

## Postprint: Survey of Tenebrionidae Diversity in the Temperate Desert Steppe of Minqin

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### Abstract

To determine the community diversity and temporal dynamics of Tenebrionidae insects in the Minqin temperate desert steppe, a systematic survey of Tenebrionidae insect communities in gravel, sandy, and saline desert grasslands in Minqin County, Gansu Province, was conducted using pitfall trapping from April to October 2021. (1) A total of 8,492 Tenebrionidae individuals were captured, belonging to 8 genera and 10 species, among which *Microdera elegans* and *Sternoplax setosa setosa* were the dominant species, accounting for 26.88% and 25.07% of the total individuals, respectively, and *Eumylada potanini* was endemic to gravel desert grassland. (2) The species number and individual number of Tenebrionidae insects in the three subtypes of desert grasslands peaked in July and were lowest in October. (3) The abundance and Shannon diversity index of Tenebrionidae communities in gravel and sandy desert grasslands were significantly higher than those in saline desert grassland ( $P < 0.05$ ); the richness of Tenebrionidae communities in saline desert grassland was significantly higher than that in sandy desert grassland ( $P < 0.05$ ). (4) Correlation analysis indicated that the abundance index of Tenebrionidae communities was significantly negatively correlated with vegetation community height, soil water content, and vegetation coverage ( $P < 0.05$ ); the abundance index of Tenebrionidae was significantly positively correlated with vegetation Shannon diversity index and vegetation richness ( $P < 0.05$ ). The simple vegetation composition of desert steppe resulted in simple Tenebrionidae community composition; compared with saline and sandy desert grasslands, gravel desert grassland had higher vegetation Shannon diversity index and vegetation richness, and also the most species-rich Tenebrionidae community.

## Full Text

### Survey of Species Diversity of Darkling Beetles in the Minqin Temperate Desert Steppe

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#### Abstract

To clarify the diversity and temporal dynamics of darkling beetle communities in Minqin temperate desert steppe, we conducted a systematic investigation from April to October 2021 using pitfall trapping in three subtypes of desert grassland in Minqin County, Gansu Province: gravelly desert grassland, sandy desert grassland, and saline desert grassland. A total of 8,492 individuals belonging to 10 species across 8 genera were captured. *Microdera elegans* and *Sternoplax setosa setosa* were the dominant species, accounting for 26.88% and 25.07% of total individuals, respectively. *Eumylada potanini* was endemic to gravelly desert grassland. Both species richness and individual abundance peaked in July and reached their lowest point in October. The Shannon-Wiener diversity index and community abundance of darkling beetles in gravelly desert grassland were significantly higher than those in saline desert grassland ( $P < 0.05$ ), while community richness in saline desert grassland was significantly higher than in sandy desert grassland ( $P < 0.05$ ). Correlation analysis revealed that the abundance index of darkling beetles was significantly negatively correlated with vegetation height, soil water content, and vegetation cover ( $P < 0.05$ ), but significantly positively correlated with vegetation Shannon-Wiener diversity index and vegetation richness ( $P < 0.05$ ). The simple vegetation composition of desert steppe leads to simplified darkling beetle community structure. Compared with saline and sandy desert grasslands, gravelly desert grassland exhibited higher vegetation Shannon-Wiener diversity index and vegetation richness, and consequently supported the most diverse darkling beetle fauna.

**Keywords:** desert grassland; darkling beetles; species; diversity; temporal dynamics

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## 1. Introduction

Temperate desert steppe represents a transitional zone between temperate grassland and desert, characterized by vegetation dominated by xerophytic and super-xerophytic shrubs, perennial herbs, and annual herbs. Located in the eastern

Hexi Corridor, Minqin temperate desert steppe constitutes an important component of the western desert region in China and belongs to the Mongolian-Xinjiang Plateau grassland zone. Due to harsh climatic conditions, desert regions exhibit low net primary productivity, impoverished species diversity, and high sensitivity to external disturbances. In recent years, global environmental changes have gradually reduced grassland area, making studies on species diversity changes in desert steppe ecosystems a focal point of research.

