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Research Paper

Changes in plant diversity along an urban–rural gradient in an expanding city in Kazakhstan, Western Siberia

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HIGHLIGHTS

- We compared plant diversity along urban–rural gradients in Kazakhstan.
- Species richness increased from the city centre to the rural surroundings.
- Plant community structure changed along urban–rural gradients.
- Changes in species characteristics can partly be explained by landscape features.

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ABSTRACT

Plant communities respond sensitively to urban expansion and therefore serve as indicators for human land use. An urban–rural gradient approach was used to examine changes in plant species composition and abundance related to human-altered habitats in the Western Siberian city of Pavlodar (Kazakhstan). This region is characterized by harsh continental environmental conditions and recent anthropogenic degradation of the original steppe grasslands as a result of enforced land-use changes (Virgin Land Campaign) and rapidly expanding urbanization. Plant diversity and abundance as well as the percentage of alien species were recorded in plots on four 20-km long transect lines running from the city centre to the rural surroundings. Various habitat and landscape characteristics were assessed along the transect lines to describe the urban–rural gradient. Based on the results of a principal component analysis considering these landscape characteristics the variable "distance to the city centre" was used as proxy for the urban–rural gradient. Plant diversity increased with increasing distance to the city centre and was also influenced by the type of land use (ornamentally managed, agricultural or unmanaged land) and the percentage cover of built-up area within a 500 m radius. The percentage of alien species decreased from 45% in the city centre to 23% in the rural surroundings. The percentage of species belonging to different plant life forms and to different evolutionary strategies were affected by different landscape characteristics. The study showed that the combined effects of expanding urbanization and agricultural land-use changes altered the plant species composition.

1. Introduction

In a rapidly urbanizing world, knowledge of ecosystem responses to urbanization is a need to ensure that cities are planned for the well-being of residents and nature (Niemelä, 2011). A combination of processes or drivers including habitat transformation, fragmentation, specific urban environmental conditions and human preferences are assumed to shape plant communities in urban areas (Williams et al., 2009). However, the magnitude of the different drivers may differ depending on the region or even the city (Niemelä, 2011).

Effects of urbanization can be examined through studies across urban–rural gradients (Burton, Samuelson, & Pan, 2009; McDonnell & Hahs, 2008; Van Heezik, Smyth, & Mathieu, 2008; Weng, 2007). Such gradients, from densely built city centres to increasingly rural surroundings occur all over the world. In many cases, however, there are highly complex indirect gradients (e.g., Du Toit & Cilliers, 2011; Hahs & McDonnell, 2006). Cities include unique habitats (e.g., domestic gardens, parks, roadside verges) that are subject to high anthropogenic impacts (e.g., fertilizers, pesticides,

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trampling, noise and artificial light). Studies on plant and insect communities revealed that species composition is changing along the urban–rural gradient, while the diversity of native species is usually reduced in urban areas but shows a peak in suburban area compared to the rural surroundings (e.g., McKinney, 2008; Ranta, 2012). In contrast, the number of alien (non-native) species is often increased in urban areas (Pyšek, 1998; Ranta, 2012). Urbanization promotes dispersal of exotic species, resulting in a gradual replacement of native biotas (McKinney, 2002). In a global perspective, this process diminishes floral and faunal distinctions among regions (Olden & Poff, 2004). Urbanization may lead to biotic homogenization (McKinney, 2006, but see Aronson et al., 2014).

Urbanization effects on biodiversity have mainly been studied in cities of Europe, North America and Australia (Aronson et al., 2014). Very little is known on the impact of urbanization in Central Asia and Western Siberia. The aim of this study was to explore different factors that influence the vegetation pattern in the agglomerate of Pavlodar, a city in north-eastern Kazakhstan. The people of this region experienced very rapid changes in the traditional husbandry system with a dramatic impact on the social and economical development as a result of the Virgin Land Campaign in 1954–1963 (see Study area). The Campaign altered original habitats resulting in significant ecosystem changes together with the increased urbanization have so far not been investigated. We aimed to disentangle habitat and landscape factors that may influence plants communities in the expanding city of Pavlodar. We also investigated whether life form and evolutionary strategy types of plants are affected by urbanization. We determined the urban–rural gradient based on 14 habitat and landscape characteristics using principal component analysis.

In particular, we addressed the following questions:

(1) Do plant species diversity and the proportion of alien (non-native) species change along the urban–rural gradient in the developing city of Pavlodar?
(2) Which habitat and landscape variables influence plant diversity and species composition along the urban–rural gradient?
(3) Do life form and evolutionary strategies of plants change along the urban–rural gradient?

