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Changes in ground-dwelling arthropod diversity related to the proximity of shrub cover in a desertified system

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A B S T R A C T

Shrub patchiness generates spatial heterogeneity across a range of scales. Little is known about shrub-patch effects on ground-dwelling arthropod diversity on small spatial scales. Using pitfall trapping, ground-dwelling arthropods were collected at three microsites (beneath and on the shrub-canopy periphery, and in open spaces) during spring, summer, and autumn, in a desertified steppe ecosystem of northwestern China. Along with distance from shrub cover, the abundance of dominant groups, including Carabidae, Tenebrionidae, and Glaphyridae families, tended to decrease and was remarkably affected by seasonality, in contrast to the abundance distribution pattern of the dominant Melolonthidae, Curculionidae, and Formicidae families. The distribution pattern of total abundance, group richness, and Fisher's α index among the microsites was also found to be affected by seasonality. Together, the abundance distribution of different dominant taxa was found to indicate distinctive responses to the microsite and seasonal variability. The distribution pattern of the ground-dwelling arthropod community among the microsites could change along with seasonality, though high diversity was found to be maintained beneath the shrub cover. This study elucidated the importance of plant-cover functions as 'keystone structures', providing heterogeneous microsite – soil arthropod relationships that altered in time and space in xeric environments.

1. Introduction

In desertified regions, the crucial role of shrubs in preventing desertification processes has been widely recognized by Maestre and Cortina (2005) and Zhao et al. (2007). The patchy distribution of perennial shrubs and shrub hummocks has been found to generate spatial heterogeneity (i.e., different microhabitats) by creating "fertile islands" (Berg and Steinberger, 2008) and "hot spots" that act as "biological hubs" in a low-nutrient matrix, with important consequences on arid land dynamics (Garner and Steinberger, 1989; Liu et al., 2011). Habitat spatial heterogeneity is well-recognized to be an important contributor to the coexistence of species in communities (Tilman and Pacala, 1993) and to population persistence (Ellner et al., 2001). According to Wiens et al. (1997), Kinnunen et al. (2001), Yaacobi et al. (2007), and Barton et al. (2009), the scale at which diverse arthropod species respond to the microhabitats depends on how they communicate with their environments. However, the complexity of such a bidirectional interaction between shrub patches and arthropod communities on a space scale is largely unknown in a desertified steppe ecosystem.

It is well understood that small organisms, including above- and below-ground arthropods, will generally respond to their environments on a small scale. Several studies have demonstrated this for the arthropod (i.e., beetles) assemblages over distances ranging up to 10 m (Antvogel and Bonn, 2001; Holland et al., 2005; Mazía et al., 2006). On such a small scale, i.e., within the given locality, the mobility of organisms was dictated behaviorally by the patchy microhabitats and by the non-random use of different patch types, relative to their availability (Addicott et al., 1987). Antvogel and Bonn (2001) and Groner and Ayal (2001) suggested that various (above- and below-ground) arthropods were preferentially monitored in densely vegetated patches that provided shelter, food resources, oviposition microsites, or refuge against predators, whereas the others might avoid such habitats because of increased predation risk (Jeffries and Lawton, 1984; Schmitz, 1998) and

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specific needs for living conditions in sparse patches (Liu et al., 2011). According to Tews et al. (2004), a better knowledge of microhabitat utilization by arthropods can enhance our understanding of community assembly, where the use of biodiversity conservation and land management on small scales is needed. So far, relatively little information has been accumulated about how co-occurring arthropod taxa interact with plant heterogeneity on a small spatial-scale basis.

Given the lack of knowledge on local arthropod assemblages and their potential impact on soil ecosystem processes, a small-scale field study was initiated in a grassland-shrubland ecotone, e.g., beneath and on the periphery of the shrub canopy, as well as in the open spaces, on a seasonal basis throughout the year in a *Caragana koushinskii* shrub system in a desertified steppe ecosystem of northwestern China. In the 1970s, an afforestation program initiative was implemented by planting the native shrub *C. koushinskii* in order to curb desertification and alleviate the detrimental effects of the shifting-sand desertified steppe. As of today, the semi-arid sandy grassland intermingles with discrete shrub patches, forming ecotones with shrubland scattered in a grassland matrix. The shrub cover and related plantation age were found to indicate a remarkable influence on the distribution of the ground-dwelling arthropod community in this region (Liu et al., 2013). However, the extent to which mobile arthropods with taxonomical and community structure differentially use the existing shrub microhabitat mosaics on a small scale, remains unclear.

The objectives of the present study were: (i) to characterize the taxonomical composition, activity level, and diversity of arthropod communities between contrasting microsites; and (ii) to evaluate the influence of shrub cover on small-scale microhabitat selection by ground-dwelling arthropods across seasons. We predicted that: (1) there was a shrub-soil feedback relationship at short gradients that could produce the observed differences in arthropod community structure; and (2) seasonality could contribute this kind of difference in the distribution pattern of ground-dwelling arthropods among the microsites.

