.L. and Sun, X., 1997. *Animal fauna and resource of Shennongjia*. Chinese Science and Technology Press, Beijing, China.