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Epiphytic lichens as indicators of grazing pressure in the Mongolian forest-steppe

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ABSTRACT

The ecological impact of the traditional land use by pastoral nomads on forest ecosystems is little studied. We analyzed the influence of livestock density on epiphytic lichen diversity in larch forests of the Mongolian forest-steppe, which we selected as a case example because pastoral nomadism is here most widespread within Central Asia. Canonical correspondence analysis showed that the epiphytic lichen vegetation was strongly influenced by the livestock density within a radius of 1 km around the sampled forests. Goats together with horses were most significant at shaping lichen vegetation in the forest edges as were horses alone in the forest interiors. This result matches with the results of interviews with 169 herder families and own field observations, which substantiate that goats preferably graze at the edges, whereas horses often browse the interiors. The livestock impact is thought to be primarily exerted through fertilization by the animals and mechanical abrasion. Based on an indicator species analyses, we propose to use epiphytic lichens as indicators of the grazing impact at different livestock densities in the Mongolian forest-steppe. The proposed indication system can be used as a tool for the rapid assessment of the livestock grazing impact. It has the advantage that it is thought to average the livestock impact of several years, which is important with regard to the nomadic style of livestock husbandry. The use of lichens as indicator species can at least partly substitute the time-consuming interviewing of the herder families to assess livestock densities and their impact on forest biodiversity. The proposed indicator system could thus be used as a planning tool for purposes of nature conservation.

1. Introduction

Epiphytic lichens are well-established indicators of acidic air pollution (Hawksworth and Rose, 1970). They can also be used to indicate different levels of nitrogen pollution (Hauck, 2010; van Herk, 1999) and as indicators of forest continuity (Rose, 1976; Tibell, 1992). In Central Asia, extensive mobile livestock keeping is an important branch of the local economies, which serves the subsistence of significant parts of the population (Griffin, 1995; Johnson et al., 2006; van Leeuwen et al., 1994). The pastures in Central Asia are often ecologically vulnerable because of unreliable rainfall and are subjected to overgrazing, degradation and soil erosion at many places (Sternberg et al., 2011; Ykhanbai et al., 2004). While effects of livestock grazing on the diversity and productivity of the ground vegetation have been studied repeatedly in grasslands (Wesche et al., 2010; Wu et al., 2009; Yoshihara et al., 2008), there are not many studies dealing with the responses of forest vegetation to mobile livestock keeping in Central Asia (Blaser et al., 1998). Since livestock in the forest-steppes of Central Asia is often little herded (Fernández-Giménez, 2000; Lkhagvadorj et al., 2013) and forests and grasslands usually form an aspect-dependent spatial small-scale pattern (Hilbig, 1995), livestock grazing is not restricted to the steppe, but regularly also extends to the forests, especially at the edges. The herders also intentionally drive their livestock into the forest to exploit its herbage in addition to that in the steppe (Lkhagvadorj et al., 2013).

While most attempts for forest conservation in Central Asia rely on the exclusion of land use from strictly protected areas (Reading et al., 2006), this concept is not applicable to forest-steppe regions populated by herders and their livestock. This is especially true in areas with high livestock densities and low income of the population. Therefore, it is necessary to develop measures for ecosystem conservation which include the protection of biodiversity in managed forest-steppes. A central issue in this context is to assess the ecological impact of traditional livestock keeping on individual forests. Since Hauck et al. (2012) found that the species richness and cover of epiphytic lichens were negatively correlated with the density of nomad summer camps in the forest-steppe of the Mongolian Altai, we became interested in the question whether lichens could be used as indicators of the severity of the livestock grazing impact

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in the Mongolian forest-steppe. Epiphytic lichens are not eaten by livestock, but are influenced by nutrient enrichment and mechanical abrasion. In their study from the Mongolian Altai, Hauck et al. (2012) could show that the bark of larch trees contained significantly more total N at the forest edge to the steppe than in the less intensely grazed forest interior. On nutrient-enriched bark, more nitrophytic lichen species were found than on nutrient-poor bark.

Mongolia was chosen as a case example for our studies, because this country has kept the most intact culture of mobile livestock keeping in Central Asia (Fernández-Giménez, 1999; Janzen, 2005), with approximately one third of the total population depending on it economically (Dagvadorj et al., 2009). Our key objective was to study whether epiphytic lichens can be used as indicators of livestock density using the fact that many lichen species are sensitive to changes in nutrient availability, which is in turn a function of the density of livestock. We combined data on epiphytic lichen diversity with the results of interviews with the local herders on human population, livestock densities, seasonal migration behavior and grazing habits from two regions of the Mongolian forest-steppe. We tested the hypothesis that the occurrence and abundance of individual epiphytic lichen species is correlated with the densities of the total livestock and of individual species of livestock around the analyzed forest stands in the forest-steppe.

