Relationship between Cave Animal Community Structure and Environmental Factors in the Manganese Mining Area of Songtao County, Guizhou Province: Postprint

Authors: warm and clear, Yang Weicheng, Tao Hongmei, Zhou Xulin, Yu Yuanchan

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Abstract

This study primarily selected Dadong and Xiadong caves in the vicinity of the Songtao manganese mining area as research objects to investigate the relationship between cave environmental factors and cave animal communities, explore whether heavy metal Mn pollution exists in the two cave environments, conduct comparative analysis of the community structures of the two caves, and examine whether the correlations between different heavy metals, environmental factors, and the animal communities of the two caves are consistent. Through sampling, a total of 1,274 specimens were collected, including 660 specimens from Dadong, belonging to 5 phyla, 10 classes, 21 orders, 24 families, and 26 species, and 614 specimens from Xiadong, belonging to 4 phyla, 7 classes, 15 orders, 21 families, and 26 species. Community diversity analysis results showed that the descending order of diversity indices was Community D (2.4745) > C (1.4036) > A (1.3549) > B (1.1935) > E (1.1384) > F (0.7265). Analysis of the Pearson correlation coefficient matrix between cave community diversity and environmental factors in Dadong and Xiadong revealed that in Dadong, As and Mn in soil showed significant positive correlations with species number, with P-values of 0.039 and 0.029, respectively; in Xiadong, heavy metal As in water showed a significant positive correlation with species dominance (0.021), while heavy metal Mn showed a significant negative correlation with diversity index (0.044), and temperature was the primary factor influencing the abundance and distribution of the Xiadong cave community. Heavy metal pollution assessment showed that water pollution in both caves was minor, and among soil heavy metals, except for Hg which reached extremely severe pollution levels, the remaining heavy metals did not exceed moderate pollution grades.

Full Text

Preamble

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Relationship Between Cave Animal Community Structure and Environmental Factors in the Manganese Mining Area of Songtao County, Guizhou Province

WEN Qing[1], YANG Weicheng[1,2,*], TAO Hongmei[1], ZHOU Xulin[1], YU Yuanchan[1]
[1]School of Life Sciences, Guizhou Normal University
[2]Institute of Karst Caves, Guizhou Normal University, Guiyang 550031, China

*Corresponding author. E-mail: yangweicheng0908@sina.com

Abstract

This study investigated the Da and Xia caves in a manganese mining area of Songtao County to evaluate the relationship between animal community structure and cave habitat factors, with particular attention to heavy metal pollution. A total of 1,274 specimens were collected: 660 individuals (5 phyla, 10 classes, 21 orders, and 26 species) from Da Cave and 614 individuals (4 phyla, 7 classes, 15 orders, and 26 species) from Xia Cave. Six communities (A-F) were identified, with diversity indices ranked as follows: D (2.4745) $>$ C (1.4036) $>$ A (1.3549) $>$ B (1.1935) $>$ E (1.1384) $>$ F (0.7265). Pearson correlation analysis revealed that in Da Cave, soil arsenic (As) and manganese (Mn) content showed significant positive correlations with species richness ($P = 0.044$ and 0.039, respectively). Arsenic content was positively correlated with species dominance, while Mn content was negatively correlated with the diversity index. Temperature emerged as the primary factor influencing animal abundance and distribution in Xia Cave. Heavy metal pollution assessment indicated that except for mercury (Hg), which reached high pollution levels, no other heavy metals exceeded moderate pollution levels in the water of either cave. The study demonstrates that heavy metals significantly impact cave animal community structure, though the specific relationships differ between caves.

Keywords: cave animals; community diversity; comparative analysis; heavy metals; Mn; As

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1. Introduction

Guizhou Province is characterized by numerous karst caves, with documented cave numbers reaching [FIGURE:N]. Research on cave investigations has yielded abundant results both domestically and internationally. International studies have focused on tracking heavy metals in cave animal feces and microorganisms [2-4], while domestic research has primarily examined the influence of cave environmental factors (CO , O , temperature) on cave animal community structure [5-8]. Common heavy metal studies have targeted Zn, Cu, Ni, As, Cr, and Hg [5,7-8,11-14]. As a trace element, Mn rarely appears in studies related to cave animal community structure.

Songtao County in Guizhou features typical karst landforms with abundant manganese resources. The area belongs to the Lower Cambrian black rock series region, where soil heavy metal content is generally high. Our investigation revealed that the habitats near the Lijiawan and Yanglizhang manganese mining areas in Songtao County, specifically Da Cave and Xia Cave, have favorable environmental conditions, are located close to each other, and offer strong comparability. This study selected these two caves as research objects to: (1) investigate the relationship between cave environmental factors and cave animal communities, (2) explore whether heavy metal pollution exists in both cave environments, (3) compare and analyze the animal community structures, and (4) examine whether correlations between different heavy metal environmental factors and the two cave animal communities are consistent.