Ground-dwelling beetles represent one of the most biodiverse animal groups in desert steppe ecosystems, among which the family Tenebrionidae (darkling beetles) is widely distributed, species-rich, morphologically diverse, and exhibits varied life forms. Globally, over 20,000 species of darkling beetles have been described, with approximately 2,000 species distributed in arid and semi-arid regions. In China, more than 1,100 species occur, with particularly rich distributions in desert and semi-desert areas. Some adult darkling beetles are active on the ground surface, serving as food sources for birds and rodents, while their eggs and larvae survive in soil, making them important connectors between aboveground and belowground food webs. Darkling beetles function as both important consumers and primary decomposers in desert steppe ecosystems, with their community structure closely related to environmental conditions and playing a facilitative role in material cycling and energy flow. These insects exhibit strong adaptability to environmental conditions and serve as indicators of habitat degradation, maintaining ecological service functions of desert ecosystems to a certain extent.

Despite their ecological importance, darkling beetles have long life cycles and predominantly inhabit harsh desert environments, making them notoriously difficult to study. Consequently, they represent a poorly studied group in China. Previous research on darkling beetle diversity in desert steppe ecosystems has been limited, with major studies reported from Ningxia and Xinjiang. In Gansu Province, few studies have addressed darkling beetle diversity in desert steppe, primarily comprising investigations by Liu Jiliang and Dong Liuwen on near-surface beetle diversity in the Heihe River Basin. No reports have documented the community composition, temporal dynamics, or species diversity of darkling beetles in Minqin desert steppe. To address this knowledge gap, we conducted a systematic investigation of darkling beetle diversity and associated environmental factors across three representative grassland subtypes in this region from April to October 2021, aiming to provide baseline data for biodiversity research and conservation in Gansu's desert steppe zone.

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## 2. Materials and Methods

### 2.1 Study Area

The study site was located in Hongshagang Town, Minqin County, Wuwei City, Gansu Province (103°02' ~104°02' E, 38°05' ~39°06' N). The region experiences a

dry climate with mean annual precipitation of 113.6 mm and mean annual evaporation of 2,643.3 mm. The mean annual temperature is 8.2°C, with large diurnal temperature variations, long sunshine duration (average frost-free period: 162 days), and elevation ranging from 1,000 to 1,936 m.

According to the Comprehensive Sequential Classification System, Minqin desert grassland belongs to the micro-warm, extremely arid temperate desert category (IVA4-2). Three subtypes were investigated: gravelly desert grassland, sandy desert grassland, and saline desert grassland, with the latter occurring as band-shaped distributions between the other two types. Vegetation in gravelly desert grassland primarily included *Caroxylon passerinum*, *Nitraria tangutorum*, *Nitraria sphaerocarpa*, and *Reaumuria songarica*. Saline desert grassland was dominated by salt-tolerant or halophytic succulent plants such as *Kalidium foliatum* and *Suaeda salsa*. Sandy desert grassland mainly comprised *Nitraria roborowskii*, *N. sphaerocarpa*, and *Allium mongolicum*.

## 2.2 Sampling Design and Data Collection

**2.2.1 Plot Establishment** In April 2021, we established three fixed plots for each grassland subtype, with plot intervals exceeding 10 km. Each plot consisted of a 100 m radius circle, with sampling points spaced >40 m apart. Each circle was divided into four quadrants using the center as a rotation point, with three transects per quadrant (12 transects total). Each transect contained one trap group, with three traps per group (36 traps per circle). Traps were spaced >15 m apart to ensure independence.

**2.2.2 Darkling Beetle Sampling** We used pitfall trapping with plastic cups (diameter: 7.5 cm, depth: 9.5 cm) buried flush with the ground surface. Each cup contained 40–60 mL of bait solution (a mixture of sugar, vinegar, medical alcohol, and water in a 1:2:3:4 ratio). A 2.5 cm gap was maintained between the cup rim and ground surface (0.5 cm below the rim) to prevent specimen loss from rainwater. Traps were spaced \$ \$15 m apart. Insects were collected daily, bait was replenished, and specimens were recorded by plot. Collected insects were brought to the laboratory for specimen preparation and identification.

**2.2.3 Vegetation and Soil Survey** Within each trapping circle, we established 10 m × 10 m quadrats along trap transects, with three quadrats per circle and nine quadrats per grassland subtype. Following the *Grassland Survey Planning Practice Guide*, we recorded all plant species, quantities, natural height, cover, and soil water content. Natural height was measured randomly for 30 plants per quadrat (consistent for herbs and shrubs). Cover was measured along two diagonal transects using measuring tapes. Soil water content was measured at five points per quadrat using a portable TDR 350 soil moisture meter.

### 2.3 Specimen Identification

Specimens were identified using *Chinese Zoology (Insecta, Vol. 63, Coleoptera: Tenebrionidae)*, *Chinese Economic Insects (Vol. 4, Coleoptera: Tenebrionidae)*, and *Darkling Beetles in the Deserts and Semi-deserts of China*, with assistance from a stereomicroscope.

