Forest Ecology and Management 334 (2014) 369–376

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Ground beetle assemblages in Beijing's new mountain forests

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ARTICLE INFO

Article history:
Received 28 July 2014
Received in revised form 15 September 2014
Accepted 18 September 2014
Available online 7 October 2014

Keywords:
Carabidae
China
Plantation
Regeneration
Temperate forest

ABSTRACT

Mature forests have been almost completely destroyed in China's northern regions, but this has been followed by large-scale reforestation in the wake of environmental degradation. Although future forest plantations are expected to expand over millions of hectares, knowledge about the ecology and biodiversity of China's replanted forests remains very limited. Addressing these knowledge gaps, we recorded ground beetle (Coleoptera: Carabidae) communities in five secondary forest types: plantations of Chinese Pine (*Pinus tabulaeformis*) and Prince Rupprecht's Larch (*Larix principis-rupprechtii*), Oak (*Quercus wutaishanica*) and Asian White Birch (*Betula platyphylla*) woodlands, and naturally regenerated mixed forest. Species richness peaked in mixed forests, while pine and oak woodlands harboured discrete communities of intermediate species richness. Oak, pine and mixed forest habitats also showed high levels of species turnover between plots. Canopy closure was an important factor influencing ground beetle assemblages and diversity, and a number of forest specialist species only occurred in pine or oak forests. We believe that some forest specialists have survived earlier deforestation and appear to be supported by new plantation forests, but maintenance of secondary native oak and mixed forests is crucial to safeguard the overall species pool.

1. Introduction

Global declines of mature forests render secondary forests and forest plantations increasingly important for the conservation of forest biodiversity (Brockerhoff et al., 2008). Global forest area declined by 5.6 million ha per year from 2005 to 2010 (FRA, 2010) with only 36% of global forest area classified as primary forest, and 53% as modified natural forests in 2005 (FAO, 2006). While forest plantations account for around 3.5% of global forests, large-scale plantations are planned in many regions of the world, and global plantation forest area expanded by approximately 14 million ha from 2000 to 2005 (FAO, 2006). Enhancing understanding of biodiversity patterns in planted and secondary forests is therefore of paramount importance to optimise their potential conservation value.

In China, forests cover approximately 195 million ha (Jia et al., 2011), but estimates suggest only 30% of this area comprises mature forest (Li, 2004). Loss of mature forest ecosystems in China has been accompanied by the extinction of at least 200 plant species and severe habitat loss for large mammals (López-Pujol et al., 2006; Sang et al., 2011); meanwhile, impacts on the species-rich insect fauna are widely unknown (You et al., 2005). The 32% decline in China's mature forest cover from 1950 to 2005 was accompanied by an increase in the proportion of land area covered by forest plantations, from 5.2% to 16% (FAO, 2006). Forest plantations are commonly established to protect watersheds and reduce soil erosion (Zhang et al., 2000), but their role in supporting biodiversity has been widely ignored. It is generally assumed that these plantations have inferior ecological functioning (Li, 2004), not least due to widespread use of tree monocultures even in ecological restoration programmes, like the Natural Forest Conservation Programme and "Grain to Green" projects (Cao et al., 2011; Lü et al., 2011). Accordingly, the net gain in China's forest cover of approximately 4 million ha annually from 2000 to 2005 (FAO, 2006) is

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http://dx.doi.org/10.1016/j.foreco.2014.09.022
0378-1127/

believed to have had little influence on forest biodiversity (Lü et al., 2011).

China's temperate forest zone has been heavily depleted of mature forests, with widespread forest plantations and secondary forests becoming integral in supporting the region's biodiversity. The forested landscape currently comprises a mosaic of patches occupied by native and exotic, broadleaved and conifer tree species (Ma and Fu, 2000), providing a unique setting for investigations into biodiversity patterns in different secondary and plantation forest types. These patterns are poorly understood, especially in relation to highly species-rich invertebrate taxa like ground beetles (Coleoptera: Carabidae). In Europe and North America, carabids have been commonly used to compare the ecology of pristine forests and exotic conifer plantations (Magura et al., 2000; Elek et al., 2001), different conifer species plantations (Jukes et al., 2001; Finch, 2005) and in relation to plantation management (Magura et al., 2002; Fuller et al., 2008). Carabids are taxonomically well known at least in temperate areas, their ecology is relatively well understood (Lövei and Sunderland, 1996; Kotze et al., 2011) and they are sensitive to environmental change, showing strong habitat specificity and low inter-patch dispersal rates (e.g. Butterfield et al., 1995; Barbaro et al., 2005; Pearce and Venier, 2006; Work et al., 2008; Koivula, 2011). With over 35,000 described species (1573 species known from China) and new descriptions reaching 100 species per year (Lorenz, 2005; Kotze et al., 2011), they are a mega-diverse taxon.