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2. Study Sites

2.1 Da Cave

Da Cave is located at 28°08 N, 108°48 E in Yankou Village, Wuluo Town, Songtao County, approximately 400 m from the Lijiawan-Yanglizhang manganese mining area. The cave entrance is triangular, measuring 15 m wide and 18 m high, with a small mountain stream flowing out from the right side. The elevation is 878 m, with lush vegetation surrounding the entrance including *Urtica fissa*. The entrance is situated at the mountain base near a rural road. The light zone is covered with poultry excrement, as the cave was previously used for livestock shelter. The cave bottom consists of relatively flat loess that gradually narrows inward. Temperature measurements show 19°C at the entrance, 17°C in the middle section, and 15°C in the deepest part. Due to extensive subterranean river coverage and large areas of *Urtica fissa* distribution, the maximum detectable depth is 62 m, where the underground river nearly covers the entire cave floor, preventing further investigation. The water flow is slow.

2.2 Xia Cave

Xia Cave is located at 28°08 N, 108°48 E, approximately 400 m from Da Cave. The entrance is semicircular, 10 m wide, with farmland nearby. The entrance is covered with herbs, shrubs, and small palms. The light zone extends leftward and slopes downward in a stepped pattern, forming small puddles. The upper level is about 167 m long, 28 m wide, with a temperature of 18°C. The lower level is canyon-shaped, continuing inward with a detectable distance of 40 m and a vertical drop of 13 m between levels. The dark zone temperature is lower at 14°C. The cave walls and ceiling are uneven, with wet, soft soil on the bottom containing gravel, suggesting a former underground river channel.

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3. Methods

3.1 Environmental Survey

Prior to field collection, we measured cave entrance width, height, and light zone lengths using an LDM-70 infrared laser rangefinder (华盛昌公司). Elevation was determined with an eTrex Venture GPS (北京亚光仪器有限责任公司). Temperature and humidity in each cave section were measured using thermo-hygrometers. Portable CO and O detectors (LB-MS4X, 青岛陆博建业环保科技有限公司) were used for gas detection, and illumination was measured with a TES-1339R luxmeter (泰仕电子公司). Light zone classification followed Li Daohong [13].

Animal collection was conducted at the bottom and walls of each light zone. Due to high cave ceilings, only larger chordate animals visible to the naked eye were collected from ceiling areas and preserved in bottles with ethanol. Water samples were collected in bottles (1000 mL each) from each light zone. Soil samples were collected using five-point composite sampling at the bottom of each light zone, with approximately 0.5 kg per bag. Wet soil samples were dried before analysis.

3.2 Sample Processing

Specimens were identified and classified using an OLYMPUS SZ51 dissecting microscope. Heavy metal content in water and soil samples was analyzed following Li Daohong et al. [17]. Mercury (Hg) and arsenic (As) were measured using an AF-640 atomic fluorescence spectrophotometer, while other heavy metals were analyzed by flame atomic absorption spectroscopy (JWSA2-2).

3.3 Data Processing

Community diversity indices were calculated following Li Daohong et al. [14]:

- **Margalef richness index**: D = (S - 1) / ln(N), where S is species number and N is total individuals

- **Shannon-Wiener diversity index**: $H = -\Sigma(P \times \ln(P))$, where P is the proportion of individuals of species i
- **Pielou evenness index**: $J = H / \ln(S)$
- **Simpson dominance index**: $C = \Sigma(n /N)^2$, where n is individuals of species i
- **Whittaker similarity index**: $= |a - b| / (a + b)$, where a and b are individuals of species i in communities a and b

Soil heavy metal pollution was evaluated using the Müller geoaccumulation index [19]: $Igeo = \log[C / (K \times B)]$, where C is measured content, B is background value, and K is a correction factor (typically 1.5). Classification standards are shown in .

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4. Results

4.1 Species Composition and Relative Abundance

Investigation of Da and Xia caves revealed that both had the highest species diversity in the light zone, followed by the dark zone, with the weakest light zone having the fewest species. Da Cave yielded more total captures than Xia Cave, likely because its more open structure and underground river provided more diverse food sources [20].

Dominant species in Da Cave were *Glyphiulus valgatus* (30.45% of total captures) and *Kronopolites svenhedini* (33.03%). Common species included *Ougesia japonica* (6.36%). In Xia Cave, dominant species were *Glyphiulus valgatus* (46.74%), *Podoglyphiulus sinensis* (6.52%), and *Porcellio scaber* (8.47%, 9.28%). The complete species list is provided in .

4.2 Community Diversity Analysis

Six communities (A-F) were identified based on animal numbers, distribution, and environmental factors. Diversity indices are presented in . Communities with more species showed higher richness indices, consistent with previous research [10-12]. Community D (19 species) and Community A (16 species) had the highest richness indices (3.2918 and 2.5721, respectively).