2. Materials and methods

2.1. Study site

The study was conducted in Yanchi County (37°04′–38°10′N and 106°30′–107°41′E), located at the southwestern fringe of Mu Us sandy land in the Ningxia Hui Autonomous Region of China (Fig. 1). The elevation ranges from 1295 to 1951 m above sea level, with an average of 1600 m from north to south. The region has a temperate, continental, semi-arid, monsoonal climate with a mean multi-annual precipitation of 289 mm; about 70% of the total precipitation occurs between June and September. Mean multi-annual potential pan-evaporation is 2014 mm per year. Mean multi-annual temperature is 8.1 °C, with lowest and highest monthly mean temperatures of −8.7 °C in January and 22.4 °C in July, respectively. Mean annual wind velocity is 2.8 m s^{-1}, and prevailing winds are mainly northwest in April and May. Sand-dust blowing at velocities over 5.0 m s^{-1} occurs at an average of 323 times per year. Wind erosion often occurs from April to mid-June, before the rainy season begins (climate data from Yanchi Meteorological Station, 1976 to 2010). In the study area, the main soil types are Sierozem, Loess, and Orthi-sandic Entisols, all of which have low fertility, loose structure, and are very susceptible to wind erosion.

Over the past decades, Yanchi County has undergone severe desertification that started in the 1950s and reached a climax in the late 1970s. This process was created mainly by human activity, including extensive fuel wood gathering and overgrazing. Today, the site is recognized as one of the main research sites for desertification studies in China. Many native plant species, including the *Caragana* shrub, were selected for long-term (i.e., nearly half a century) afforestation to stabilize the mobile sand land in this region. The *Caragana* plantations, both artificial and natural, accounted for an area of *ca.* 33.37% of the whole sandy grassland, with a mean density of 915–3015 plants per hectare. Together with gradual stabilization of the shifting sand land, some short grasses, legumes, and forb plants invaded the sites, and a stabilized shrub-grass combined vegetation system was established, forming a shrubland-grassland ecotone with discrete shrub patches within the sandy grassland. The herbaceous vegetation in the arid desertified steppe is dominated by annual (*Agriophyllum squarrosum*, *Salsola collina*, *Corispermum hyssopifolium*, and *Artemisia scoparia*), perennial (*Pennisetum centrasiaticum*, *Aneurolepidium dasystachys*, and *Cleistogenes gracilis*), and subshrub (*Artemisia ordosica* and *Lespedeza potaninii*) plant cover.

2.2. Experimental design

Three replicate sites (30 m × 30 m) at least 150 m apart from each other were established in a 10-year-old fenced shrubland-grassland ecotone (*ca.* 3 ha). At each sampling site, the sampling points were located at three microsite environs to encompass the range of microsite conditions most commonly encountered by

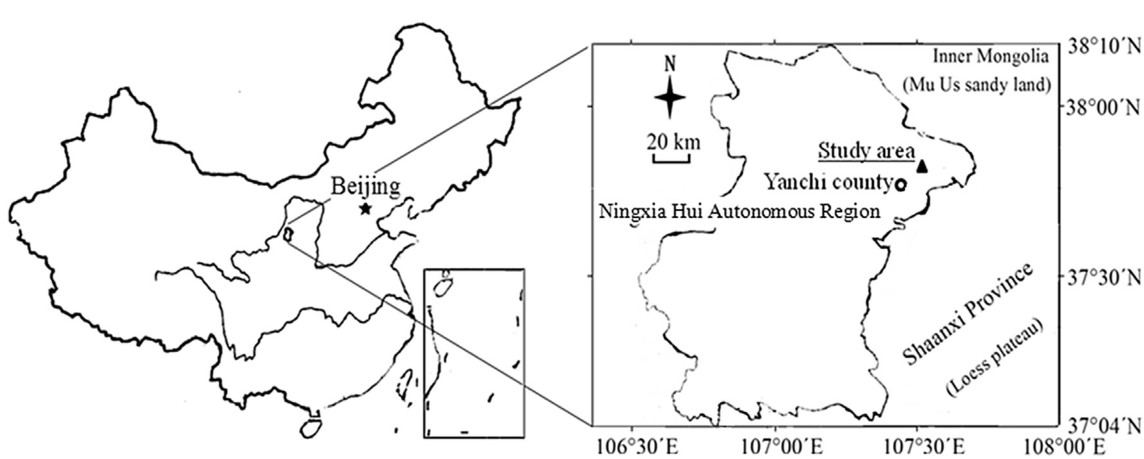

Fig. 1. Location of study area (Triangle) in a desertified steppe of Ningxia, northwestern China.