Open Journal of Ecology, 2015, 5, 39-54
Published Online March 2015 in SciRes. http://www.scirp.org/journal/oje
http://dx.doi.org/10.4236/oje.2015.53005

Study on the Classification and Diversity of Zonal Rodent Community in Semi-Desert and Desert Areas of China

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Received 9 February 2015; accepted 28 February 2015; published 5 March 2015

Abstract

Many studies focus on rodent community pattern and changing at present in the world, but most of them are conducted in small plots. Few studies investigated the rodent community classification and diversity in semi-desert and desert areas at regional scale, although some researchers started to study the change of animal community patterns on a large scale. We investigated rodent communities in desert, non-irrigated farming land and desert steppe of Inner Mongolia, covering an area of 380,000 km^2 from May to August in 1988-1993 and in 1998-2003, respectively, in order to reveal the changing characteristics of zonal rodent communities. The community classification and diversity of rodents were analyzed in research areas. The results suggested that the communities could be classified in 9 zonal types. *Spermophilus dauricus*, *Cricetulus longicaudatus* and *Eutamias sibiricus* were dominant species in Community I; *Phodopus roborovskii*, *Cricetulus barabansis* and *Cricetulus longicaudatus* were dominant in Community II; *Meriones unguiculatus*, *Phodopus roborovskii* and *Cricetulus longicaudatus* were dominant in Community III; *Allactaga sibirica*, *Allactaga bullata* and *Spermophilus dauricus* were dominant in Community IV; *Allactaga bullata*, *Dipus sagitta* and *Meriones unguiculatus* were dominant in Community V; *Meriones meridianus*, *Spermophilus dauricus* and *Allactaga bullata* were dominant in Community VI; *Allactaga sibirica*, *Allactaga bullata* and *Dipus sagitta* were dominant in Community VII; *Phodopus roborovskii*, *Dipus sagitta* and *Allactaga sibirica* were dominant in Community VIII; *Meriones meridianus*, *Dipus sagitta* and *Allactaga sibirica* were dominant in Community IX. The community diversity and evenness analysis showed that the edge effect of community, the effect of disturbance and habitat fragmentation and scale effect were significantly correlated with community diversity in the

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How to cite this paper: Wu, X.D., Fu, H.P., Yuan, S., Gao, Q.R. and Yue, X.X. (2015) Study on the Classification and Diversity of Zonal Rodent Community in Semi-Desert and Desert Areas of China. *Open Journal of Ecology*, **5**, 39-54.
http://dx.doi.org/10.4236/oje.2015.53005

semi-desert and desert regions. The ordinal results of 9 zonal rodent communities were in accordance with the results analyzed with similar community indices, showing the habitat change in the characteristics of the above-mentioned groups.

Keywords

Rodent Community, Classification, Desert Ecosystem

1. Introduction

Animal community, which is a functional unit and organizational structure, is one of focuses in ecological research. The deserts of the world provide natural laboratories for the study of community structure and processes influencing that structure. Because of the common biotic condition and simple vegetation structure of deserts, these systems have played a prominent role in developing and testing ideas in community ecology [1].

Human activities have led to extensive habitat fragmentation, and habitat patchiness has been a prominent structural feature of landscapes [2]. As human-dominated landscape becomes more prevalent, an understanding of the effects of habitat fragmentation on communities and organisms populations takes on increasing importance for biota conservation and management in an advanced small scale [3]-[6]. So studies on patch must be connected with regional and landscape scales. The connection between intra-patch, inter-patch and the effects of scaling-up of local performance on regional animals must be questioned. Studies on the animal community diversity in regional scale are the most frontier field in landscape ecology, community ecology and preservation of biodiversity nowadays [7]. The kernel problems discussed recent years are the changing state of animal diversity in different regional scale [8], the relationship between habitat-heterogeneity and community diversity and the relationship between fragmentation of habitat disturbed and community diversity [9]. Many studies on rodent community patterns and changing were conducted at present in the world, but almost all the studies were conducted in small plots. Some researchers started to study the change of animal community patterns on a large scale, *i.e*., macro-ecology appeared at present [10], which reviewed the spatial pattern and correlation ship of major eco-environmental problems: soil erosion, desertification, salinization, and so on, then a regional classification of eco-environment sensitivity in China was developed, and the characteristics of each sub-region of eco-environment sensitivity, including the differences of animal community pattern sensitivity, were described. However, few studies investigating the rodent community classification and diversity conducted in semi-desert and desert areas at regional scale in China.

The ecological environment of semi-desert and desert areas degenerated quickly than other areas in Inner Mongolia. In the region, desertification, saltiness, soil erosion and grassland damage caused by rodents are increasingly worse. This particular area will be the important study frame for ecosystem conservation in western China. The Chinese government started a project for controlling sand source of sand storm around Beijing and Tianjin. In 2000, it was concluded that 34 counties of Inner Mongolia were the key areas to achieve the proposed control. Most of the 34 counties are located in the region. The comprehensive control measures are required in ecological construction, restoration and preservation of grassland in the region, particularly the pest control caused by rodents. The objective of this project was to study the community classification and zonal rodents' diversity in semi-desert and desert areas of Inner Mongolia. Through field investigation, the project provided scientific guidance and theoretic basis for pest rodent control in ecological construction and grassland restoration.

2. Materials and Methods

2.1. Study Site

The research was conducted in the semi-desert and desert of Inner Mongolia (97˚10'E-115˚12'E, 37˚24'N-44˚42'N). This region belongs to typical continental arid region. The East/West bound coincide basically with climate and the humid coefficient ranges from 0.2 to 0.05. Other geological scope includes Northwest Xilinggule, Middle and West Wulanchabu Plateau, Central and North Bayannaoer and Alashan.

