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Community Structure and Diversity Distributions of Small Mammals in Different Sample Plots in the Eastern Part of Wuling Mountains

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Abstract: Five years' (2000–2004) continuous study has been carried out on small mammals such as rodents in seven different sample plots, at three different altitudes and in six different ecological environment types in the eastern part of the Wuling Mountains, south bank of the Three Gorges of Yangtze River in Hubei. A total of 29 297 rat clamps/times were placed and 2 271 small mammals such as rodents were captured, and 26 small mammals were captured by other means. All the small mammals captured belonged to 8 families 19 genera and 24 species, of which rodentia accounted for 70.83% and insectivora 29.17%. Through analysis of the data, the results showed that: 1）although the species richness had a trend of increasing along different sample plots as altitude increased from south to north, quite a few species showed a wide habitat range in a vertical distribution（15 species were dispersed over three zones and two species over two zones）, indicating a strong adaptability of small mammals such as rodents at lower altitudes in most areas and comparatively less vertical span of entire mountains; 2）whether in seven different sample plots or six different ecological types, *Apodemus agrarius* and *Rattus norvegicus* were dominant species below 1 200 m, and *Anourosorex squamipes*, *Niviventer confucianus* and *Apodemus draco* were dominant above altitudes of 1 300 m，however, in quantity they were short of identical regularity，meaning they did not increase as the altitude did，or decrease as the ecological areas changed; 3）the density in winter was obviously greater than that in spring, and the distribution showed an increasing trend along with altitude, but the density in different sample plots was short of identical regularity, showing changes in different seasons and altitude grades had an important impact on small mammals such as rodents; 4) in species diversity and evenness index, there were obvious changes between the seven different sample plots, probably caused by frequent human interference in this area. Comparatively speaking, there was less human interference at high altitudes where vegetation was rich and had a high diversity and evenness index, and the boundary effect and community stability were obvious. Most ecological types have been seriously interfered with due to excessive assart at low altitudes with singular vegetation and low diversity and evenness index and poor community stability, showing an ecosystem with poor anti-reversion. If human interference can be reduced in those communities at high altitudes with low diversity and evenness index, the biological diversity in the communities will gradually recover to similar levels of other ecological areas.

Key words: Small mammals; Community structure; Species diversity; Sample plots; Eastern part of Wuling Mountains

武陵山东段不同样地小型兽类群落结构及多样性分布

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摘要：2000—2004 年对长江三峡南岸的武陵山东段 7 个不同样地、3 个不同海拔梯度和 6 种生境类型的啮齿

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等小兽进行了 5 年调查。共布放鼠铗 29 297 铗次，获得啮齿等小兽 2 271 只；其他方法获 26 只，分隶于 8 科 19 属 24 种。其中啮齿目占 70.83%，食虫目占 29.17%。对所获数据分析结果表明：1）虽物种丰富度具有从南向北随海拔升高而增加的趋势，但在垂直分布上有相当一部分物种呈现较宽的分布；2）无论在 7 个不同样地，还是在 6 种生境，1200m 以下均以黑线姬鼠(*Apodemus agrarius*)和褐家鼠(*Rattus norvegicus*)为优势种；1 300 m 以上则以短尾鼩(*Anourosorex squamipes*)、社鼠(*Niviventer confucianus*)和中华姬鼠(*Apodemus draco*)为优势，但在数量上缺乏规律性；3）冬季密度明显大于春季，沿海拔高度呈梯度增高，但不同样地的密度缺乏一致规律性；4）7 个不同样地多样性和均匀度均呈现较大变化。这可能与该地区人为干预较多有关。