In comparison to Europe and the US, carabid assemblages in northern China currently remain poorly understood. Yu et al. (2010) suggest that in temperate China, native pine (*Pinus tabulaeformis* (Carr.)) plantations support fewer carabid species and individuals than natural oak (*Quercus wutaishanica* (Mayr)) forests, while *Carabus* spp. appear to be more abundant in mixed broadleaf forests and larch plantations than in oak forests (Yu et al., 2004). However, little else is known.

Our study therefore addresses the urgent need for a better understanding of changes in ground beetle communities between different temperate forest types in China. We aim to assess the relative contribution of different plantation types and naturally regenerated forests towards α- and γ-diversity of ground beetles, while also assessing the contribution of environmental factors towards observed diversity patterns. Our findings have implications for the future planning, management and restoration of secondary forests and plantations in the temperate forests of China.

2. Material and methods

2.1. Study area

The study was conducted at the Beijing Forest Ecosystem Research Station (BFERS), 114 km west of Beijing city centre (40°00′N, 115°26′E, Fig. 1) in the transitional zone between the North China Plain and the Mongolian altiplano. The area around the BFERS has an altitudinal range of 800–2300 m and experiences a cool-temperature monsoon climate, with an average annual temperature of 4.8 °C (January −10.1 °C, July 18.3 °C). Average annual precipitation reaches 612 mm, with 78% of rainfall occurring between June and August (Sang, 2004).

The oak-dominated (*Q. wutaishanica*) forests originally covering most of the study area were destroyed during extensive deforestation in the 1960s (Li, 2004; Yu et al., 2010). Subsequent soil erosion and flooding stimulated the establishment of widespread non-extractive forest plantations. Unlike many exotic conifer plantations found across the globe, the plantation tree species are chiefly native to the wider region, although they naturally occur in mixed forests rather than monoculture, and often at different elevations to the current plantations (Zhang et al., 2009). The resulting reforested landscape is highly fragmented, with a mosaic of different forest and scrub types, farmland and settlements (Ma and Fu, 2000).

The area surrounding the BFERS is dominated by secondary *Q. wutaishanica* woodland, while stands of the native birch species *Betula platyphylla* (Sukaczev) and *B. dahurica* (Pall.) have become established, especially at higher elevations. Natural regeneration has also led to the establishment of a mixed forest of broadleaved and conifer species, while non-extractive pine (*P. tabulaeformis*) and larch (*Larix principis-rupprechtii* (Mayr.)) plantations cover significant areas. *P. tabulaeformis* is a popular plantation species naturally co-occurring with *Q. wutaishanica* at elevations of 1200–2000 m, whereas *L. principis-rupprechtii* grows naturally at elevations between 1610 and 2445 m in northern China (Zhang et al., 2009), although larch monocultures are commonly encountered at lower altitudes.

We selected study sites in the five dominant forest types: larch, pine, mixed, oak and birch forest. These all harbour a well-developed and diverse understory of subdominant trees, shrubs and herbs. All study sites were located on steep slopes of 15–39° between 1165 m and 1410 m, with larch and birch forest sites located on north-exposed slopes in accordance with their general distribution, while sites representing the other forest types varied in their exposition. Following exploration of forest type boundaries on the ground, four plots were selected in each forest type to survey vegetation and sample ground beetles. Plots were positioned at least 50 m away from each other to ensure sample independence (Digweed et al., 1995). A distance of at least 15 m was kept to any path or open space to minimise edge effects. This was deemed sufficient since carabids do not respond strongly to edge effects in forest landscapes (Heliölä et al., 2001). Plots were located in areas that appeared representative of the overall forest structure, and plot locations were recorded using GPS. In the centre of each plot location, two pitfall traps were set two metres apart, giving a total of eight traps per forest type. Plots were necessarily grouped relatively closely together due to the small patch size of each forest type and the need to avoid transitional zones. Plot locations were selected to provide distinct results in relation to the specific carabid assemblages supported by each forest type.

2.2. Ground beetle sampling

Sampling occurred over ten weeks between July and August 2011 and over thirteen weeks between June and September 2012, to coincide with peaks in carabid activity reported from the same area (Yu et al., 2006). Plastic cups with a diameter of 7.5 cm and a depth of 10.2 cm were used as pitfall traps, protected by a metal roof positioned ∼6 cm above the cups. Traps were filled with 100–150 millilitres of a super-saturated salt water solution (>300 g salt/L) with a small amount of detergent added to break the surface tension. Salt solution has the advantage of being odourless and not attractive to particular species, thereby minimising bias in the species composition within samples (Kotze et al., 2011). For the same reason, we did not use bait in the pitfall traps. Traps were emptied at least fortnightly throughout the sampling period, and no disturbance of traps by animals or people was observed during the sampling period. Reliance on pitfall trapping for assessments of carabid communities is associated with known problems, including overrepresentation of large-bodied species (Work et al., 2002), but field testing of alternative methods including light trapping and litter sampling yielded very low capture rates. Pitfall trap samples represent activity densities rather than "true" densities (Baars, 1979; Spence and Niemelä, 1994); therefore, 'abundance' in this paper always refers to 'activity density' rather than true abundance patterns.