The research areas have obvious seasonal changes with short spring and autumn, hot summer and cold winter. Annual average temperature from the east to the west ranges from 2˚C to 5˚C. Annual precipitation from west to east ranges from 45 to 250 mm, but about 70 percent falls is from June to September. Annual evaporation is 2500 - 4700 mm, which is 10 - 104.5 times of the annual rainfall.

In eastern and middle of research areas, soil types are chestnut and dark brown earth, and soil layer is thicker with small amounts of thick sands and crushed gravel on the surface. In hilly zone of eastern and middle of research areas, soil type is light chestnut, soil texture is thicker showing some degree of desertification, and soil surface is covered with thick sands and gravels. In western of research areas, the soil type is mainly grey yermosol and grey brown earth, but the soil is light grey yermosol along Helan Mountains. The general characters of the soil are of a weak eluvia effect, the soil texture is loose, and the content of organic matter, in the topsoil, is only 1% - 1.5%, but rich in soluble salts.

The vegetation types included in research areas are temperate desert steppe, temperate steppe desert and desert. Desert steppe mainly consists of *Stipa klemenzii* + *Kengia songarica*, *S. breviflora* + *Artemisia frigida*, *S. gobica* + *Ajania achilleoides* and *Artemisia ordosica* + miscellaneous grasses. The steppe desert mainly consists of super xeric-shrubs and semi-shrubs, such as *Caragana tibetica*, *C. brachypoda*, *C. Korshinskii* and *Potaninia mongolia*, but there are many annuals.

The desert is mainly distributed in Alashan league and mainly consists of xeric-shrubs, halo-shrubs, semi-shrubs, small shrubs and small semi-shrubs. The main dominant species belong to *Chenopodiaceae*, *Compositae* and *Zygophyllaceae* family; the desert types in Alashan are classified as follows:

1) Sandy desert. The dominant species are *Artemisia sphaerocephala*, *Calligonum mongolicum*, *Ammopiptanthus mongolicus*, *Nitraria sibirica*, *Zygophyllum xanthoxylum*, *Nitraria tangutorum*, *Haloxylon ammodendron and Psammochloa villose* etc., accompanied by annuals, such as *Agriophyllum arenarium*, *A. squarrosum*, etc.

2) Sandy and gravel desert. The dominant species are *Haloxylon ammodendron*, *Reaumuria songarica*, *Ammopiptanthus mongolicus*, *Zygophyllum xanthoxylum*, *Potaninia mongolica*, etc. accompanied by *Nitraria sphaerocarpa*, *Calligonum mongolicum*, *Artemisia arenaria*, *Salsola passerine*.

3) Gravel desert. The dominant species are *Reaumuria songarica*, *Salsola passerine*, *Brachanth gobicum*, accompanied by *Cerodentoides lateens*, *Salsola laricifolia*, *Artemisia arenaria*, *A. xerophytic*.

4) Saline desert. The dominant species are *Kalidium gracile*, *K. foliatum*, *Nitraria tangutorum*, *Reaumuria songarica*, *Sympegma regelii*, *S. passerin*, accompanied by *Achanatherum splenden*, *Phragmites anstralis*, *Saussurea salsa*, *Polygonum sibiricum*, etc.

2.2. Rodent Investigation

This study was conducted in 1988-1993 and in 1998-2003 respectively. We collected rodent data from 68 sites located in the desert and semi desert areas of Inner Mongolia, covering an area of 380,000 km^2 (**Figure 1**). We selected 3 - 5 sampling plots in each of the 68 sites to capture rodents. The number of sampling plots was determined in consideration of changes of landforms, topography and vegetation in the area. The sampling plots included all kinds of vegetation and landforms. Finally, we set 317 sampling plots. Five transect lines were set in each sampling plot, and transect lines were 50 m apart. Along a transect line, 100 snap-traps, baited with peanuts, were spaced at an interval of 5 m. The traps were set after sunset and checked two times in 24 hours after they have been laid. The rodents captured were measured and weighted; the reproductive status and contents in the stomach were also checked. Since the sampling investigation could not be completed in the whole investigated area in a year, it can only be unanimous in months (or seasons); therefore, the investigated time was from May to August.

3. Data Analysis

The relative abundance is defined as the total number of captured animals/total number of snap-traps × 100 [11]. The rodent communities were classified by SAS9.0 software with minimal distance method in quick cluster analysis. The data matrix fed to quick cluster analysis was formed relative abundance of each rodent species from all sites (sequence number of sites formed the lines of the matrix, the relative abundance of rodent species formed the rows of the matrix, 317 × 23). The parameter used in quick clustering was Eu's Distance as follows:

First, three clustering points were chosen according to the distributive characteristics of zonal vegetation, landforms and topography to cluster preliminary. The 9 clusters, 13 clusters, and 15 clusters were chosen as