关键词：小型兽类；群落结构；物种多样性；样地；武陵山东部
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To explore temporal and spatial patterns of species diversity and population fluctuation in different areas is a major topic in biodiversity research (Zhou et al, 2000; Krasnoov et al, 2004). Small mammals, such as rodents and insectivores are always well-adapted to the environment and have a wide distribution. Their relatively stable population and sensitivity to the environment mean they play an important role in the maintenance of ecosystem balance as well as the transmission of a number of natural diseases (e.g. plague, Epidemic hemorrhagic fever, Q fever and Scrub typhus). They are the main indicator species for the changes in the ecological environment (Scott et al, 1987，Zhou et al, 2002) and for communicable disease surveillance and control in large-scale construction projects (Chen et al, 2003; Zhang et al, 2005). Moreover, in some areas with fragments of vegetation and serious human interference, they are the main biomes with highly mobility (Gong et al, 1997, 2001b, 2001c; Chen et al, 1998；Li et al, 2003). Therefore, they have an important position in maintaining the food chain, food web, nutrient cycle and the structure and function of an ecological system (Shuai et al, 2006). Some small mammals with excessive density harm crops and grasslands, endanger public health security of people and domestic animals and harm agriculture and stock raising development.

The eastern part of Wuling Mountain is with subtropical evergreen broad-leaved forests and deciduous broad-leaved forest ecosystems. The region, which is situated in the southern margin of the Three Gorges Dam, is also the infectious disease-prone areas with typhus, hemorrhagic fever and others in China, whose ecological environment has an important influence on the control of sources of disease in the Three Gorges reservoir area.

There were only a few reports of the investigations and studies on small mammals, such as rodentia and insectivora, in the eastern part of Wuling Mountains on the southern bank of the Three Gorges and several other sites (Li et al, 1987, 2001; Song et al, 1999; Wang et al, 2006). So far no investigation has been carried out on the community structure, distribution trends, species diversity and the dominance of small mammals in this region. This paper will try to analyze the community structure of small mammals in the eastern part of Wuling Mountains based on the materials collected from seven sample plots scattered over three different elevation gradients and six different habitat types (Liu et al, 2007a), from April to May and October to November each year during 2000−2004 and data from Lichuan Centre for Disease Prevention and Control obtained from the epidemic hemorrhagic fever survey in Shabaxi and Duting in 1984 were also used. We aimed to reveal or clarify the relation between the diversity change pattern of different sample plots and the elevation and geographic environment, so as to provide basic data for the prevention and control of endemic typhus and epidemic hemorrhagic fever as well as the restoration and reconstruction of ecological environment in the south of the Three Gorges area of Yangtze River.

1 Methods

1.1 Investigation sites

The eastern part of Wuling Mountain is 28°52′–31°09′N, 107°04′–110°61′E, with subtropical evergreen broad-leaved forests and deciduous broad-leaved forest ecosystems. It sits on the eastern extension of the Yunnan-Guizhou Plateau, including the nine counties on the south of the Three Gorges of Yangtze River and most of Northwestern Hunan. The area is characterized by a unique eroded karst landscape with undulating mountains. Elevations range from 60m to 2252.2m. Natural vegetation differs at the different altitudes, i.e. the evergreen broad-leaved forest below 1200m, deciduous evergreen broad-leaved forests within 1 300-1 500 m, deciduous broad-leaved forests within 1600-1800m and small shrubs and bushes above 1800m. The landscape is diverse with complex environmental conditions. Except for Lichuan Xingdoushan, Hefeng

Mulinzi, Wufeng Houhe, Shimen Hupingshan and Badagongshan National Nature Reserve at the junction of the provinces Hunan and Hubei with small proportions of the original forest and rare plant communities, most of the area is fragmented from artificial cultivated larch forests, villages and large areas of farmland. The population of small mammals, such as rodentia and insectivora, are large and specific diversity is high.

According to altitude, the vertical zoning of vegetation and habitat conditions in the Mountains, the investigation was carried out at 34 sites in 12 counties (Lvcongpo and Guangdongya Forestry Centre in S.W. Hubei; Duling and Niuzhuang in Wufeng; Shuanghe and Zhongying in Enshi; Taiping and Gongjiaya in Hefeng; Pingbaying in Xianfeng; Xingdoushan and Duting in Lichuan; Badagongshan, Tianpingshan and Wudaoshui in N.W Hunan and Chayuan and Tianzishan in Zhangjiajie). These sites were clustered into seven geographical plots and six habitat types (lateral ridge woods, hillside creek woods, slope woods, hillside farmland shrub, man-made woods and woods around tea-gardens) to compare the diversity of small mammal communities (rodentia and insectivora) among various mountains and sample plots under frequent human activities.

