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Zoological Research

Correlation Between the Animal Community Structure and Environmental Factors in Dongbei Cave and Shuijiang Cave of Guizhou Province

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Abstract: Mollusks, arthropods and chordates which were visible to the naked eye were observed and collected in Dongbei and Shuijiang caves of Libo county five times between February and July from 2002 to 2005. Four hundred and forty samples from Dongbei Cave were classified into three phyla, five classes, 10 orders, 20 families and 39 species or groups of species. Four hundred and ninety-eight samples from Shuijiang Cave were classified into three phyla, six classes, 11 orders, 20 families and 25 species or groups of species. Six animal communities were identified in the light belt of the two caves according to their species types and numbers of individuals in the light belt of two cave. The communities which have the highest values of species richness community diversity, maximum diversity, evenness, dominance and community similarity are respectively: B (4.1059), H (2.4716), B (3.3322), E (0.9042), C (0.3442) and A–C (0.5251). The community diversity and correlation of environmental factors were also studied. The temperature, humidity, content of CO_2 and N_2, content of organic matter and some inorganic salts in soil were analyzed by Pearson correlation. The results showed that the content of organic matter in soil is positively related to species number, species richness and maximum community diversity, with correlations of 0.885, 0.909, 0.868 respectively (two-tailed significance test, $P \leqslant 0.05$), and significantly positively related to diversity, with the coefficient of 0.611, (two-tailed significance test, $P \leqslant 0.1$). This suggests that the content of organic matter in soil is one of the important elements influencing the community variation of cave animals. Outside the cave, temperature and humidity are important factors impacting on community diversity. As the temperature in all seasons in the cave is stable and the humidity is always high (above 90%), the temperature and humidity have weak correlation to community diversity in caves.

Key words: Animal community structure; Environmental factor; Dongbei Cave; Shuijiang Cave; Guizhou province

贵州董背洞和水江洞内动物群落结构与部分环境因子的相关性

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摘要: 在2002—2005年的2月和7月共5次赴荔波董背洞和水江洞对肉眼能见到的软体动物、节肢动物和脊索动物进行了观察和采集, 在董背洞共获标本440号, 隶属3门5纲10目20科39种或类群; 在水江洞共获标本498号, 隶属3门6纲11目20科25种或类群。根据上述两洞内各光带中动物种类和数量组成不同, 将其划分为6个动物群落, 经群落多样性分析, 物种丰富度、群落多样性、最大多样性、均匀度、优势度和相似性指数最高的分别是群落B(4.1059)、H(2.4716)、B(3.3322)、E(0.9042)、C(0.3442)和A—C(0.5251)。此外还研究了群落多样性与部分环境因子的相关性, 如温度、湿度、空气中CO_2和N_2含量、土壤有机质和部分无机盐含量等。用

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Pearson 相关系数进行分析，结果显示土壤中有机质的含量与物种数、物种丰富度和群落最大多样性指数都呈极显著正相关，相关系数分别为 0.885、0.909 和 0.868(双尾显著性检验均 $P \leqslant 0.05$)，与群落多样性指数呈显著正相关，相关系数为 0.611(双尾显著性检验，$P \geqslant 0.1$)，由此证明土壤有机质的含量是影响洞穴动物群落变化的重要因子之一；在地表，温、湿度是影响动物群落多样性变化的重要因子，但在特殊的溶洞内由于洞尾段的温度四季较稳定和整个洞穴内的湿度均较高，故与群落多样性的相关性不显著。