2. Methods

2.1. Study area

The study was conducted in the city of Pavlodar (331,000 inhabitants) and its surroundings in northern-eastern Kazakhstan (Fig. 1). Pavlodar was chosen as one of the centres of the Virgin Land Campaign in 1954–1963 because of the existing traffic infrastructure system and the potentially fertile arable soils. During the Campaign, the area of crop cultivation in the region increased from 0.8 to 2.8 million hectares. Approximately 200,000 people were transferred to the state farms in the Pavlodar region (an increase of the population by 37% during the first two years), which led to a pronounced shortage of housing (Insebaev et al., 2007). However, due to the failure of the Campaign large areas of intensive farming have been abandoned by now (De Beurs & Henebry, 2004). Consequently, the Campaign accelerated industrial and economical development. Nowadays the Pavlodar region includes several huge industrial agglomerates, and the share of the urban population increased by almost 70%. Specific factors that impacted the ecosystems include an uncontrolled intensive grazing, burning of grassland vegetation due to the dry climate, deposition of waste and contamination by petroleum products from pipelines and traffic.

Situated at the eastern embankment of the river Irtysh in the Western Siberian Plateau at the elevation of 125–150 m above sea level, Pavlodar has a dry continental climate with a mean annual precipitation of 228 mm and a mean annual temperature of 2.1 °C (National Hydrometeorological Service of the Republic of Kazakhstan, 2011). Mean January temperature is −18.1 °C (minimum temperature: −47 °C) and mean July temperature 21.3 °C (maximum temperature: 42 °C). There is usually a constant snow cover (depth 12–14 cm) from the beginning of November to the beginning of April.

The Irtysh valley runs from south to north. The width of river Irtysh varies from 500–800 m at low water level to 1200–1500 m during the flood period in spring. The eastern embankment of the river is formed by a 25–50 m high slope, while the western bank of the river passes into a 12–15 km wide floodplain with several small streams. The bedrock of the study area consists of eroded Pliocene deposits covered by a Pleistocene layer of sand, gravel and loess loam, sometimes with pebble stones (Kalinina, 1961). A major part of the investigation area was originally dry bunch feather-grass (*Stipa* ssp.) or fescue (*Festuca* ssp.) steppe, while in the flood plain a forb-rich meadow steppe occurred (Rachkovskaya & Bragina, 2012).

2.2. Sampling design and plant survey

Plant surveys were carried out between late June and early August 2012. Four 20 km-long transect lines were installed, beginning in the centre of Pavlodar (52°16.58′ N, 76°56.26′ E) and running in the four main directions (N, E, S, W) from the city centre into the rural surroundings (Fig. 1). The western transect line crossed the Irtysh valley with its alluvial floodplains, while the other three transect lines covered residential and agricultural areas in originally dry steppe-like grassland. Plant surveys were made at distances of 2 km along each transect line resulting in 4 × 10 sites plus the common site in the centre of Pavlodar city (in total 41 sites). At each site four sampling plots, measuring 5 m × 5 m and situated 20 m from each other, were installed.

Species richness of vascular plants, their abundance and vegetation cover (%) were recorded in each plot. Spontaneously growing species were only recorded. Abundance of plant species was assessed using the Braun-Blanquet method (1964). Abundance classes were transformed as follows: *r*: 0.01%; +0.1%; 1:5%; 2:17.5%, 3:37.5%; 4:62.5% and 5:87.5%. Plant species were identified following Pavlov (1956–1966) and Goloskokov (1972). Nomenclature was adjusted following Czerepanov (1995). Information on non-native (alien) plant species was obtained from Nurmukhambetova (2002), Kamkin (2009) and Leonova (2010). Information on the species composition of the original vegetation cover was extracted from Lavrenko (1991). A Red Data List of plants in Kazakhstan is not yet available. Therefore the conservation status of plants was derived from the Red List of Kazakh SSR (Bikov, 1981).

2.3. Habitat and landscape structure characteristics

For each sampling site, the intensity of disturbance and type of land use were assessed in the field (Table 1). For the intensity of disturbance, the impact of each of ten different types of disturbance was visually estimated in each plot using the four categories: absent (0), low (1), moderate (2) and high (3) (Appendix A). The scores of the 10 types of disturbance were added for each plot and the mean of four plots was calculated as a semi-quantitative measure of the overall intensity of disturbance for each sampling site. The type of land use was assigned to one of three categories (Table 1).

Four habitat and seven landscape characteristics were derived from satellite maps (Google Earth, 2013). Habitat characteristics included the distance of the sampling site to the nearest building or built-up area, the distance to the nearest road, the distance to the nearest wooded area and the distance to the nearest water