1.2 Methods

At least 300 snap baits with peanuts were used each month for a whole year to capture small mammals in Duting and Shabaxi in Lichuan, At the other 32 sites, small mammals were collected by snap-nights during April to May and October to November each year with pedal iron snaps baited with fresh pork. Snaps were placed along 1 to 2 trapping lines about 4m apart from each other depending on the terrain. We placed the snaps in the evening and checked in the morning and then changed the station everyday. Additionally, arboreal and underground mammals were collected by shootings and digging respectively. With the Shannon-Wiener Index formula $H'=-\sum_{i=1}^{s} P_i \ln P_i$ (H' was the diversity Index and P_i was the proportion representation by species i), we calculated the diversity Index in various habitat types; Evenness index was calculated with the Pielou formula, $J = H'/\ln S$ (J = evenness index and S = the number of species); and ecological dominance was calculated with Simpson formula $C = \sum_{i=1}^{s}(ni/N)^2$ (C was the ecological dominance, N_i was the number of species i, and N was the total number of individuals captured) (Zhao & Guo, 1990; Ma, 1994).

2 Results

2.1 Small mammal community composition in the eastern part of Wuling Mountains

With a total of 29297 trap-nights, 2271 individuals were captured. Another 26 individuals (24 arboreal small mammals, one sample of insectivora and one of rodentia) were captured by other methods. Samples belonged to 8 families, 19 genera and 24 species, including 17 species of rodentia, which accounted for 70.63% of all captured species and seven species of insectivora, accounting for 29.17% (Tab. 1).

2.2 Small mammal community structure in the eastern part of Wuling Mountains

The communities of the small mammals were confirmed based on the ratio of number of individuals of each species to the total number captured in each plot: species accounting for more than 10% were the dominant species, 1% to 10% were common species and species whose proportion below 1% were rare（Xu et al, 1999）. The statistic excluded the 26 small mammals caught with other methods because of uncertain factors.

2.2.1 Evergreen broad-leaved forest zone (600–1200m) This zone covered the widest range in the survey, from Hupingshan at the junction of Hunan and Hubei provinces in the east, to Lichuan Xingdoushan in the west and south to Zhangjiajie in Northwestern Hunan. In this region, poor forests with a mass of farmlands were dotted with *Pinus*, *Larix* and tall trees and shrubs. There were 19 species of small mammals captured: *Apodemus agrarius* (35.48%), *Rattus norvegicus* (28.29%) and *Niviventer confucianus* (12.20%) were the dominant species; *Crocidura attenuata* (7.86%), *Mus musculus* (5.46%), *Caryomys eva* (3.97%) and *Anourosorex squamipes* (1.87%) were the common species; and *Blarinella quadraticauda* (0.22%), *Typhlomys cinereus* (0.22%) and *Scapanulus oweni* (0.07%) were the rare species.

2.2.2 Deciduous and evergreen broad-leaved mixed forest zone (1 300–1 500 m) This zone was relatively narrow, where the sample sites were located in Badong Yehuaping S.W. Hubei, Wufeng Changpo, Hefeng Zhongying and Tianpingshan N.W Hunan. The forest was relatively rich with a range of rare plants and original secondary forest communities. 17 species of small mammals were caught in this forest zone: *Anourosorex squamipes* (32.66%), *Niviventer confucianus* (16.16%) and *Apodemus draco* (14.48%) were the dominant species; *Apodemus peninsulae* (9.76%), *Caryomys eva* (7.74%) and *Apodemus agrarius* (5.39%) took the second place; the remaining species accounted for a certain proportion. *Nasillus gracilis* (0.34%) was found at an altitude of 1 550 m, which was the lowest limit of the distribution of this species known in the mountains.