关键词：动物群落结构；环境因子；董背洞；水江洞；贵州省
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Karst caves are a special and comparatively isolated ecological system and are ideal sites to study ecological processes. Cave biology in China, in particular cave animals, have not received enough attention and its research status stays low compared with international research levels. Furthermore some fields are still unstudied such as cave ecological geographic features, ecological variation, physiology of cave animals and their origin and evolution. The international research of cave animals has focused on basic morphological taxonomy, including discovery and description of new species (Watanabe, 1992; Sket, 1999), cave fauna taxonomy (Elliot, 1985; Pech, 1992), cave fauna distribution (Decu & Iliffe, 1983; Sket, 1994) and cave fauna diversity (Stewwart, 1998; Divid & Sket, 2000). In China, a large number of studies on cave animals have focused on basic morphological taxonomy (Li et al, 2003; Huang et al, 2002; Wang et al, 1989) and ecology (Chen, 1985; Li et al, 2002). Information on community structure has rarely been published both inside and outside China, except for data on the community structure and animal geography of invertebrates (Peck, 1981b). Reports of cave communities and their evolution have been published both abroad (Sbordoni et al, 1980) and in China (Li et al, 2001) as well. There have been sporadic reports on the correlation between environmental factors and community structure, some reports covering temperature, humidity and pH value (Gunther et al, 1985; Chapman, 1983; Griffith, 1991; Li et al, 2001). However, reports investigating the effect of CO_2 content organic matter and mineral composition of caves and their correlation with cave community structures have never been published. This article is a pilot study and it is hoped that it will stimulate global cave fauna study.

1 Natural environment

Dongbei Cave is located in Shuipu village, Yuping town, Libo County. The cave opening is near the foothill at 581 m in elevation and oriented 75° toward the southwest. The geographical position of the oblong cave opening is 25°28′49.3″ in 1atitude, 107°53′50.5″ in longitude. The cave is four meters at its maximum width and two and a half meters at its maximum height. Shrubs, ferns and lichens grow around the cave with a paddy field at its front. The total length of the cave is 220 m. The cave is oval shaped. The light belt is nine meters long with dripping water, moist ground and stones where plants like lichens and mosses grow. The dim light belt, which is behind the light belt, is 19 m in length and there are ripraps and dripping water at its bottom. The dark belt is 192 m. A fissure in the cave ceiling stretches to the overlapping area between the dim light belt and the dark belt. Many tree roots from the fissure extend toward the end of the cave. Mainly sinter sediments cover the ground of the dark belt. Some stalagmites and stalactites are distributed throughout the dark belt.

Shuijiang Cave is located in Shuipu Village, Yuping town, about four km from Lipo County. There are two openings at the foothill. The front opening is comparatively larger and faces 65° southeast and is at 556 m in elevation. The geographical position is 25°33′13.6″ in latitude, 107°55′19.9″ in longitude. A cluster of shrubs grows in the opening and a stream lies about 15 m in front. The cave is 40 m at its maximum height and 50 m at its maximum width. The total length of the cave is 308 m and it is oval in shape. Some small streams flow from the cave in summer and dry in winter. The light belt is 63 m long and the basal ground is low in the front and rises to the back, and is comprised of mainly loose soil and irregular stones. Lichens, mosses and algae grow in this area. The dim light belt is 65 m long with dripping water, little soil and a large amount of collapsing stones. The dark belt is 180 m long with a large amount of soil and cobblestones on the bottom and some stalactites with dripping water from the ceiling.

2 Method

Five surveys on mollusks, arthropods and chordates visible to the naked eye in Dongbei and Shuijiang caves were carried out between February and July from 2002 to 2005. Classification of light belts, sample site selection and sizing, specimen collection were the same as in Li et al (2001). The geographic coordinates and elevation were measured with a GPS receptor (eTrex Venture, USA). Temperature and humidity were measured with JWS A2 - 2 barothermohygrogram (Beijing Yaguang Equipment Ltd Company). The pH value of the dripping water in the caves was measured with fine pH test paper. Air samples, in bags with the dimensions of a basket-ball, were collected in various light belts (light belt, dim light belt and dark belt). The air samples were analyzed for their content of CO_2, O_2 and N in the laboratory using a GC-16A chromatogram instrument (Daojin Company, Japan). One kg of mixed soil sample from representative areas of each light belt were collected to measure the content of organic matter including Ca, K, Na and P. Soil was analysed using a PE ICP 5300V. Some faunal specimens could only be identified to their families or genus due to limited faunal information or the capture only of juveniles.