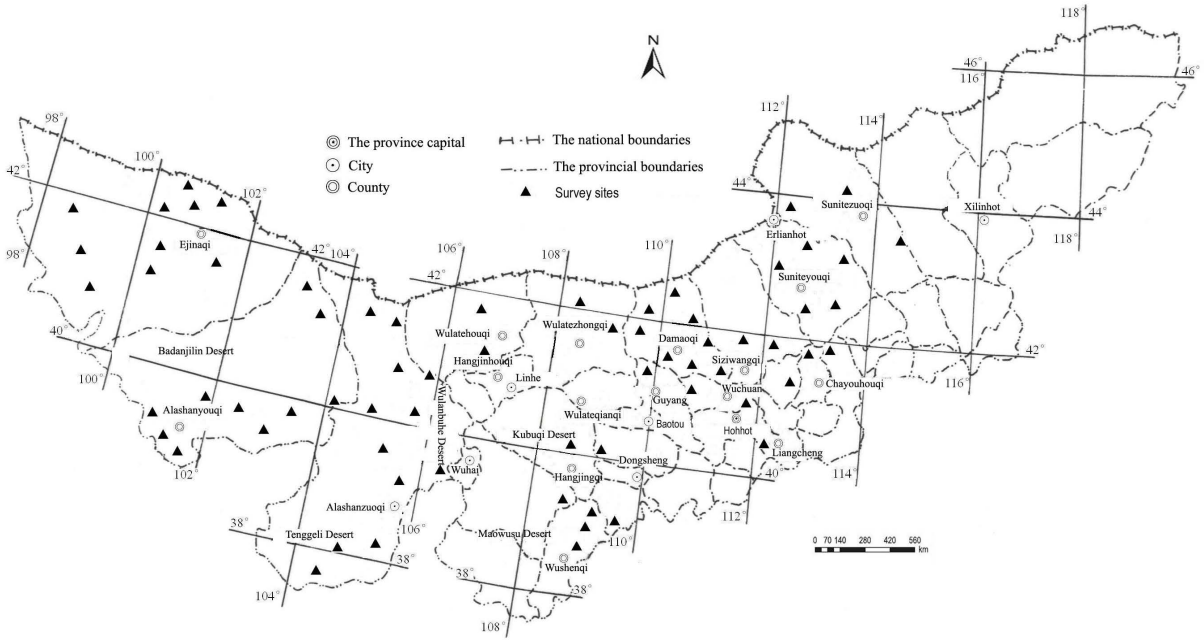

Figure 1. Sketch map of main plots of investigated rodent communities in semi-desert and desert regions of Inner Mongolia.

classification objects according the actual ten sub-groups of zonal vegetation in desert steppe, steppe desert and desert in the area, meanwhile there are hilly steppe sub-group, sandy steppe sub-group, woodland, hillside field, non-irrigated farmland and zonal vegetation [12] [13].

Second, the similar groups were clustered with the second parameters of "group average value" and "middle distance" of Eu's distance to determine the zonal community types of rodents in the researched area.

Third, best clustering point was chosen.

Base on the results of quick cluster, we analyzed distribution of each community, and plot the distribution with Arc View 3.2.

We calculated Whittaker's similarity indices between rodent communities, the formulas are as follows [14]:

$$I = 1 - 0.5 \times \left(\sum_{i=1}^{S} \left| a_i - b_i \right| \right) \tag{1}$$

where S is the number of the common species that both Community A and Community B have; a and b are the ratio of individuals of one species in Community A and Community B respectively.

The community diversity were analyzed with Shannon-Wiener diversity index and Pielou evenness index [15] [16], the formulas are as follows:

$$H = -\sum P_i \ln P_i \tag{2}$$

where H is Shannon-Wiener's diversity indices, P_i is the relative abundance ratio of species i to total species in one community.

$$J = H / H_{\max} \tag{3}$$

where J is Pielou evenness indices; $H_{\max}$ is the theoretic maximum value of Shannon-Wiener's diversity indices.

4. Results

4.1. Classification and Distributive Characteristics of Zonal Rodent Communities

We laid 157,702 traps, and captured 4833 individuals belonged to 37 rodent species in research areas (**Table 1** and **Table 2**). We chose 23 rodent species which was distributed widely, and representative to build quick cluster data matrix.

Table 1. Rodent fauna in semi-desert and desert regions of Inner Mongolia.

Rodent species	Semi-desert area															Desert area		
	DM	MM	SZQ	SYQ	CHQ	SQW	DMQ	WC	BT	GY	BTS	WQQ	HJQ	YQ	HM	AZQ	AYQ	EQ
Lepus capensis			[a]+	+	+	+	+	+	+	+	+	+	+	+		+	+	
Ochotona cansus															+			
Ochotona daurica			+	+		+	+	+										
Ochotona pallasi			+															
Eutamias sibiricus	+	+																
Spermophilus erythrogenys						+	+											
Spermophilus dauricus			+	+	+	+	+	+	+	+	+	+	+			+		
Marmota himalayana																	+	
Cricetulus eversmanni			+	+	+	+	+	+	+	+	+	+	+	+		+	+	+
Cricetulus longicaudatus	+	+	+			+	+	+	+	+	+	+	+		+	+		
Cricetulus triton						+	+		+		+							
Cricetulus migratorius																	+	+
Phodopus roborovskii			+	+	+	+	+	+	+	+	+	+	+	+		+	+	+
Cricetulus barabensis		+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	
Phodopus sungorus			+	+	+	+	+	+	+	+	+	+						
Rhombomys opimus							+									+		
Meriones meridianus							+			+	+	+	+	+		+	+	+
Meriones unguiculatus			+	+	+	+	+	+	+	+	+	+	+			+		
Meriones tamariscinus																		+
Clethrionony rufocanus	+	+																
Stylodipus andrewsi						+	+											
Allactaga sibirica			+	+	+	+	+	+	+	+	+	+	+			+	+	+
Allactaga bullata						+	+									+	+	+
Cardicoranius paradoxus			+	+												+	+	+
Dipus sagitta						+	+		+	+	+	+	+	+		+	+	+
Salpingotus kozlovi						+	+									+	+	+
Salpingotus crassicauda																	+	
Euchoreutus naso																+	+	+
Apodemus speciosus	+	+													+			
Rattus confucianus															+			
Rattus norvegicus			+	+	+	+	+	+	+	+	+	+	+			+	+	+
Mus musculus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Microtus mandarinus	+							+										
Lagurus przewalskii						+	+											
Microtus fortis														+				
Myospalax fontanneri	+	+																
Ellobius talpinus			+	+	+	+	+	+	+	+	+	+	+	+				

[a]Plus sign represents rodent species captured in sampling plot. DM: Daqing mountain, MM: Manhan mountain, SZQ: Sunitezuoqi, SYQ: Suniteyouqi, CHQ: Chayouhouqi, SWQ: Siziwangqi, DMQ: Damaoqi, GY: Guyang, WC: Wuchuan, BT: Baotou, BTS: Baotou suburbs, WQQ: Wulateqianqi, HJQ: Hangjingqi, YQ:Yiqi, HM: Helan mountain, AZQ: Azuoqi, AYQ: Ayouqi, EQ: Ejinaqi.