Tab. 1 Vertical distribution, faunal elements and composition of small mammals in the Eastern part of Wuling mountains

Species		Small mammals composition in the different sample plots							Vertical distribution			Faunal element		
		DL	NZ	LCP	SH	TPS	XDS	ZJJ	600–1200m	1300–1500m	1600–1800m	Palaearctic	Oriental	Wide spread
Apodemus agrarius		5.07	0.28	7.78	6.92	3.91	39.62	66.67	35.27	5.35	2.45			√
A. peninsulae		2.03	3.07	10.37	2.31				0.37	9.70	3.37	√		
A. draco		21.96	19.83	18.73	4.62				1.49	14.38	22.05	√		
A. chcvrieri		2.03		1.15						0.67	1.23		√	
Caryomys eva		9.80	3.35	15.56	1.54	5.47	1.34	17.73	3.94	7.69	9.95		√	
Eothenomys melanogaster			0.28	0.29		2.34	0.45		0.30	1.00	0.31		√	
Niviventer confucianus		29.05	16.20	8.36	22.31	45.31	4.69	4.26	12.13	16.05	14.85		√	
N. fulvescens		1.35							0.30				√	
Leopoldamys edwardsi		3.04	0.56	0.29				0.71	0.22	2.34	0.46		√	
Rattus tanezumi		0.68	0.28	0.29	1.54		0.67		0.60	1.00	0.15			√
R. norvegicus		1.69	0.28	0.58	10.77	4.69	39.84	2.84	28.13	3.34	0.15			√
Mus musculus				0.58			8.15		5.43		0.31			√
Sciurotamias davidianus			4.19								2.30	√		
Dremomys rufigenis		0.68								0.67			√	
Petaurista alborufus		2.36							0.52				√	
Rhizomys sinensis						0.78			0.07				√	
Typhlomys cinereus		3.72	3.63	2.02				0.71	0.22	1.00	3.98		√	
Anourosorex squamipes		8.45	45.25	23.63	43.08	13.28			1.86	32.44	33.69		√	
Blarinella quadraticauda		1.35	1.96	2.59	2.31	0.78			0.22	2.01	2.30		√	
Crocidura attenuata		1.69		5.48	3.85	22.66	5.25	3.55	7.81	1.34	0.15		√	
Sorex cylindricauda		0.68									0.31	√		
Soriculus salenskii		4.05	0.84	1.15		0.78		3.55	1.04	0.67	1.38		√	
Scapanulus oweni					0.77				0.07				√	
Nasillus gracilis		0.34		1.15						0.33	0.61		√	
Total	Species number	19	14	17	11	10	8	8	19	17	19	4	16	4
	Individual number	296	358	347	130	128	896	141	1344	299	653	(16.67)*	(66.66)	(16.67)

DL: Duling area (1100-1800m); NZ: Niuzhuang area (1500-1800m); LCP: Lucongpo area (1200-1700m); SH: Shuanghe area (700-1450m); TPS: Tianpingshan area (800-1400m); XDS: Xingdoushan area (600-1200m); ZJJ: Zhangjiajie area (1000m).

*The data in the brackets are the percentage of species fauna.

2.2.3 Deciduous broad-leaved forest zone (1600–1800 m) The investigation scope was the narrowest where most sample sites were mainly located in Badong Lvcongpo, Niuzhuang and Guangdongya forestry centre in Wufeng, and the region from Duling to Hupingshan at the junction of S.W. Hunan and N.W. Hubei. The woods were almost intact. However, there was a large range of Japanese cedar forest on the northern slope with thick moss plants and humus. 19 species of small mammals captured there: *Anourosorex squamipes* (34.48%), *Apodemus draco* (22.57%), *Niviventer confucianus* (15.20%) and *Caryomys eva* (10.19%) were the dominant species; *Typhlomys cinereus* (4.08%), *Apodemus peninsulae* (3.45%) and *Apodemus agrarius* (2.51%) were second; *Blarinella quadraticauda* (2.35%), *Soriculus salenskii* (1.41%) and *Nasillus gracilis* (0.63%) were the rare species, and *Sorex cylindricauda* (0.31%)

was collected only in this zone.