Species richness was calculated according to the Richness index by Margalf:

$$D = (S - 1)/\ln N$$

Community diversity was calculated according to the Shannon-Weiner index:

$$H' = -\sum_{i}^{s}(Pi)[\ln(Pi)] \quad \frac{H'}{H'_{max}}$$

Dominance was calculated using Simpson's index:

$$C = \sum(n_i/N)^2$$

The degree of similarity is calculated using Whittaker's index:

$$J' = 1 - 0.5(\sum_{i}^{s} |a_i - b_i|)$$

The correlation was calculated according to the Pearson Correlation Index:

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

in which r represents the correlation coefficient, $\bar{x}$ and $\bar{y}$ are the mean values, respectively; x_i and y_i are the i value of x and y, n is the sample number. The range of r is between +1 and -1. When $r > 0$, the two variables have a positive association, when $r < 0$, the two variables have a negative association. When $|r| < 0.3$, x and y have little association; when $0.3 \leqslant |r| < 0.5$, x and y are weakly associated; when $0.5 \leqslant |r| < 0.8$, x and y have a significant association; when $|r| \geqslant 0.8$, x and y have a strong association. As the diversity units are inconsistent with the units of environmental factors, the primary analysis should be conducted using standard deviations to avoid dimension influence.

3 Results and Analysis

3.1 Species (group) composition and relative numbers

Four hundred and forty animals in Dongbei Cave were collected, of which 39 species or groups of species, in three phyla, five classes, 10 orders and 20 families (Tab. 1 and 2) were identified. Four hundred and ninety-eight animals in Shuijiang Cave were collected and 25 species or species groups, in three phyla, six classes, 11 orders and 25 families were identified (Tab. 1 and 3).

According to Tab. 3, the dominant species in Dongbei Cave is *Diestrammena marmorata*, accounting for 24.55% of the total, which mostly appears in the dim light belt at 47.50%. The dominant species in Shuijiang Cave is *Myotis myotis*, accounting for 28.12% of total species, which mostly appears in dim light belt at 55.22%.

3.2 Community constitution

According to species composition, individual numbers in various belts of caves and environmental factors, the animals in Dongbei and Shuijiang caves can be classified into six communities. They are:

Community A: *Diestrammena marmorata* + *Tegenaria domestica*, which are dominant species and distributed in the light belt of Dongbei Cave, accounting for 24.66% and 19.18% of the total number of animals.

Community B: *Opilio* + *Diestrammena marmorata*, which are dominant species and distributed in the

Tab.1 Systematic statistics of the animals in Dongbei and Shuijiang caves of Guizhou Province

Cave name	Phylum	Class	Order	Family	Species (or species group)
Dongbei Cave	3	5	10	20	39
Shuijiang Cave	3	6	11	20	25

Tab. 2 The number of individuals of each species or species group (mollusks, arthropods and chordates) within the three light belt types in Dongbei Cave

Species (or species group)	LB	DLB	DB	P
Cyclophoridae				
Cyclophorus exaltatus			3	0.68
Scabrina laciniata		3		0.68
Ptychopoma sp.		3		0.68
Platyrhaphe hunana		4		0.91
Cyclophorus martensianus		2		0.45
Diplommalina consularis	1			0.23
Subulinidae				
Opeas striatissimum	1		2	0.68
O. gracilior	3	3		1.36
Clausiliidae				
Phaedusa pallidocincta		5		1.14
Euphaedusa libonensis nov. sp.			2	0.45
E. sp.		3		0.68
Enidae				
Mirus sp.		2		0.45
Ariophantidae				
Kaliella munipurensis		9		2.05
K. polygyra	3	3		1.36
K. sp.	1			0.23
Macrochlamys rejecta	3			0.68
M. planula	2	2		0.91
Trochomorpha borealis			16	3.64
Camaemidae				
Moellendorffia trisinuata		2	1	0.68
Camaena cicatricose			1	0.23
Bradybaenidae				
Bradybaena sp.	5			1.14
Stilpnodiscus vernicinus		9		2.05
Phalangiidae				
Opilio sp.	3	85	3	20.68
Agelenidae				
Tegenaria domestica	14	4	28	10.45
Coelotes luctuosus	2		2	0.91
Agelena difficilis		1	1	0.45
Theridiidae				
Achaearanea tepidariorum	2	1		0.68
Psechridae				
Psechrus sinensis	1			0.23
Salticidae				
Euophrys undulatovittata	2		1	0.68
Filistatidae				
Filistata sp.	2			0.45
Glyphiulidae				
Glyphiulus valgatus		2	7	2.05
Cambalopsidae				
Podoglyphiulus sp.		7	5	2.73
Paradoxosomatidae				
Kronopus sp.	6	8		3.18
Kronopolites sp.	4		8	2.73
Cryllacridae				
Diestrammena marmorata	18	46	44	24.55
Noctuidae				
Sypna picta		3	2	1.14
Culicidae		2	5	1.59
Hipposideridae				
Aselliscus wheeleri			15	3.41
Hipposideros armiger			12	2.73
Total	73	209	158	100
Percentage(%)	16.59	47.50	35.91	100