Table 2. The structure of rodent fauna in semi-desert and desert region of Inner Mongolia.

Rodent species	The number of captured rodent	Ratio (%)	Relative abundance (%)
Lepus capensis	25	0.52	0.016
Ochotona cansus	4	0.083	0.0025
Ochotona pallasi	1	0.021	0.0007
Ochotona daurica	3	0.062	0.0019
Eatamias sibiricus	28	0.58	0.0178
Spermophilus erythrogenys	16	0.33	0.0101
Spermophilus dauricus	361	7.47	0.2289
Marmota himalayana	2	0.041	0.0013
Cricetulus eversmanni	126	0.026	0.0799
Cricetulus longicaudatus	161	3.33	0.1021
Cricetulus triton	3	0.062	0.0019
Cricetulus migrodentorius	24	0.5	0.0152
Phodopus roborovskii	656	13.57	0.416
Cricetulus barabensis	204	4.221	0.1294
Phodopus sungorus	136	2.82	0.0862
Rhombomys opimus	3	0.062	0.0019
Meriones meridianus	566	11.71	0.3589
Meriones unguiculatus	260	5.38	0.1649
Meriones tamariscinus	2	0.041	0.0013
Clethrionony rufocanus	5	0.104	0.0032
Myospalax forntaneri	2	0.041	0.0013
Ellobius talpinus	2	0.041	0.0013
Microtus fortis	2	0.041	0.0013
Lagurus przewalskii	1	0.021	0.0007
Stylodipus andrewsi	12	0.25	0.0076
Allactaga sibirica	813	16.82	0.5155
Allactaga bullata	432	8.95	0.2739
Cardiocranius paradoxus	42	0.87	0.0266
Dipus sagitta	721	14.92	0.4572
Salpingotus kozlovi	50	1.04	0.0317
Salpingotus crassicauda	3	0.062	0.0019
Euchoreutus naso	57	1.18	0.0361
Apodemus speciosus	50	1.04	0.0317
Rodenttus confucianus	9	0.19	0.0057
Rodenttus norvegicus	18	0.37	0.0114
Mus musculus	33	0.68	0.0209
Total	4833	100	

The zonal communities were classified with the method of quick cluster (**Tables 3-5**). Similar clusters were merged according to the similarity to the cluster closed to the current cluster average and the centre distance between current cluster and central cluster, it was considered that the effect of classifying into 9 clusters was the best (**Table 3**).

The rodent communities in the research area were divided into 9 communities according to the classification results of 9 clusters and combination with zonal vegetation of ten sub-groups in desert steppe, steppe desert and desert, and the characteristics of topography and landforms (**Figure 2**). The communities are as follows:

Community I *Spermophilus dauricus* + *Cricetulus longicaudatus* + *Eutamias sibiricus* community. The community habitat is secondary forest and grassland in front of the mountains in middle part of Yingshan Mountains located in the more humid area of the Southeast research area, it was distributed continuously in the Manhan Mountains in Liangcheng and Heling counties in front of Daqing Mountains.

Community II *Phodopus roborovskii* + *Cricetulus barabansis* + *Cricetulus longicaudatus* community. The community habitat is farmland on the top mountain or artificial grassland in the North Yingshan Mountains,

Table 3. Nine clusters results of rodents with Quick Cluster Analysis.

Cluster	Frequency	RMS std deviation	Maximum distance from seed to observation	Nearest cluster	Centerior distance
1	11	0.8072	6.7510	6	13.0420
2	17	1.1109	9.0322	6	16.0146
3	75	4.5658	44.5995	4	58.0155
4	41	2.5589	28.6868	9	31.5281
5	16	1.2174	9.4380	2	16.5859
6	15	1.0179	8.0489	1	13.0420
7	19	1.3735	10.5057	5	17.6617
8	101	6.1293	5405085	3	88.0060
9	22	1.8441	18.5973	7	20.6635

Table 4. Thirteen clusters results of rodents with Quick Cluster Analysis.

Cluster	Frequency	RMS std deviation	Maximum distance from seed to observation	Nearest cluster	Centerior distance
1	11	0.8072	6.7510	5	12.5463
2	101	6.1292	54.5085	7	86.0064
3	6	0.9576	7.0865	13	5.2341
4	9	0.8372	7.6475	10	8.1486
5	14	0.9684	7.6440	1	12.5463
6	16	1.0344	8.0577	4	12.8159
7	71	4.3258	44.5995	9	55.5169
8	3	1.8517	14.9345	12	10.2194
9	40	2.4888	25.3051	8	27.3986
10	7	0.9006	6.0896	4	8.1486
11	13	0.9911	7.0928	3	12.7418
12	20	1.7835	17.6053	8	10.2194
13	6	0.8746	6.3443	3	5.2341