2.3 Species richness and changes in dominance

2.3.1 Species richness in different plots and changing trends Species richness was the highest in the three plots at the highest elevation (around 1800m), 19 species collected in Duling, 17 in Lucongpo and 14 in Niuzhuang; secondly in Shuanghe and Tianpingshan at lower elevations (around 1400 m), 11 and 10 species were collected respectively; in Xingdoushan and Zhangjiajie with the lowest elevation (around 1100m) eight species were caught. As a whole, the species richness of the small mammals in the eastern part of Wuling Mountains gradually decreased from north to south and gradually increased with increasing elevation. Small mammals in the seven plots could be generally clarified into two types: one type of some species well adapted to the environment, such as *Caryomys eva*, *Niviventer confucianu* and *Apodemus agrarius*, which could be trapped in various plots and elevations; the other type included species with poor adaptability to the environment, such as *Nasillus gracilis*, *Sorex cylindricauda*, *Typhlomys cinereu* and *Scapanulus oweni*, whose distribution was limited to the ridges of the mountains with better ecological conditions and at higher altitudes and valleys in several sites (Liu et al, 2003), showing a high dependence on evaluation, temperature, humidity and ecological conditions.

2.3.2 Dominance in various plots and habitat types In the seven plots, *Anourosorex squamipes* (Niuzhuang 47.23%, Lvcongpo 23.63%, Shuanghe 43.08% and Tianpingshan 13.39%), *Niviventer confucianus* (Duling 30.18%, Niuzhuang 16.91%, Shuanghe 22.31% and Tianpingshan 45.67%) and *Apodemus draco* (Duling 22.81%, Niuzhuang 20.70%, Lvcongpo 18.73%) were the dominant species in three or more plots. *Rattus norvegicus* (Xingdoushan 39.84% and Shuanghe 10.77%), *Apodemus agrarius* (Xingdoushan 39.62% and Zhangjiajie 66.67%), *Caryomys eva* (Lvcongpo 15.56% and Zhangjiajie 17.32%), *Crocidura attenuata* (Tianpingshan 22.83%) and *Apodemus peninsulae* (Lvcongpo 10.37%) were dominant in one or two plots. This distribution showed that the former six species were the dominant species of small mammals in the eastern part of Wuling Mountains, and this result was also supported by the investigations of their vertical distributions at different elevations (Tab. 2). However, based on the distribution of the small mammals along the mountains, it seems that the trend of species richness changing was not correlated with vegetation, but the dominant species significantly correlated with elevation: i.e. *Apodemus agrarius* (35.48%) and *Rattus norvegicus* (28.29%) were dominant below 1200m and *Anourosorex squamipes* (32.66%-34.48%) dominant above 1300m. In addition, a certain number of *Apodemus agrarius* were captured in various plots and snaps were frequently placed indoors and outside residential areas and surrounding farmland for about one year in Lichuan Duting and Shabaxi. For this reason *Apodemus agrarius* and *Rattus norvegicus* were the dominant species below 1200m. It showed that mainly *R. norvegicus* had a close relation with human and residential areas below 1200m in the eastern part of Wuling Mountains, secondly *Apodemus agrarius*.

In the six habitat types, *Anourosorex squamipes* accounted for a relatively high proportion in lateral ridge woods (37.56%), hillside creek woods (20.58%) and slope woods (28.31%); *Apodemus agrarius* in woods around tea-gardens (77.06%) and hillside farmland shrubs (35.18%), *Caryomys eva* in man-made woods (21.89%). Excluding the data in 1984 from Lichuan, rodentia were dominant (71.66%) in spring and Insecctivora (mainly *Anourosorex squamipes*) (72.44%) in winter. However, the pattern of seasonal population changes and monthly conversion and replacement between Rodents and Carnivores during a whole year needs further investigation.