LB: Light belt; DLB: Dim light belt; DB: Dark belt.

P: percentage of total. Numbers of individuals are totaled from the five surveys Species over 15% of the total are dominant species; species between 1 – 15% of the total are common; species below 1% of the total are rare.

dim light belt of Dongbei Cave (40.67% and 22.01%).

Community C: *Diestrammena marmorata* + *Tegenaria domestica*, which are dominant species and distributed in the dark belt of Dongbei Cave (27.85% and 17.72%).

Community D: *Boysidia guiyangensis* + *Formosana kiangsiensis*, which are dominant species and distributed in the light belt of Shuijiang Cave (22.75% and 17.96%).

Community E: *Diestrammena marmorata* + *Tipla*, which are dominant species and distributed in the dim light belt of Shuijiang Cave (both 19.64%).

Community F: *Myotis myotis* + *Kaliella polygyra*, which are dominant species and distributed in the dark belt of Shuijiang Cave (50.91% and 26.19%).

3.3 Community diversity

The results for community diversity calculations are listed in Tab. 4 and 5.

According to Tab. 4, Community B has the highest species richness (4.1059). The index describes the number of species and individuals in the whole community; the greater the number of species, the higher the richness; whereas the greater the number of individuals, the lower the richness. Community B is located in the dim light belt of Dongbei Cave, which is larger than the light belt, has higher organic matter soil content (0.77%) and where some low plants grow (such as lichens and mosses). Community A has the highest community diversity (2.4716), reflecting species number and distribution evenness of each species in the whole population. In other words, the greater the

Tab. 3　The number of individuals of each species group (mollusks, arthropods and chordates) within the three light belt types in Shuijiang Cave

Species or group	LB	DLB	DB	P
Cyclophoridae				
Cyclophorus exaltatus	1	1		0.40
Viviparidae				
Viviparus rivularis	1	1		0.40
Pomatiopsidae				
Iglica sp.		1		0.20
Erhaia sp.		1	1	0.40
Clausiliidae				
Formosana kiangsiensis	30			6.03
Ariophantidae				
Trochomorpha borealis			3	0.60
Kaliella polygyra		3	72	15.06
Macrochlamys sp.			7	1.41
Microcystis sp.		2		0.40
Pupillidae				
Boysidia guiyangensis	38	5		8.64
Bradybaenidae				
Bradybaena sp.	1		3	0.80
Oniscidae				
Pocellio scaber	23	6		5.82
Araneidae				
Araneus ventricosus	13	5		3.62
Theridiidae				
Achaearanea tepidariorum	3	3		1.20
Uloboridae				
Zosis geniculatus	1			0.20
Amaurobiidae				
Coelotes sp.			3	0.60
Segestriidae				
Segestria sp.	1			0.20
Lithobiidae				
Bothrolys asperatus	2	3		1.00
Paradoxosomatidae				
Kronopus sp	1	2		0.60
Hylomini sp.	1	1		0.40
Cryllacridae				
Diestrammena marmorata	5	11	12	5.62
Myrmeleontidae				
Myrmeleon formicarius	21			4.22
Noctuidae				
Sypna picta			2	0.40
Tipulidae				
Tipla sp.	25	11	32	13.66
Vespertilionidae				
Myotis myotis			140	28.12
Total	167	56	275	100
Percentage(%)	33.53	11.24	55.22	100

Annotation is the same as for Tab. 2.