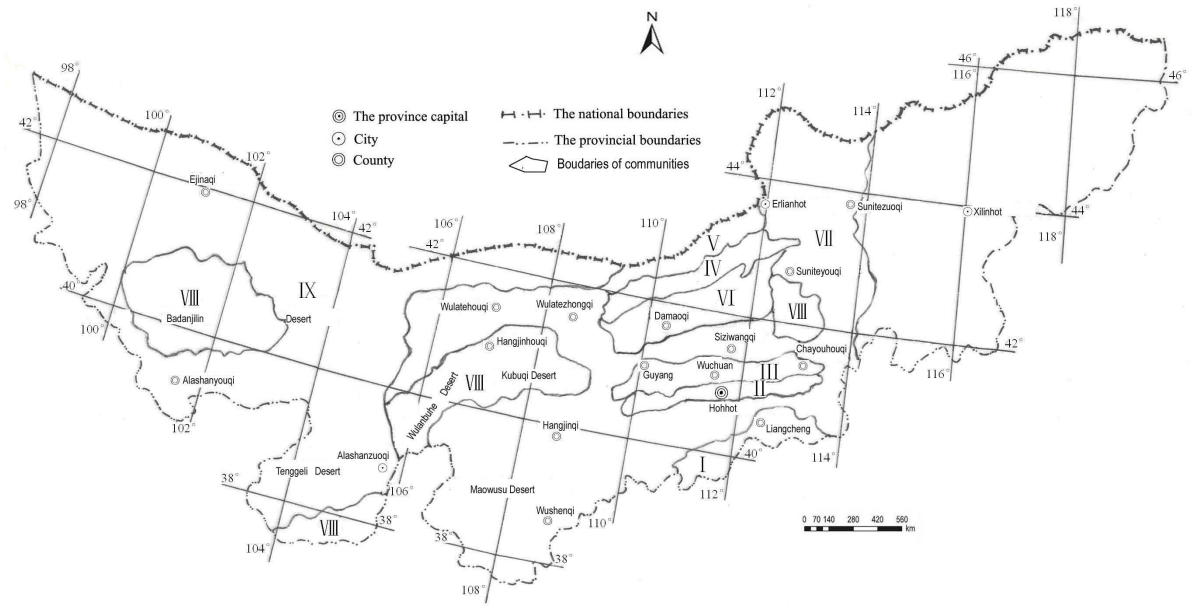

Figure 2. The distribution map of 9 zone rodent communities in semi-desert and desert of Inner Mongolia.

Table 5. Fifteen clusters results of rodents with Quick Cluster Analysis.

Cluster	Frequency	RMS std deviation	Maximum distance from seed to observation	Nearest cluster	Centroid distance
1	6	0.5443	3.6115	9	6.5412
2	13	0.9911	7.0928	6	12.7418
3	6	0.8746	6.3443	6	5.2341
4	71	4.3258	44.5995	7	55.5169
5	20	1.7835	17.6053	12	10.2194
6	6	0.9576	7.0865	3	5.2341
7	40	2.4888	25.3051	12	27.3986
8	7	0.9006	6.0896	13	7.7201
9	7	0.6069	3.4003	1	6.5412
10	10	0.7164	5.7851	15	8.5299
11	101	6.1293	54.5085	4	86.0064
12	3	1.8517	14.9345	5	10.2194
13	8	0.7363	5.0701	8	7.7201
14	12	0.8550	7.2126	13	10.4582
15	7	0.6556	4.1779	9	7.1006

there were large number of *Circetulus barabansis* in the artificial grassland.

Community III *Meriones unguiculatus* + *Phodopus roborovskii* + *Cricetulus longicaudatus* community. The community habitat is non-irrigated farmland in the North Yingshan Mountains, the zonal vegetation of the community is desert steppe, since it was disturbed heavily by humans and reclaimed to cultivate crops, the grassland mixed with farmland was formed, and the damage caused by rodents in this region was the heaviest in Inner Mongolia arid area.

Community II and Community II are distributed continuously in Chayouhouqi, Wuchan county, Damaoqi and South Siziwangqi, which is the zonal community after the landscape where the whole semi-desert area is seriously fragmentized.

Community IV *Allactaga sibirica* + *Allactaga bullata* + *Spermophilus dauricus* community. The community habitat is a transition zone from desert steppe to steppe desert, mainly distributed in Damaoqi and in the Central North Siziwangqi.

Community V *Allactage bullata* + *Dipus sagitta* + *Meriones unguiculatus* community. The community habitat is steppe desert in the North desert steppe, mainly distributed in the North part of Damaoqi and Siziwangqi.

Community VI *Meriones meridianus* + *Spermophilus dauricus* + *Allactaga bullata* community. The community habitat, heavily disturbed by humans was in desert steppe of the semi-desert in the research area, mainly distributed in Suniteyouqi, Damaoqi and Central South of Siziwangqi in the form of consecutive ribbon.

Community VII *Allactaga sibirica* + *Allactaga bullata* + *Dipus sagitta* community. The community habitat is desert steppe in the research area, mainly distributed in Northwest Xilingguole League extending to the North and Central East Wulanchabu League, Southeast Bayannaoer League and Southwest Ordos City. Many parts of this area were reclaimed into farmlands, waste farmland was mixed with grassland, which is typical crisscross zone of farming and animal husbandry; the ecological environment in here is fragile.

Community VIII *Phodopus roborovskii* + *Dipus sagitta* + *Allactaga sibirica* community. The community habitat is sandy land and land covered with sands in semi-desert and desert especially in Hunshandake Desert, Kubuqi Desert, Maowusu Desert, Tenggeli Desert and Badanjilin Desert.

Community IX *Meriones meridianus* + *Dipus sagitta* + *Allactaga sibirica* community. The community habitat is a vast desert in the research area, distributed in whole Alashan and Wulatezhonghouqi in the north of Langshan Mountains. This zonal community is widely distributed in the research area including many kinds of zonal vegetation and topography such as artificial grassland, hilly land, reclaimed region etc.

4.2. The Zonal Community Structure Characteristics

4.2.1. Community Structure Characteristics

The community structure differed among 9 zonal communities of rodent (**Table 6**).

Community I is *Spermophilus dauricus* + *Cricetulus longicaudatus* + *Eutamias* sibiricus. The community consists of 9 species of rodents. *Eutamias sibiricus*, *Apodemus speciosus* and *clethrionomys rugocanus* that are adapted to the forest land and mainly distributed in this area, the dominant species are *Spermophilus dauricus* and *Cricetulus longicaudatus*, and the relative abundance is 0.59% and 0.29% respectively.