2.4 Density comparison

The overall capture rate of the 7 sample plots was 7.75%. Capture rate in 4 of the 7 plots was above 10%: Zhangjiajie area, Niuzhuang area, Tianpingshan area and Lucongpo area. The capture rates were 13.74%, 11.82%, 10.72% and 10.24% respectively. Capture rate in Duling area was at a mid-level of 8.15% while Shuanghe area and Xingdoushan area had the lowest density of 6.98% and 5.82% respectively. In the year 1984, we placed 14674 snaps in residential areas and around farmland in two sampling sites of Xingdoushan area (Shabaxi and Duting, Lichuan city) and caught 835 individuals. The capture rate of Xingdoushan area increased from 5.82% to 8.31% if these two sites were not included. It showed that the small mammal density in the wild natural environments was usually higher than that in residential areas and around farmland.

Moreover, the average density of small mammals became higher as the altitude increased: 6.86% below 1200m, 8.17% from 1300m to 1500m and 10.30% from 1600m to 1800m. The density in winter (18.48%) was obviously higher than that in spring (7.27%). Although

Tab. 2 Comparison of the dominant species of small mammals in different sample plots and habitats in the Eastern part of Wuling Mountains①

	Sample plots and habitat types	Altitude (m)	Species number	Dominant species	Common species	Rare species	List and percentage of dominant species
Ⅰ	Duling area	1100–1800	17	3	11	3	*Niviventer confucianus* (29.97%) *Apodemus draco* (22.65%) *Caryomys eva* (10.10%)
	Niuzhuang area	1500–1800	13	3	4	6	*Anourosorex squamipes* (47.23%) *Apodemus draco* (20.70%) *Niviventer confucianus* (16.91%)
	Lucongpo area	1200–1700	17	4	8	5	*Anourosorex squamipes* ((23.63%) *Apodemus draco* (18.73%) *Caryomys eva* (15.56%) *Apodemus peninsulae* (10.37%)
	Shuanghe area	1100–1450	11	3	7	1	*Anourosorex squamipes* (43.08%) *Niviventer confucianus* (22.31%) *Rattus norvegicus* (10.77%)
	Tianpingshan area	800–1400	9	3	3	3	*Niviventer confucianus* (46.67%) *Crocidura attenuata* (22.83%) *Anourosorex squamipes* (13.39%)
	Xingdoushan area	700–1200	8	2	4	2	*Rattus norvegicus* (39.84%) *Apodemus agrarius* (39.62%)
	Zhangjiajie area	1000	8	2	4	2	*Apodemus agrarius* (66.67%) *Caryomys eva* (17.73%)
Ⅱ	Lateral ridge woods	1600–1800	16	3	6	7	*Anourosorex squamipes* (37.56%) *Apodemus draco* (24.67%) *Niviventer confucianus* (17.33%)
	Hillside creek woods	800–1400	16	3	11	2	*Niviventer confucianus* (24.28%) *Anourosorex squamipes* (20.58%) *Apodemus draco* (12.76%)
	Slope woods	700–1450	13	4	5	4	*Anourosorex squamipes* (28.31%) *Niviventer confucianus* (26.03%) *Apodemus draco* (10.96%) *A. agrarius* (10.05%)
	Hillside farmland shrub	900–1450	15	2	5	8	*Apodemus agrarius* (35.18%) *Rattus norvegicus* (34.89%)
	Man-made woods	850–1700	14	3	11	0	*Caryomys eva* (21.89%) *Niviventer confucianus* (20.90%) *Crocidura attenuata* (10.95%)
	Woods around tea-gardens	1000	4	2	1	1	*Apodemus agrarius* (77.06%) *Caryomys eva* (18.35%)
Ⅲ	Evergreen broad-leave forest	600–1200	17	3	6	8	*Apodemus agrarius* (35.48%) *Rattus norvegicus* (28.29%) *Niviventer confucianus* (12.20%)
	Mixed evergreen and deciduous forest	1300–1500	16	3	10	3	*Anourosorex squamipes* (32.66%) *Niviventer confucianus* (16.16%) *Apodemus draco* (14.18%)
	Deciduous forest	1600–1800	19	3	8	8	*Anourosorex squamipes* (33.69%) *Apodemus draco* (22.05%) *Niviventer confucianus* (14.85%)