Tab. 4　Richness, diversity, evenness and dominance indices of different communities

Community	S	D	H'	H'_{max}	J'	C
A	18	3.9623	2.4716	2.8904	0.8551	0.1189
B	23	4.1059	2.1411	3.3322	0.6425	0.2228
C	19	3.5448	2.3273	2.9444	0.7904	0.1423
D	15	2.7273	2.1167	2.7081	0.7816	0.1487
E	14	3.2296	2.3864	2.6391	0.9042	0.1175
F	10	1.5168	1.3837	2.3026	0.6009	0.3442

S: No. of species; D: Species richness; H': Community diversity; J': the degree of similarity; C: Dominance.

species and greater the evenness, the higher the diversity and vice versa. Community A is located in the light belt of Dongbei Cave, where a number of plant species, such as ferns, lichens, mosses and gramineous plants grow, which also provide food resources for polyphagous animals.

In addition, some species such as *Diestrammena marmorata*, distributed around the cave entrance, might migrate into the cave temporarily to avoid low temperatures in winter or droughts outside the cave and gradually they have adapted to cave environments and settled down in the light belt. All these might stimulate the increase of diversity in the light belt. The highest evenness is in Community E (0.3442) in the dim light belt of Shuijiang Cave where there are no populations of large species. The sequence of dominant species within a community from high to low is: Community F (0.3442) > B (0.2228) > D (0.1487) > C (0.1423) > A (0.1189) > E (0.1175), which is opposite to the evenness sequence (E > A > C > D > B > F), reflecting the negative correlation between dominance and evenness (See the analysis in 3.4). The highest dominance falls on Community F, which is distributed in the dark belt of Shuijiang Cave, where the largest population is of *Myotis myotis*. The good vegetation around Shuijiang Cave provides sound ecological environment for insects, which indirectly provides *Myotis myotis* with abundant food resources.

The data in Tab. 5 shows that the three highest indices in similarity are Communities A – C, D – E and A – B in the same cave, while the three lowest are C – D, B – D and A – D in different caves. Hence, these suggest that similarity is generally high between neighboring communities (belts) and low between the distant communities (belts). The environmental factors in neighboring communities are similar but vary greatly between distant communities.

Tab. 5 Similarity index between every pair of communities

Community	A	B	C	D	E
B	0.3615				
C	0.5251	0.3192			
D	0.0629	0.0483	0.0418		
E	0.3094	0.2647	0.2401	0.5137	
F	0.0957	0.0692	0.0675	0.1554	0.2529

Tab. 6 Values of environmental factors in different communities

CO	AT(℃)	H (%)	pH	AO (%)	AN (%)	ACO (%)	SK (mg/kg)	SNa (mg/kg)	SCa (%)	SP (mg/kg)	SOM (%)
A	17	90	7.0	21.0	77.0	0.058	5 188	464	1.96	826	0.77
B	16	94	7.0	20.6	76.0	0.055	4 533	596	1.48	1 075	0.77
C	14	100	6.5	21.0	77.6	0.046	3 316	614	1.78	176	0.59
D	23	86	6.9	21.0	77.8	0.045	3 668	958	13.5	4 481	0.42
E	20	91	6.0	21.0	77.8	0.054	2 918	318	23.0	1 356	0.46
F	18	95	6.5	21.0	77.8	0.050	2 478	580	31.3	3 152	0.34

CO = Community; AT = Air temperature; H = Humidity; pH = pH value; AO = Content of O_2 in air; AN = Content of N in air; ACO = Content of dioxides in air; SK = Content of K in soil; SNa = Content of Na in soil; SCa = Content of Ca in soil; SP = Content of P in soil; SOM = Content of organic matter in soil.

