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Original article

# Coleoptera in the Altai Mountains (Mongolia): species richness and community patterns along an ecological gradient

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A B S T R A C T

The Altai Mountains located in western Mongolia comprise diverse habitats including forest, mountain steppe, dry steppe, semidesert, and desert. This study used advanced statistics to examine how diversity and species composition of beetle communities depend on vegetation pattern and environmental factors along an ecological gradient from steppe to desert. Our study included the beetle families Tenebrionidae, Carabidae, Curculionidae, and Coccinellidae, which account for the majority of the known beetle fauna in the area. The most abundant Coleoptera in all plots were *Harpalus limbaris*, *Corsyra fusula*, and *Anatolica cellicola*; otherwise, we caught a large number of rare species. The beta diversity of communities was correlated with distance between plots. Species richness of beetles was positively impacted by plant cover and correlated negatively with rising temperatures, whereas Shannon diversity of beetle communities was significantly higher in areas with higher precipitation. Distribution and community composition of Coleopterans were governed by environmental factors, especially plant diversity, mean annual temperature, and summer precipitation, as revealed by redundancy analysis.



## Introduction

Quantification of spatiotemporal patterns of species' distributions and their causal link to abiotic and biotic environmental variables is important for understanding community structure and the mechanisms regulating the structure (Menge and Olson 1990). Ecological gradients are measures of the physical environment that explain the distribution of organisms and ecosystems in terms of environmental tolerances (Clayden 2007); therefore, gradient analysis can be a good explanation of community pattern with the concept of the ecological niche (Chase and Leibold 2003). Many ecological gradients can be detected by observing vegetation differences that are visible at fairly broad geographic scales (Clayden 2007); for example, Pfeiffer et al (2003) demonstrated the correlation of ant and plant community pattern along a 1,000-km gradient from steppe to desert in Mongolia. Steep ecological gradients can be found at mountain ranges, where climate and vegetation changes with altitude within short distance, making them feasible sites to compare community patterns at medium range. Moreover, high mountains are often important centers of origin and differentiation for distinctive ecosystems and fauna (Mani 1968; Bharti et al 2013), thus adding phylogenetic and faunistic understanding to community studies.

The Mongolian Altai Mountains are a complex mountain system of Central Asia extending approximately 2,000 km in a southeast–northwest direction from Gobi Desert to the West Siberian Plain (Mikhaylov and Owen 2015). Within the 16 phytogeographical regions of Mongolia, the Altai Mountains have the second highest species richness of plants (Ariuntsetseg and Boldgiv 2009), which may support a high invertebrate species richness. Vegetation zonation in the Altai region is characterized by a wide distribution of steppes on the slopes in all directions, whereas isolated fragments of steppe–deserts occur at the valley bottom (Ogureeva et al 2013).

Beetles are good indicators of ecological changes (Lee et al 2012, 2014) and exhibit particular adaptations to arid habitats (Chelazzi and Colombini 1989; Pfeiffer and Bayannasan 2012; Fattorini and Salvati 2014), with their communities varying with microclimate, soil character, and vegetation type. Thanks to this adaptability, beetles occur in niches throughout all ecosystems, such as in soil, roots of plants, inside of the plant stem and bark, below rocks, as well as in wood and water (Tsendsuren and Ulykpan 1979). Many

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species of beetle are closely associated with certain flowering plants, as larvae and adults feed on parts of the plant or on other insects or fungi associated with particular plant species (Cooter 1991). Beetles also play an important role in ecosystem functioning by loosening and mixing soil to provide conditions for plant growth (Ulykpan and Aibek 2010), and accelerate the nutrient cycle by redistributing dung, carrion, and leaf litter for decomposition (Danzan et al 1989).

Numerous studies of Coleoptera have been performed in Mongolia. The earlier studies mainly focused on species determination. In Mongolia, Tenebrionidae comprised 164 species (Medvedev 1990); Carabidae, 260 species (Tsendsuren and Ulykpan 1979); and Curculionidae, about 200 species (Ter-Minisyan and Medvedev 1975; Korotyaev 1979); meanwhile, in the Coccinellidae, 53 species of 22 genera were recorded (Tsendsuren and Ulykpan 1979; Bielawski 1984). Recently, several ecological studies on the region's beetle fauna have been conducted. Dudko et al (2010) studied the Carabidae of the Russian Southwestern Altai Mountains, whereas Pfeiffer and Bayannasan (2012) and Paknia et al (2013) explored diversity patterns and ecological niches of Mongolian Tenebrionidae. Beetles of these two families have been reviewed by Dorj (2013) in the vicinity of the Mongolian great lakes depression, where they are indicators of soil character and vegetation patterns. In spite of these efforts, there is still a lack of information about beetle ecology in Western Mongolia.