Ⅰ: Seven entries different sample plots; Ⅱ: Six entries different habitat type; Ⅲ: Three entries different altitude gradients.

①The 26 small mammals such as rodents captured by gunning and digging rat nest were not included in the statistics.

the habitat area decreased at high altitudes, the complex vegetation type, high humidity and relatively stable environment resulted in diversification of inhabited environments, tiny ecological landscapes and microclimates, which were more suitable for the survival and reproduction of different kinds of small mammals, especially insectivores, therefore, the density increased with altitudes higher. On the contrary, when the altitude lowered, the vegetation type gradually became simpler, and farmland, which had made up most of the area, became fragmented. Continual human disturbance influenced some species and reduced density. Higher density in winter may be due to little food being available for rodents and insectivores in that period so they would have to make a greater effort to find food for survival (Tab. 3).

Tab. 3 Comparison of density of Small mammals at different sample plots, altitudes and seasons in the eastern part of Wuling mountains

	Small mammals density in the different sample plots							Small mammals density in the different altitudes			Small mammals density in the different seasons①	
Appellation	DL	NZ	LCP	SH	TPS	XDS	ZJJ	600–1200 m	1300–1500 m	1600–1800 m	Spring	Winter
No. Trap-nights	3 522	2 903	3 390	1 863	1 185	1 5408	1 026	1 9468	3 636	6 193	11300	3323
No.of Individual	287	343	347	130	127	896	141	1 336	297	638	822	614
Density	8.15	11.82	10.24	6.98	10.72	5.82	13.74	6.86	8.17	10.30	7.27	18.48

DL: Duling area (1100–1800m); NZ: Niuzhuang area (1500–1800m); LCP: Lucongpo area (1200–1700m); SH: Shuanghe area (700–1450m); TPS: Tianpingshan area (800–1400m); XDS: Xingdoushan area (600–1200m); ZJJ: Zhangjiajie area (1000m).

①The rat clamps placed and small mammal specimens collected indoor and outdoor and around the farmland in Shabaxi and Duting, Lichuan city in 1984 were not included.

2.5 Diversity, evenness and ecological dominance

Small mammals such as rodents and insectivores are highly mobile animals whose distribution is not only directly influenced by the altitude and vegetation types, but also strongly related to human disturbance (Tab. 4). Among the seven different sampling plots, Duling area and Lucongpo area with the highest altitude (1 800 m) and less human interference and ideal forest vegetation had the highest diversity (3.1731 and 3.1483) and evenness indices (1.0978 and 1.1112), as well as the lowest ecological dominance indices (0.1655, 0.1435). Shuanghe area, Tianpingshan area and Niuzhuang area with more human disturbance, poorer forest vegetation and more farmland and villages took the second place. The lowest diversity occurred in Xingdoushan area and Zhangjiajie area (1.9495 and 1.6150), together with the lowest evenness indices (0.9375 and 0.7767) and highest ecological dominance indices (0.3276, 0.4811). These two areas were at the lowest altitude (1 100 m) with frequent human disturbance and the forest badly destroyed. Diversity index is an important measure of the stability of a community. The H' value will be highest when every single individual of a community belongs to a different species, indicating the highest diversity and the most equal distribution. Generally, we consider a community to be highly stable if it has a complex structure and many different species, because the diversity and evenness of such communities are always high, whereas the ecological dominance index is low. Considering our results, the stability of the small mamm-

Tab. 4 The species diversity, evenness and ecological dominance indices of small mammals in the different sample plots in the Eastern part of Wuling mountains