Community II is *Phodopus roborovskii* + *Cricetulus barabansis* + *Cricetulus longicaudatus*. The community habitat is farmland on the top of the mountain and artificial grassland in north of the Yingshan Mountains, it consists of 9 species of rodents, there are large number of *Cricetulus barabansis* in artificial grassland, the relative abundance was 0.51%, but the number of *Phodopus roborovskii* was the highest in farmland, the relative abundance was 0.78%.

Community III is *Meriones unguiculatus* + *Phodopus roborovskii* + *Cricetulus longicaudatus*. This zonal community is widely distributed in non-irrigated farmland in the North of Yingshan Mountains, the zonal vegetation is desert steppe, since it was disturbed heavily by humans and a vast amount of it was reclaimed to cultivate crops, the grassland mixed with farmland was formed and the damage caused by rodents in this region was the heaviest in Inner Mongolia. This community consists of 13 species of rodents; most of them are harmful to farmland. The dominant species in the community is *Meriones unguiculatus* and *Phodopus roborovskii*, the relative abundance were 0.40% and 0.37% respectively; the relative abundance of *Cricetulus longicaudatus* and *Allactaga sibirica* were also higher, 0.27% and 0.19% respectively.

Community IV is *Allactaga sibirica* + *A. bullata* + *Spermophilus dauricus*. This community is in the transition zone from desert steppe to steppe desert mainly distributed in Damaoqi and Central North Siziwangqi. The community consists of 10 species of rodents, but most of them belong to the typical desert steppe species, the relative abundance of *Allactaga sibirica*, and *A. bullata* were 1.22% and 1.16% respectively.

Community V is *Allactaga bullata* + *Dipus sagitta* + *Meriones unguiculatus*. This community is in the North part of desert steppe. The community consists of 11 species of rodents; most of them are desert species, the relative abundance of *Allactaga bullata* and *Dipus sagitta* accounted for 73.4% of total rodents captured.

Community VI is *Meriones meridianus* + *Spermophilus dauricus* + *Allactaga sibirica*. The community is

Table 6. The relative abundance of rodent in each zonal rodent community in semi-desert and desert regions of Inner Mongolia (%).

Rodent species	Community								
	I	II	III	IV	V	VI	VII	VIII	IX
Eutamias sibiricus	0.2200	0.04700	0.0080	[b]–	–	0.0100	0.0046	–	–
Spermophilus erythrogenys	–	–	–	0.0540	0.1900	0.1400	–	–	–
Spermophilus dauricus	0.5900	0.3400	0.0750	0.3500	0.0160	0.8500	0.1800	0.1600	0.0072
Salpingotus crassicauda	–	–	0.0330	–	–	–	0.0360	–	0.0072
Stylodipus andrewsi	–	–	–	0.0270	0.0940	0.0200	–	0.0070	–
Dipus sagitta	–	0.0160	–	0.1400	0.8800	0.2800	0.4400	0.9100	0.4800
Allactaga bullata	–	–	–	1.1600	2.0300	0.5000	0.6300	0.0150	0.0650
Allactaga sibirica	0.1800	0.0940	0.1900	1.2200	0.0310	0.7200	0.8400	0.6900	0.4900
Rodenttus confucianus	0.0500	–	–	–	–	–	–	–	0.0097
Apodemus speciosus	0.0500	0.0230	0.0250	–	–	–	–	–	0.1000
Cricetulus eversmanni	–	–	0.0670	0.1100	0.1100	0.0800	0.2400	0.0070	0.0500
Cricetulus barabansis	0.1700	0.5100	0.0830	–	–	0.1200	–	0.1600	0.0630
Cricetulus migrodentorius	–	–	–	–	–	–	–	0.0070	0.0530
Cricetulus longicaudatus	0.2900	0.4000	0.2700	–	–	–	–	–	0.1300
Phodopus sungorus	–	0.0160	0.0920	0.1600	0.1700	0.3200	0.0270	0.0099	0.1500
Phodopus roborovskii	–	0.7800	0.3700	–	0.0470	0.1900	0.0960	0.9200	0.2700
Rhombomys opimus	–	–	–	–	0.0160	–	–	–	0.0024
Meriones unguiculatus	–	0.1800	0.4000	0.3500	0.3800	0.2400	0.0640	0.1700	0.1100
Meriones meridianus	0.0300	0.1900	0.0750	0.0270	–	1.2900	0.0046	0.2900	0.6900
Clethrionomys rufocanus	0.0100	0.0160	0.0170	–	–	–	–	–	–
Ochotona cansus	–	–	–	–	–	–	–	–	0.0097
Euchoreutus naso	–	–	–	–	–	–	–	–	0.1500
Meriones tamariscinus	–	–	–	–	–	–	–	–	0.0024
Number of traps	9450	1,2789	12,019	3700	6362	9680	21,932	40,365	41,396
Number of captured rodent	151	333	204	133	252	461	563	1375	1151

[b]Minus sign represents no rodent was captured.

distributed in desert steppe degenerodented and undergoing a heavy desertification, particularly in Suniteyouqi, Siziwangqi and Central North Damaoqi. It consists of 13 species of rodents, there is a lot of *Meriones meridianus* in this area, and relative abundance reached to 1.29%.

Community VIII is *Allactaga sibirica* + *A. bullata* + *Dipus sagitta*. This zonal community is widely distributed in typical desert steppe, mainly distributed in the Northeast Xilingguole League extending West to the North and the Central East part of Wulanchabu League, the Southeast Bayannaoer League and the Southeast Erdos, meanwhile some parts of this area were reclaimed into farmland, waste farmland was mixed with grassland, which is a typical crisscross zone of farming and animal husbandry, the ecological environment is fragile. This community consists of 11 species, *Allactaga bullata* is typical desert steppe species, the relative abundance was 0.63%, and the relative abundance of *A. sibirica* was the highest, 0.84%.