In this study, we examined how diversity of beetle communities depends on vegetation pattern and environmental factors along a gradient from steppe to desert in Mongolian Altai Mountains. Our study sites covered three different ecological habitats: steppe, desert steppe, and desert. Plant communities and their dominant species changed gradually from steppe to desert plots: *Festuca*–*Artemisia* and *Chenopodium*–*Bassia* communities changed to *Phragmites*–*Kalidium* communities. Geographically, the sites were patchily distributed with steppes mainly found at higher altitudes (2,494–2,856 m), whereas deserts and semideserts were located in the lowlands (1,238–1,920 m).

What is the spatial distribution of beetle species in different ecological zones of this region? How do vegetation type, climate, altitude, and latitude influence beetle biodiversity, including species richness, diversity, and abundance? These questions we wanted to answer in our study. In detail, the following objectives were chosen:

1. Determination of Coleoptera species richness and abundance
2. Estimation of plant diversity and productivity, in order to compare it to soil beetle diversity and distribution in each plot along the gradient
3. Evaluation of different habitat conditions and environmental factors (latitude, mean yearly and mean summer temperature and precipitation) at the study sites, with a special focus on their impact on beetle species distribution

## Materials and methods

### *Study site position*

The Altai Mountains northeastern part is linked to the Sayan Mountains ecological region, and the southeastern part extends into the Gobi-Altai region (Klinge et al 2003). The Altai region's climate is severely continental: because of the influence of the great Asiatic anticyclone, or high-pressure area, the winter is long and cold (Mikhaylov and Owen 2015). Our study sites comprised two provinces of Mongolia: Gobi-Altai and Khovd. The climate in Gobi-Altai is highly variable. In the alpine zone, average air temperature is +20°C in July, dropping to −20°C in January. Average annual precipitation in Gobi-Altai is 80–135 mm, with mountain areas having a colder and wetter climate. More northern Khovd has a continental cold desert climate with long, dry, freezing winters and short warm summers; average temperature is −24.3°C in January and +16.5°C in July, and average precipitation is 120–140 mm, with rainfalls heavily concentrated in summer (Oyuntuya 1976).

We used satellite data from National Oceanic and Atmospheric Administration-Earth System Research Laboratory Physical Sciences Division, Boulder Colorado (from their web site, http://www.esrl.noaa.gov/psd/) to extract long-term monthly means of temperature and precipitation for our study plots for an approximate 30-year period between 1981 and 2010. The high-resolution land database gridded 0.5° latitude × 0.5° longitude was taken for analysis (Willmott and Matsuura 2015). We applied QGis 2.8.1 program to read out climate NetCDF data according to Gregory (2014). Q2 For our plots, we extracted average annual temperature, average temperature during summer months, average annual precipitation, and average precipitation in summer months.

Mongolia can be classified into six ecological zones that generally follow the north to south elevation gradient, including alpine, mountain taiga (forest), forest steppe, steppe, desert steppe, and desert zones (Angerer et al 2008). The extensive grasslands of the central Asian steppe dominate the central and eastern parts of Altai Mountains. From north to south, Altai Mountains gradually changes from mountain forest steppe and meadow steppe to dry steppe (grass steppe), desert steppe (semidesert) to desert (Hilbig 2007). Therefore, we selected study sites along a gradient of vegetation and altitude between 2,856 m (Plot 1—Sutai Mountain, steppe) and 1,238 m (Plot 7—Tohom, desert; Table 1). Sampling beetles along altitudinal gradients is a proven method to assess the niche differences of species (Fidan and Sirin 2016). Q3 We took samples from two Mongolian provinces in the Altai Mountain region, Gobi-Altai aimag and Khovd aimag. In total, seven plots of diverse habitats were chosen (Figure 1), which differed in altitude and vegetation cover (Table 1, Figures 2A–G):

1. Sutai Mountain—high-altitude steppe site at the foot of snow-capped Sutai Mountain in Gobi-Altai province. The dominant plant species were *Artemisia frigida* Willd. and *Festuca lenensis* Drob.
2. Dulanhan—remote steppe site in Gobi-Altai province dominated by plant species *Caragana korshinskii* Kom. and *Artemisia palustris* L.
3. Gurvan Tsenkher—desert steppe overgrazed area in Khovd province dominated by *Potentilla* sp. and *Bassia dasiphylla* (Fisch. et Mey).
4. Dund Tsenkher river—desert steppe at a rocky mountain site in Khovd province with high plant diversity, dominated by *Chenopodium acuminatum* Wiild and *Bassia dasiphylla* (Fisch. et Mey).
5. Manhan—semidesert site the center of Khovd province dominated by *Anabasis brevifolia* C.A. Mey., *Stipa glareosa* P. Smirn., and *Eragrostis minor* L.
6. Sharga Gobi oasis—desert site in Gobi-Altai province with relatively richer flora than the surrounding sandy area. Dominated by *Phragmites communis* Trin., *Kalidium* sp. Moq. and *Achnatherum splendens* Trin.
7. Tohom—desert area outside the Sharga Gobi site with stony terrain and sparse coverage of *Ephedra equisetina* Bunge and *Kalidium* sp. Moq.

### *Data collection*

Our study was conducted in July and August in 2013. At the seven study sites, beetles were collected with pitfall traps, a proven