Tab. 7 Values of diversity and environmental factors in different animal communities by standard deviations

Community	A	B	C	D	E	F
Species(S)	0.33292	1.44266	0.55487	–0.33292	–0.55487	–1.44266
Richness(D)	0.81657	0.96668	0.38016	–0.47438	0.05068	–1.73972
Diversity(H')	0.84608	0.00836	0.48032	–0.05348	0.63012	–1.91140
Greatest Diversity (H'_{max})	0.25416	1.53600	0.41084	–0.27476	–0.47496	–1.45128
Evenness(J')	0.77087	–1.01731	0.27714	0.15266	1.18385	–1.36720
Dominance(C)	–0.72085	0.45862	–0.45522	–0.38256	–0.73675	1.83676
Temperature(AT)	–0.31623	–0.63246	–1.26491	1.58114	0.63246	0.00000
Humidity(H)	–0.55523	0.27762	1.52689	–1.38809	–0.34702	0.48583
pH value(pH)	0.88900	0.88900	–0.38100	0.63500	–1.65100	–0.38100
O_2(AO)	0.40825	–2.04124	0.40825	0.40825	0.40825	0.40825
N_2(AN)	–0.46107	–1.84428	0.36886	0.64550	0.64550	0.64550
CO_2(ACO)	1.28142	0.70478	–1.02514	–1.21735	0.51257	–0.25628
K(SK)	1.48104	0.83625	–0.36177	–0.01526	–0.75356	–1.18670
Na(SNa)	–0.58484	0.03606	0.12073	1.73885	–1.27160	–0.03920
Ca(SCa)	–0.80144	–0.83912	–0.81557	0.10440	0.85011	1.50162
P(SP)	–0.62408	–0.47148	–1.02243	1.61587	–0.29927	0.80140
Organic matter(SOM)	1.15790	1.15790	0.17323	–0.75674	–0.53792	–1.19437

3.4 Analysis of correlation between community diversity and environmental factors

The environmental factors in each community were measured in summer (including temperature and content of CO_2 and organic matter in soil). The values are shown in Tab. 6. The correlations between environmental factors and diversity in various communities were analyzed with SPSS12.0.

Correlation of the indices listed in Tab. 7 were calculated according to Pearson Correlation and the correlation coefficient matrix is listed in Tab. 8.

From Tab. 8, it appears that N content is strongly negatively related to species number and to maximum diversity. The correlation coefficients are -0.823 and -0.844, respectively (two-tailed significance test, $P \leqslant 0.05$). Ca content in soil is strongly negatively related to species number, species richness and the maximum community diversity. The correlation coefficients

Tab. 8 Pearson correlation coefficient matrix of different species in animal communities in Dongbei Cave and Shuijiang Cave

R	*S*	*D*	*H'*	*H'*max	*J'*	*C*	AT	H	pH	AO	AN	ACO	SK	SNa	SCa	SP
D	0.903*															
H'	0.597	0.853*														
*H'*max	0.995**	0.896*	0.583													
J'	0.041	0.424	0.826*	0.025												
C	−0.389	−0.674	−0.956**	−0.375	−0.918**											
AT	−0.519	−0.414	−0.113	−0.461	0.208	−0.111										
H	0.203	0.038	−0.161	0.151	−0.315	0.302	−0.869*									
pH	0.524	0.344	0.046	0.520	−0.332	0.043	−0.080	−0.264								
AO	−0.707	−0.474	0.004	−0.752	0.498	−0.225	0.310	−0.136	−0.436							
AN	−0.823*	−0.683	0.218	−0.844*	0.321	0.044	0.455	−0.100	−0.618	0.904*						
ACO	0.273	0.477	0.295	0.290	0.152	−0.103	−0.231	−0.139	0.127	−0.345	−0.578					
SK	0.727	0.783	0.576	0.719	0.184	−0.428	−0.208	−0.287	0.777	−0.410	−0.724	0.559				
SNa	0.022	−0.244	−0.251	0.028	−0.328	0.117	0.391	−0.294	0.537	−0.018	0.105	−0.721	0.020			
SCa	−0.921**	−0.879*	−0.683	−0.888*	−0.204	0.531	0.504	−0.149	−0.611	0.411	0.640	−0.172	−0.804	−0.124		
SP	−0.597	−0.706	−0.566	−0.554	−0.298	0.355	0.831*	−0.619	0.126	0.231	0.429	−0.482	−0.340	0.677	0.569	
SOM	0.885*	0.908*	0.611	0.868*	0.129	−0.378	−0.571	0.120	0.571	−0.567	−0.842*	0.615	0.891*	−0.240	−0.874*	−0.693