Code	Sample plots	Altitude (m)	Species number (S)	Individual number (N)	Species diversity index (H')	Evenness index (J)	Predominant index (C')
1	Duling area	1100–1800	17	289	3.1731	1.0978	0.1655
2	Niuzhuang area	1500–1800	13	343	2.2383	0.8726	0.2988
3	Lucongpo area	1200–1700	17	347	3.1483	1.1112	0.1435
4	Shuanghe area	700–1500	11	130	2.4950	1.0405	0.2569
5	Tianpingshan area	800–1400	9	127	2.2512	1.0246	0.2861
6	Xingdoushan area	600–1200	8	896	1.9495	0.9375	0.3276
7	.Zhangjiajie area	1000	8	141	1.6150	0.7767	0.4811

1–7:7 different Sample plots.

al communities in 7 sample plots in the eastern part of Wuling Mountain is as follows: Duling area > Lvcongpo area > Shuanghe area > Tianpingshan area > Niuzhuang area > Xingdoushan area > Zhangjiajie area. We can draw the following conclusions: generally the stability of small mammal communities at higher altitudes is higher than that at lower altitudes, and in habitats of good vegetation it is more stable than in habitats facing frequent human activities.

3 Discussion

3.1 Small mammals captured in this survey from the eastern part of Wuling Mountains belonged to two orders, eight families and 19 genera, 24 species, of which 70.83% were rodents and 29.17% were insectivores. Four species were Palaearctic，16 were Oriental species, and the other four species were wide spread, accounting for 16.67%, 66.66% and 16.67% respectively. The faunal elements were similar to that in Cangshan and Yulong Mountains in Yunnan (Gong et al, 1997, 2001a), where the Oriental element was dominant.

3.2 Species richness of small mammals in this area increased with altitude increased from south to north. On the other hand, there were also many species that could live at a wide range of vertical distribution (15 species could be caught in three different altitude gradients and two species could be captured in two different altitude gradients). The adaptation of small mammals such as rodents and insectivores to the environment may explain the result. The low altitude of most places in this area and the relatively small vertical span of the cordillera may also explain such results. The results also showed that the terrain could influence the distribution pattern of small mammal species.

3.3 Whether in all the seven different sample plots or the six different habitat types (Liu, 2007b), *Apodemus agrarius* and *Rattus norvegicus* were the dominant species below 1200 m, and above 1300 m *Anourosorex squamipes*, *Niviventer confucianus* and *Apodemus draco* were the dominant species. However the results did not show any consistent change in pattern of their abundance as the altitude increased or the habitat type changed. *Caryomys eva* lived in some sample plots and habitat types, accounting for a considerable proportion.

Seasonal and altitude gradient influence were important to the density of small mammals (Stevens, 1992). Small mammal density in winter was obviously higher than that in spring, and increased as the altitude increased, but this trend was not consistent among different sample plots.

3.4 Diversity and evenness of small mammal community showed great varieties among seven different sample plots. This may have been due to human disturbance (Xiao et al, 2002). Diversity and evenness indices were high at high altitudes with little human disturbance and rich vegetation types, where the boundary effect and community stability were obvious. Niuzhuang area was an exception. Although it was at a high altitude between 1 500 m to 1 800 m, large populations lead to serious human disturbance and low diversity and evenness indices. Most ecological types have been seriously interfered with due to excessive assart at low altitudes with singular vegetation and low diversity and evenness index and poor community stability, showing an ecosystem with poor anti-reversion.

We can draw the following conclusions with analysis: Low altitudes are adverse to the coexistence of different kinds of small mammals and if human interference can be reduced in those communities at high altitudes with low diversity and evenness index, and wildwood and diversification of the environment and vegetation types can be reserved, the biological diversity in the communities will gradually recover to similar levels of other ecological areas. At the same time the density of rodents harmful to human heath and public health security such as *Apodemus agrarius* and *Rattus norvegicus* can be reduced.

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