Community VIII is *Phodopus roborovskii* + *Dipus sagitta* + *Allactaga sibirica*. This community is distributed in sandy land and land covered with sands, particularly in desert (Hongshandake Desert, Kubuqi Desert, Tenggeli Desert and Badanjiling Desert). The community consists of 13 species of rodents, and the relative abundance of *Phodopus roborovskii* and *Dipus sagitta* reached to 1.83%.

Community IX is *Meriones meridianus* + *Allactaga sibirica* + *Dipus sagitta*. This zonal community is widely distributed in research area; it is distributed in the whole Alashan desert and the desert in the North of the Langshan Mountains including many kinds of zonal vegetation and topography such as: artificial grassland, hilly land, reclaimed region etc. There are 9 rodent species in this zonal community. The percentage in abundance of *Meriones meridianus*, *Allactaga sibirica* and *Dipus sagitta* was over 60%.

4.2.2. Diversity and Evenness Analysis of the Communities

The differences among 9 communities were compared with Whittaker's similarity indices (**Table 7**), the cluster dendrogram can be drawn according to the similarity indices (**Figure 3**). The communities were clustered into 5 groups based on similarity index 0.5621. Group 1 consists of Community VI, Community VIII and Community IX, which is distributed in the driest and widest area in the researched region including whole Alashan desert, sandy land and degenerated desert steppe. *Meriones meridianus* and *Dipus sagitta* play a key role in connection of the communities in group 1. Group 2 consists of Community IV and Community VII, which is distributed in typical desert steppe, and the similarity index between Community IV and Community VII reached to 0.7482. *Allactaga bullata* and *Spermophilus dauricus* play a key role in connecting the communities in group 2. Group 3 consists of Communities II and III, which are distributed in the non-irrigated farming area in the unique crisscross zone of farming and animal husbandry. The ecological environment in this region is the most fragile.

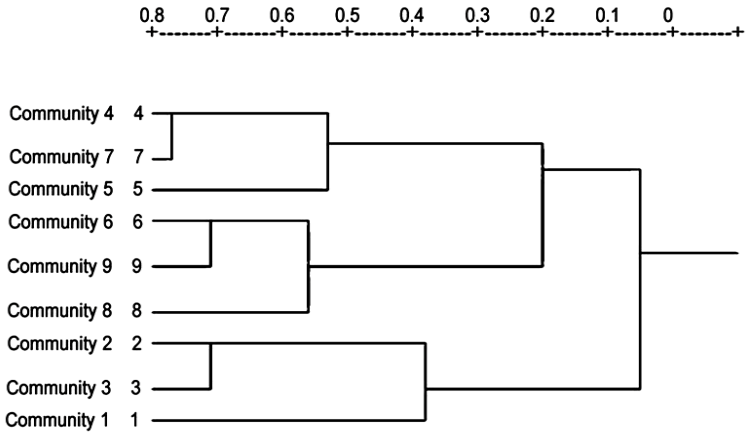

Figure 3. The cluster dendrogram of Whittaker's indices of similarity of 9 zonal rodent communities.

Table 7. The similarity indices of 9 zonal rodent communities.

	I	II	III	IV	V	VI	VII	VIII
II	0.4772							
III	0.4087	0.6372						
IV	0.2179	0.2224	0.3374					
V	0.0119	0.1050	0.1906	0.5621				
VI	0.3387	0.3664	0.3894	0.5306	0.3323			
VII	0.1855	0.1831	0.2687	0.7482	0.5064	0.4777		
VIII	0.2256	0.5287	0.5352	0.3748	0.3254	0.4849	0.5141	
IX	0.2437	0.3384	0.4373	0.3284	0.2999	0.6412	0.4482	0.6033

Phodopus roborovskii and *Meriones unguiculatus* play a key role in connecting the communities. Group 4 consists of only Community V, which is distributed in the distinct steppe desert of this area. Group 5 is distributed in the secondary forestland and grassland in front of the mountain in central part of Yingshan Mountains (**Figure 3**).

The diversity indices of Community IX, Community III and Community VI are higher than others. The diversity index of Community V was the lowest among all communities (**Table 8**). Community IX distributes in the typical desert in the research area, those habitats are the main zonal vegetation in this area and vast in region. There are plentiful variation in topography, surface features and landforms, and in which many kinds of rodents live, the diversity indices are high, but the evenness indices are not showing an uneven distribution of rodent species in this region. Community III is in the non-irrigated farming land located in the typical crisscross zone of farming and animal husbandry in Inner Mongolia. Its primeval vegetation is typical desert steppe. Since it has been disturbed by humans to cultivate crops, waste farming land and fallow mixed with grassland formed, the landscape and habitat were seriously broken, many kinds of rodents in grassland and farming land were distributed in this area, and the community diversity indices are high, which showed clear characteristics of crisscross zone of communities.

Community VI is in desert steppe degenerated and have undergone a heavy desertification. The habitat was heavily fragmentized due to human activities. The species diversity in the community was increased during the fragmentation of habitat [17]. Evenness of Community III was the highest, but that of Community V was the lowest (**Table 8**).

5. Discussions

5.1. On Division of Zonal Community

Ecological researches at larger space scale are necessary in zonal resources management and pest rodent comprehensive control. The formulation of zonal rodent community is based on the viewpoint of this ecosystem, meanwhile advanced science and technology makes it possible to process large samples and a great deal of information. We studied rodent community at regional scale according to landforms, topography and zonal vegetation characteristics, and found out zonal rodent communities correspond to the distribution of zonal vegetation in this area. At same time, it notably reflected the characteristics of distribution and structure of rodent community formed in the process of fragmentation of grassland landscape under disturbed heavily by human, such as zonal Community II, Community III and Community IV. Non-zonal community is zonal vegetation of small area, which is not the object studied in this paper. Meanwhile, the scale of describing community is also a problem; it was suggested to study community characteristics in macro-scale in the theory of scale-pattern in modern landscape ecology and community ecology [3] [5] [18] [19]. There are many type of habitat in large region

Table 8. The diversity and evenness indices of component species of different rodent communities in the semi-desert and desert region of Inner Mongolia.