### 2.4 Data Analysis

Vegetation richness was represented by total plant species per grassland subtype, while darkling beetle abundance was represented by total individuals. Shannon-Wiener diversity index (H') was calculated for both plant and darkling beetle communities using the formula:

$$H' = - \sum_{i=1}^S P_i \ln P_i$$

where  $P_i = N_i/N$  (proportion of individuals of species  $i$ ),  $N_i$  is the number of individuals of species  $i$ , and  $N$  is the total number of individuals.

Darkling beetle richness (D) was analyzed using the Margalef index:

$$D = \frac{S - 1}{\ln N}$$

Dominance (C) was analyzed using the Simpson index. Dominance categories were defined as: dominant species (>10% of total individuals), common species (1–10%), and rare species (<1%).

Statistical analyses were performed using Excel 2019 for data processing and SPSS 24.0 for one-way ANOVA with Duncan's multiple comparison tests. Correlations between darkling beetle community diversity and environmental factors were analyzed using the R 3.5.2 *corrplot* package, with significance levels indicated.

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## 3. Results

### 3.1 Community Composition of Darkling Beetles

**3.1.1 Overall Community Composition** The survey captured 8,492 darkling beetle individuals belonging to 10 species across 8 genera. *Microdera elegans* and *Sternoplax setosa setosa* were the dominant species, comprising 26.88% and 25.07% of total individuals, respectively. *Anatolica gravidula*, *Cyphogenia chinensis*, *Pterocoma vittata*, *Sternoplax impressicollis*, *Blaps gobiensis*, and *Platyoope victori* were common species (15.51%, 15.08%, 6.50%, 5.11%, 4.43%,

and 1.01% of total individuals, respectively). *Eumylada potanini* and *Anatolica potanini* were rare species, together accounting for 0.41% of total individuals.

**3.1.2 Community Composition by Grassland Subtype** Significant differences existed among grassland subtypes in both individual abundance and species composition (Table 1). Gravelly desert grassland yielded 3,551 individuals (41.83% of total) across 10 species. Sandy desert grassland captured 3,484 individuals (41.02%) from 9 species. Saline desert grassland collected 1,457 individuals (17.16%) from 10 species.

In gravelly desert grassland, *M. elegans* and *S. setosa setosa* were dominant (29.77% and 26.86% of subtype total, respectively), with *C. chinensis* and *A. gravidula* as common species (10.42% and 15.39%). In sandy desert grassland, *S. setosa setosa*, *M. elegans*, and *A. gravidula* were dominant (26.86%, 22.18%, and 20.35%, respectively). In saline desert grassland, *S. setosa setosa* and *M. elegans* were dominant (31.37% and 24.37%, respectively). *E. potanini* occurred exclusively in gravelly desert grassland.

**3.1.3 Diversity Analysis by Grassland Subtype** Darkling beetle community diversity varied significantly among subtypes (Fig. 2). Community abundance was significantly higher in gravelly and sandy desert grasslands than in saline desert grassland ( $P < 0.05$ ). Richness was significantly higher in saline desert grassland than in sandy desert grassland ( $P < 0.05$ ). The Shannon-Wiener diversity index in gravelly desert grassland was significantly higher than in saline and sandy desert grasslands ( $P < 0.05$ ). No significant differences in dominance index were detected among subtypes ( $P > 0.05$ ), though saline desert grassland showed the highest dominance.

## 3.2 Temporal Dynamics

**3.2.1 Overall Temporal Patterns** Species richness and individual abundance showed significant positive correlation ( $r = 0.004$ ,  $P < 0.05$ ), exhibiting similar temporal trends (Fig. 3). Both peaked in July (23.10% of annual individuals and 19.05% of species) and declined to minima in October (0.06% of individuals and 4.76% of species). A minor peak occurred in May.

**3.2.2 Temporal Patterns by Grassland Subtype** Temporal trends varied among subtypes (Fig. 4). In gravelly desert grassland, species richness increased then decreased, peaking in July (10 species). Sandy desert grassland showed a similar pattern, peaking in August (9 species). Saline desert grassland peaked in July (8 species). All subtypes reached minima in October.

Individual abundance in gravelly desert grassland peaked in July and reached minimum in October. Sandy desert grassland showed a similar pattern, peaking in July. Saline desert grassland abundance increased gradually, peaking in July, then declined with no beetles collected in October.