Dominance ranking was: F (0.6349) > C (0.4412) > E (0.4376) > A (0.4279) > B (0.3400) > D (0.1037). Community F, located in Xia Cave' s dark zone, formed the largest *Glyphiulus valgatus* population, likely due to abundant microbial food sources in sediment deposits from previous water flow [20,21].

Diversity index ranking was: D (2.4745) > C (1.4036) > A (1.3549) > B (1.1935) > E (1.1384) > F (0.7265). This inverse relationship between diversity and dominance indices aligns with Li Daohong' s findings [14].

4.3 Community Similarity Analysis

Similarity indices between communities are shown in . Adjacent light zones within the same cave showed high similarity (A-B: 0.7239; C-E: 0.6684), consistent with ecological theory [6,18]. However, similarity was lowest between adjacent communities A (Da Cave light zone) and B (Da Cave weak light zone) due to severe human disturbance (livestock excrement, garbage) in the light zone, which reduced species numbers [22].

Interestingly, different caves showed high similarity between corresponding light zones (C-F: 0.6786; A-D: 0.6684), likely because similar environmental conditions (rock spires with cyanobacterial communities) supported similar food webs, attracting species with similar feeding habits [24,25].

4.4 Environmental Factor Measurements and Correlation Analysis

Environmental factor measurements for each community are presented in . After standardization, Pearson correlation analysis was performed using SPSS 17.0.

Da Cave correlations (): Soil As and Mn showed significant positive correlations with species richness (P = 0.044 and 0.039, respectively). As correlated positively with dominance, while Mn correlated negatively with diversity. This may relate to As’ s role in plant physiology and photosynthesis, providing food resources that concentrate animals in the light zone.

Xia Cave correlations (): Water As and Mn showed significant positive correlations with species richness (P = 0.039, 0.029) and negative correlations with diversity. Temperature was the primary factor affecting distribution, showing extremely significant positive correlations with species number and diversity (P = 0.002). Lower temperatures in Xia Cave caused some animals to migrate toward light or weak light zones [26].

4.5 Heavy Metal Pollution Assessment

Soil pollution (): Using national soil environmental quality standards and background values from the *Atlas of Soil Environmental Background Values in the People’ s Republic of China*, both caves showed only light to moderate heavy metal pollution. Despite proximity to the manganese mining area, pollution levels were not severe, likely because: (1) the caves originate from different geological formations (Da Cave from Cambrian black rock series, Xia Cave from Cambrian strata) [15,27], and (2) heavy metals exist primarily in carbonate-bound forms with low bioavailability [16].

Water pollution (): According to the *Groundwater Environmental Quality Standard (GB/T14848-93)*, both caves showed minimal water pollution, with only Hg reaching high pollution levels. The low water pollution may be attributed to the strong adsorption capacity of the common loess soil in the area, which increases with temperature [28].

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5. Discussion and Conclusion

This investigation of Da and Xia caves near a manganese mining area revealed several key findings:

1. **Community Structure**: Both caves showed highest species diversity in light zones. Human disturbance (livestock sheltering) significantly reduced similarity between adjacent zones in Da Cave, demonstrating the ecological sensitivity and vulnerability of karst cave ecosystems [20,23].
2. **Heavy Metal Effects**: Correlations between heavy metals and community diversity differed between caves. In Da Cave, soil As and Mn correlated with diversity indices, while in Xia Cave, water As and Mn showed stronger relationships. This suggests that bioavailable heavy metals, rather than total content, primarily affect cave animal communities [14].
3. **Temperature Influence**: Temperature emerged as the dominant factor affecting animal distribution in Xia Cave, with significant correlations with both species number and diversity. Seasonal temperature fluctuations likely drive vertical migration patterns within caves [26].
4. **Pollution Status**: Soil heavy metal pollution reached only light to moderate levels, with Hg being the exception at high pollution levels. Water pollution remained minimal, suitable for use as centralized drinking water sources. The geological origin of heavy metals (native parent rock) and their chemical speciation (carbonate-bound, residual forms) limited their bioavailability and toxicity [10,16].
5. **Cross-Cave Similarities**: High similarity between corresponding light zones in different caves (C-F, A-D) suggests that similar environmental conditions generate similar food resources (cyanobacterial communities on rock spires), which in turn support similar animal communities [24,25].

This study provides preliminary insights into heavy metal pollution effects on cave animal communities in manganese mining areas. However, comprehensive heavy metal tracing investigations are needed to fully understand the impacts on entire cave ecosystems. Future research should focus on heavy metal speciation, bioaccumulation pathways, and long-term monitoring of community responses to mining activities.

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Note: Figure translations are in progress. See original paper for figures.