**$P \leqslant 0.01$ (Two-tailed test); * $P \leqslant 0.05$ (Two-tailed test); R = Pearson correlation coefficient; S = No. species.

are −0.921, −0.879 and −0.888, respectively (two-tailed significance tests: species number, $P \leqslant 0.01$; species richness and maximum community diversity index, $P \leqslant 0.05$). Content of organic matter in soil is strongly positively related to species number, species richness and the maximum community diversity. The correlation coefficients are 0.885, 0.909 and 0.868, respectively (two-tailed significance test, $P \leqslant 0.05$). Other environmental factors are not significantly correlated to community diversity.

Amongst all indices, species number is strongly positively related to species richness and community diversity. The correlation coefficients are 0.903 and 0.995, respectively (two-tailed significance test: species richness, $P \leqslant 0.05$; community diversity, $P \leqslant 0.01$). Species richness is strongly positively related to community diversity and the maximum community diversity. The correlation coefficients are 0.853 and 0.896 (two-tailed significance test, $P \leqslant 0.05$). Community diversity is strongly positively related to community evenness and strongly negatively related to population dominance. The correlation coefficients are 0.826 and −0.956 respectively (two-tailed test: community evenness, $P \leqslant 0.05$; population dominance, $P \leqslant 0.01$). Community evenness is strongly negatively related to population dominance. The correlation coefficient is −0.918 (two-tailed significance test, $P \leqslant 0.01$). The remaining factors are not significantly associated.

5 Discussion

The calculation and analysis in 3.3 proved that environmental factors manipulated the indices of community diversity, while those indices were correlated and influenced each other. The data in Tab. 8 suggests that the organic matter content is significantly positively related to species numbers, community richness and maximum community diversity and positively related to community diversity. Thus we concluded that many environmental factors in the cave influence the community diversity, such as daylight illumination, temperature, humidity, pH value, CO_2, soil organic matter and various minerals, of which the content of organic matter is the main factor. Organic matter can be brought into the cave through air currents, plants growing near the entrance and bats and other animals. At the far end of the cave, organic matter in soil comes from seeping water and then becomes the food for many polyphagous invertebrates such as mollusks and diplopods. Animals higher in the food chain (spiders and bats) then eat these insects and the food web in the cave has thus been formed. Outside the cave, temperature and humidity would be important factors impacting community diversity. As the temperature in all seasons inside the cave is stable and the humidity is always high (above 90%), the temperature and humidity have weak correlation to community diversity (See Tab. 8).

Some abundant species, like *Trochomorpha borealis* and *Kaliella polygyra*, inhabit the dark belt of the cave and their shells became flimsy and colors faded due to their long stay in the dark belt. The origin and evolution of these animals should be particularly interesting to science. In such special habitation, especially in the dark belt, animals vary easily and the rate of evolution will be higher than outside the cave. When variations accumulate to a certain degree, new subspecies or species may occur. For example, the new species *Euphaedusa libonensis* has been found in Dongbei Cave (Li et al, 2003). As caves are ideal sites to study the origin and evolution of cave ecological systems, it is necessary to preserve primitive cave habitation. Recently, some large caves with good landscapes have been opened to tourists since the development of the tourism industry. However, neither useful methods nor good experience has proved successful in balancing cave tourism and preservation of cave fauna. However, some international methods can be used for reference, for example that specific parts or branches of caves are isolated and only open for scientific use in Postojna, Slovenia.

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References:

Chapman P. 1983. Quantitative analysis of cave: Dwelling invertebrates in estado falcon, Venezuela[J]. *NSS Bull*, **45**(2): 40–44.