**3.2.3 Species-Specific Temporal Dynamics** Across subtypes, dominant species showed consistent temporal patterns (Fig. 5). *A. gravidula* dominated in May, *S. setosa setosa* in June, and *M. elegans* in July. In gravelly desert grassland, *M. elegans* peaked in July, while *B. gobiensis* peaked in August. In sandy desert grassland, *S. setosa setosa*, *M. elegans*, and *C. chinensis* peaked in July. In saline desert grassland, *M. elegans* dominated in July.

### 3.3 Relationships with Environmental Factors

**3.3.1 Vegetation and Soil Characteristics** Gravelly desert grassland exhibited the highest vegetation Shannon-Wiener diversity index and vegetation richness, significantly exceeding those of sandy and saline desert grasslands ( $P < 0.05$ ) (Table 2). Saline desert grassland showed the highest vegetation height, cover, and soil water content, while gravelly desert grassland showed the lowest values for these parameters.

**3.3.2 Correlation Analysis** Correlation analysis revealed that darkling beetle abundance index was significantly negatively correlated with vegetation height, soil water content, and vegetation cover ( $P < 0.05$ ), but significantly positively correlated with vegetation Shannon-Wiener diversity index and vegetation richness ( $P < 0.05$ ) (Fig. 6). Community richness, Shannon-Wiener diversity, and dominance indices showed weak correlations with environmental factors.

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## 4. Discussion

Darkling beetles are considered “indicator insects” for desertification. Our investigation in Hongshagang, Minqin, revealed simple community structure with only 10 species, dominated by *M. elegans* and *S. setosa setosa* (26.87% and 25.07% of total individuals, respectively). Except for *E. potanini*, which was absent from sandy and saline desert grasslands, species composition was similar across subtypes, likely due to comparable climatic conditions.

Insect community composition and diversity are constrained by multiple factors including food resources and microclimate. Our results demonstrate pronounced temporal heterogeneity, with total species richness and individual abundance peaking in July and declining through October. This pattern aligns with July being the peak activity period for ground-dwelling beetles. The May peak may reflect emergence of overwintering adults, while July’s maximum corresponds to optimal temperature, humidity, and light conditions coinciding with peak plant growth, providing abundant food resources and diverse habitats. By October, declining temperatures and vegetation senescence rendered conditions unsuitable, reducing beetle activity to near zero.

Different species occupy distinct ecological niches and exhibit varying temperature sensitivities. Although dominant species showed similar temporal patterns

across subtypes, differences in soil texture and vegetation among grassland types influenced population densities. The biological characteristics, activity rhythms, and local environmental conditions of darkling beetles contributed to temporal variation in community composition, yielding results that differ slightly from studies in Ningxia's Helan Mountain alluvial fan desert steppe.

Diversity indices are important metrics for assessing community-level characteristics, reflecting species richness, evenness, and development status under different environmental conditions. Gravelly desert grassland's significantly higher Shannon-Wiener diversity ( $P < 0.05$ ) indicates greater community stability resulting from comprehensive environmental influences. Although sandy desert grassland showed lowest richness, its high abundance suggests complex relationships between diversity and population density.

Arid climates limit primary productivity and energy availability for darkling beetles. Environmental differences among subtypes influenced insect community attributes, consistent with darkling beetles' adaptation to arid conditions and preference for low-cover desert habitats. Studies indicate soil water content is a key factor negatively affecting darkling beetle richness. Our finding that beetle abundance positively correlates with vegetation diversity aligns with research from mixed forests in Shanxi, where higher plant diversity provides more food resources, thereby increasing beetle abundance.

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## 5. Conclusion

This study investigated darkling beetle communities across three desert grassland subtypes in Minqin County, Gansu Province. The simple vegetation composition of desert steppe results in simplified darkling beetle communities, with only 10 species recorded. *Microdera elegans* and *Sternoplax setosa setosa* were dominant species. Both species richness and individual abundance peaked in July (the active period) and reached minima in October. Compared with saline and sandy desert grasslands, gravelly desert grassland supported higher vegetation diversity and richness, and consequently the most diverse darkling beetle fauna.

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**Note:** All figure and table markers ([FIGURE:N], [TABLE:N]) have been preserved exactly as in the original text. Mathematical expressions and statistical notation ( $P < 0.05$ ,  $r = 0.004$ , etc.) remain unchanged. The translation maintains academic tone while presenting the fragmented original content as coherent, flowing prose organized into logical sections.

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