2. Materials and methods

2.1. Study areas

The study was carried out in two regions of the Mongolian forest-steppe, namely in the Mongolian Altai and the Khangai, western Mongolia (Fig. 1) in 2010 and 2011. In the Mongolian Altai, the study was conducted south and southeast of Lake Dayan (48°14′39″–48°16′3″ N, 88°50′17″–88°57′0″ E) in the Dayan administrative subunit (‘bag’) in the Altai Tavan Bogd National Park in the province (‘aimag’) of Bayan-Ulgii, western Mongolia, 110 km SW of the city of Ulgii. The study sites in the Khangai Mountains were located in the valley of the river Shireegiin Gol (47°29′11″–47°30′37″ N, 96°59′20″–97°13′59″ E), ca. 30 km SSE of the city of Uliastai and 40 SW of Mt. Otgontenger in the province of Zavkhan. The elevation of both study regions was >2000 m a.s.l. The climate is highly continental with low winter temperatures and a relatively narrow peak of precipitation in summer. Both study areas are typical forest-steppe landscapes with pure forests of Siberian larch (*Larix sibirica* Ledeb.) on north-facing mountain slopes and steppe in the footslopes and in the valleys; *L. sibirica* covers approximately 80% of the forested area in Mongolia (Tsogtbaatar, 2004). The south-facing slopes are covered with dry mountain steppe. The valleys serve for summer camps for pastoral nomads during summer; in the Altai some of the herders live there the whole year.

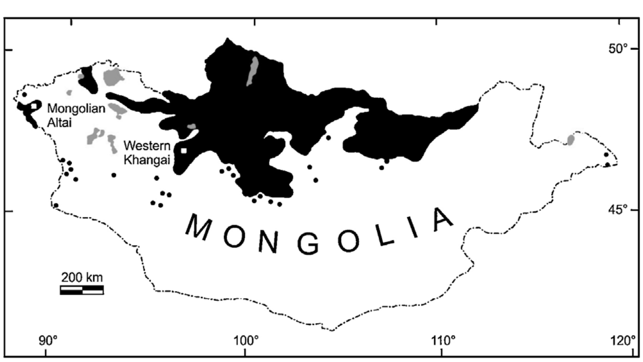

Fig. 1. Position of the study areas in the Mongolian Altai and the western Khangai in western Mongolia. Black areas are landscapes which are dominated by continuous conifer forest or forest-steppe; black dots mark isolated conifer forests; gray areas represent lakes.

2.2. Assessment of epiphytic lichen diversity

Data of epiphytic lichen diversity were recorded from 480 trees of *L. sibirica* with a stem diameter at breast height of ≥15 cm. These trees were distributed over 24 sample plots with 20 trees each. In each study region, six plots were selected each at the forest edge to the steppe and at least 50 m within the forest interior. The lower boundary of the forest edge plot was identical with the forest line to the adjacent grassland. Plot size was 20 m × 20 m size. If more than 20 trees with a stem diameter ≥15 cm were available on these plots, the 20 trees growing most closely to the lower edge of the plot were selected in order to include those trees in the sampling which were most exposed to edge conditions. On plots with less than 20 trees, additional trees growing most closely to the sample plot were selected in addition to the trees on the plot. This sampling procedure was applied because the plots where also used for biodiversity surveys in other groups of organisms. Forest stands were selected on north-facing slopes by making use of the relatively even aspect-dependent spatial pattern of forest patches and steppe in the Mongolian forest-steppe. In both study regions, the investigated forest stands were aligned in a row at the southern rim of a valley, which was inhabited by several nomad families. The mean distance between neighboring study sites was 2.2 ± 0.5 km in the Mongolian Altai and 3.8 ± 0.5 km in the Khangai. Though site selection was not at random, it was little subjective because forest patches in near equidistance were chosen without bias by looking at the vegetation or stand density before. However, relatively moist depressions, which occur locally on the mountains slopes, were deliberately avoided to improve the comparability between the individual sites.

On each sample tree, all individual lichen species were recorded on the trunks in a height of 0–1 m above the ground, including all aspects, i.e. the whole circumference of the trunk. The cover of each species was estimated in percent. Cover values of <1% were processed with the value of 0.5% in the data analyses. The recording of lichens was limited to the lowest 1 m of the tree trunks, because the stems were virtually devoid of lichens above this height; the few lichen thalli found above the trunk base were not specialized species but consistently species which also occurred (in higher quantity) at 0–1 m above the ground. Coarse roots located above the soil surface were included in the investigated bark surfaces. Nomenclature is based on Urbanavichus (2010), except for *Xanthoria* s.l. where we follow Fedorenko et al. (2012). Lichen data presentation in the scope of the present paper is limited to data which are related to the immediate context of grazing pressure responses. Species richness (α-diversity) is given as the total species numbers per plot or tree; values of tree-level species richness were averaged plot-wise, before included in further calculations.

2.3. Interviews with the local population

The nomad families living in the grasslands in front of the studied larch forests were interviewed during summer 2010 in the Mongolian Altai and summer 2011 in the Khangai. This included 82 households with 442 members in the Altai and 87 households with 347 members in the Khangai. Interviews were held with at least one member of each household at their homes in the Mongolian language. In the Mongolian Altai, where most nomads belong to the Kazakh minority and usually do not speak Mongolian, a translator with socioeconomy background acted as a translator. The position of each household at the time of the interview was recorded using GPS. A fixed questionnaire was used to obtain data on the number