Chen ZF. 1985. Study on spider ecology in Shuanglong cave of Jinhua [J]. *Acta of Hangzhou Normal College* (*Natural Sciences*), **12** (1): 24–28. (in Chinese)

Decu VG, Iliffe TM. 1983. A review of the terrestrial cavernicolous fauna of Romania[J]. *NSS Bull*, **45**(4): 86–97.

Divid CC, Sket B. 2000. Hutspots of subterranean biodiversity in cave and wells[J]. *Journal of Cave and Karst Studies*, **62**(1): 11–17.

Elliot WR. 1985. The cave fauna of California[J]. *Proc NSS Ann Meet* (*in NSS Bull*), **48**(1): 59.

Griffith DM. 1991. The effects of substrate moisture on survival of adult cave beetles (*Neaphaenops tellkampfi*) and cave cricket eggs (*Hadenoecus suberraneus*) in a sandy deep cave site[J]. *NSS Bull*, **53**(2): 98–103.

Gunther L, Friedrich W. 1985. Time-keeping mechanisms and their ecological significance in cavemicolous animals[J]. *NSS Bull*, **47**(2): 147–162.

Huang H, Li DH, Peng XJ, Li SQ. 2002. Two new troglobitic species of the genus coelotes from China (Araneae: Amaurobiidae)[J]. *Acta Zootaxonomica Sinica*, **27**(1): 78–81. (in Chinese)

Li DH, Luo R. 2001. Study of the relationship between the animal community structure and distribution and part of environmental factors in Longdog cave of Guizhou province[J]. *Carsologica Sinica*, **20**(4): 315–320. (in Chinese)

Li DH, Luo R. 2002. The preliminary investigation and observation of the karst cave bats in the mid region of Guizhou province[J]. *Journal of Guizhou Normal University* (*Natural Sciences*), **20**(2): 41–45. (in Chinese)

Li DH, Luo R, Chen H. 2001. Study on the animal communities in Dadongkou cave, Guizhou province[J]. *Acta Ecologica Sinica*, **21** (1): 126–130. (in Chinese)

Li DH, Luo TC, Chen DN. 2003. A new species of land snail from Guizhou province, China (Pulmonata, Stylommatophora, Clausiliidae)[J]. *Acta Zootaxonomica Sinica*, **28**(3): 446–447. (in Chinese)

Peck SB. 1981b. Community composition and zoogeography of the invertebrate cave fauna of Barbados[J]. *Fla Entomol*, **64**(4): 519–527.

Peck SB. 1992. A synopsis of the invertebrate cave fauna of Jamaica[J]. *NSS Bull*, **54**(1): 37–60.

Sbordoni V, Vomerro V, Argano R, Zullini. 1980. The cave fauna of Chtapas (Mcxico): Tropical and temperate cave communities and their evolution[A]. In: Furtado JI. Proceedings 5th International Symposium of Tropical Ecology, Malaysia[C]. The International Society of Tropical Ecology, 687–692.

Sket B. 1994. Distribution patterns of some subterranean Crustacea in the territory of the former Yugoslavia[J]. *Hydrobiologia*, **287**: 65–75.

Sket B. 1999. *Niphargus aquilex dobati* ssp. n. (Crustacea, Amphipoda) from the karst of Slovenia[J]. *Mitt Verb dt Hohlen-u Karstforsch*, **45** (2): 54–56.

Stewwart BP. 1998. A summary of diversity and distribution of the obligate cave-inhabiting faunas of the United States and Canada[J]. *Journal of Cave and Karst Studies*, **60**(1): 18–26.

Wang DZ, Chen YY. 1989. Descriptions of three new species of Cyprinidae from Guizhou province, China (Cypriniformes: Cyprinidae)[J]. *Acta Academia Medicinae Zunyi*, **12**(4): 29–34. (in Chinese)

Watanabe Y. 1992. Two new species of the group of *Lathrobium pollens* (Coleoptera, Staphylinidae) from central Honshu[J]. *Japan J Speled Soc Japan*, **17**: 39–45.