Community	^cS	H	H_{max}	J
I	9	1.7705	2.1972	0.8058
II	12	1.9326	2.4849	0.7777
III	13	2.1259	2.5649	0.8288
IV	10	1.6911	2.3026	0.7344
V	11	1.5063	2.3979	0.6282
VI	13	2.1150	2.5649	0.8246
VII	11	1.7670	2.3979	0.7371
VIII	12	1.8218	2.4849	0.7331
IX	19	2.2956	2.9444	0.7796

^cS: the number of rodent species, H: Shannon-Wiener diversity index, H_{max}: The maximum value of Shannon-Wiener diversity index, J: Pielou evenness index.

in Community IX, particularly Forestland of Helanshan Mountains takes over in it, which showed the character of studying zonal community in region-scale. With the application of 3S technique to management of ecosystem resources, it has important theoretical and practical significance to study the changing characteristics of zonal rodent community on the basis of vast amount of sampling combined with 3S (GPS, RS and GIS) technique.

5.2. Relationship of Rodent Community Pattern with Degenerated Ecosystem and Fragmentation Habitat

Studies on the animal community diversity at regional scale are the most frontier field in landscape ecology, community ecology and biodiversity conservation nowadays [20]-[23]. The kernel problems discussed in recent years are the changing state of animal diversity [7] [9] [24] [25], the relationship between habitat-heterogeneity and community diversity and the relationship between fragmentation of habitat and community diversity at different regional scales [9].

The habitat-heterogeneity hypothesis put forward originally by MacArthur was that the increase in number of different habitat would result in the increase of species diversity [26]. Habitat-heterogeneity has important effects on many ecological process [27] [28], including epidemiology [29], the relationship between host and parasite, predator and prey [30] [31], population genetics [32], interspecies competition [33], dynamics of population and Meta-population [34]-[37], community structure and biodiversity [38]-[40], and conservation biology [41].

Various results have been obtained by different researchers. Most of their results showed that animal community diversity varied in different scales [7]-[9] [24] [42] [43]. Williams *et al*. found out that both the complexity of community and habitat-heterogeneity affect the structure of mammal population [7], but the relationship is varied with the change of space scale, which verified the point of view that the functional factors affecting space pattern have ecological reciprocal effect also affecting to inter habitats, which was put forward by Schluter and Ricklets [44], who found out that the three functional factors are significantly correlated with the space pattern of diversity of partial mammals and proved that scale process in parts is very important in constructing in parts mammals population. Though the complexity of morphology and structure of habitat can be determined by the existence of given centralized species, the species diversity affected notably and habitat-heterogeneity intensified depend on scale.

All the ecosystems show heterogeneity and patchiness at wide a scale [45]. The patchiness is the base for population dynamics, organization and stability and cycle of elements. The effect of patchiness and humans disturbance is the key to preservation of rare species and spread of pest species. There are four basic viewpoints on predicting change of community and function of ecosystem [4]. 1) The landscape is structured hierarchically by a small number of structuring processes into a small number of levels, each characterized by a distinct scale of "architectural" texture and of temporal speed of variables. 2) Each of the small number of processes that influence structure does so over limited scale ranges. The temporal and architecture of ecosystem quanta are determined by three broad groups of processes, each dominating over different ranges of scale. 3) On the one hand because of the non-linear nature of mesoscale disturbance processes, fine-scale knowledge of autecology cannot simply be aggregated to represent behavior at scales beyond the scale of a patch or gap. On the other analyses of the function of disturbance processes at mesoscale can provide a bridge between analyses of patch dynamics. 4) Behavioral and morphological attributes of animals can be used as a bioassay of existing landscape structure or as a predictor of the impacts of changes in vegetation pattern on animal community structure.

Brower and Dooley, and Harrison put forward study in patch at small scale should be connected with study at regional scale and landscape scale [3] [5]. For a study like this, people will ask how the process among patches is connected with process inter patches and how the animals in regional scope change due to scale-up of local performance? In the meantime, mammals are used as a model organism to test all the principles in landscape ecology, but no one try to study how mammal density is changed with patch change in size. Therefore, they think that how the mammal population responded to patch or fragmentized habitat is basic. This viewpoint is more novel explanation than general analysis.

6. Conclusion

In this study, we analyzed and compared the zonal rodent Community III, Community VI and Community IX distributed in the representative area, and tried to analyze and compare the structure and dynamics of community

in middle scale. The results showed that the community diversity of Community III, Community VI and Community IX was the highest in 9 zonal communities. Community III is distributed in non-irrigated farmland of typical crisscross zone of farming and animal husbandry in Inner Mongolia; grassland is mixed with farmland and food is relatively rich. There are many species of rodents that adapt to grassland. Farmland and desert in this area and the community diversity showed the characteristics of an ecological crisscross zone. Community VI is distributed in desert steppe after disturbed by humans; due to habitat's fragmentation, the patches of farmland, grassland, fallow and the patch are caused by fast progressive sand which is partially distributed in (*i.e*. the heterogeneity of habitat is increased, and the community diversity is increased). The high diversity of Community IX is caused by scale effect, because high species diversity often occurs on large scale. Our research results also showed that the community diversity (α diversity) was significantly correlated with edge effect of community, effect of disturbance and fragmentation of habitat and scale effect in regional scale.

Acknowledgements

This experiment was funded by National Natural Science Foundation of China (Grant #30760044, 30560028 and 31160096) and Ministry of Education Key Laboratory of Grassland Resources. We wish to acknowledge for Ganghui Zhuang, Hongjun Gan, Guohai Sang and Manliang Zhao for assistance in the field.

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