Conference Paper

Changes to Species Diversity of Vegetation Communities during Restorative Successions in Different Types of Forests

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Abstract

In this work, we study changes in species diversity of vegetation communities during restorative successions at logging sites in different types of forests, using the South Ural region as an example. Data from 180 geobotanical relevés of logging sites and secondary forests of different ages of the four main types of the South Ural region forest communities (cool-temperate dark-coniferous, nemoral broad-leaved, hemiboreal light-coniferous and boreal light-coniferous forests) were analyzed. Trends in changes to species diversity manifest themselves in different ways during each stage of the 'native forest – logging – secondary forest' succession sequence. In broad-leaved and cool-temperate dark-coniferous forests, changes in species diversity follow the parabolic trajectory during restorative successions at clear-cutting sites; in other words, the diversity initially increases and then decreases during the progress of the succession. This is caused by the introduction of invasive synanthropic species during the early stages of the succession. The level of species diversity at clear-cutting sites in hemiboreal light-coniferous forests barely changes due to the rapid expansion of reed grass, which prevents the invasion of synanthropic species in the logging areas.

Keywords: species diversity, restorative succession, logging, secondary forests, synanthropic species

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1. Introduction

Forests are one of the most important ecosystems on our planet. However, due to the extensive exploitation and transformation of woodlands into agricultural areas, global forestry resources were diminished two-fold over the last three centuries. Nevertheless, human society is not ready to give up timber harvesting and logging will remain a common practice. The transition to an intensive type of forest management leading to the establishment of high-yield plantations is currently underway in many developed countries. In Russia, forest management continues to be predominantly extensive, which leads to many logging sites being left for natural reforestation. This in turn results in the formation of secondary forests of lesser value (from a harvesting perspective) and, more importantly, in the decrease of biodiversity at these sites. The latter is a reason for the intensive investigation of the processes leading to the formation of secondary forests [1–3]. The aim of this work is to study changes in species diversity in vegetation communities during restorative successions at logging sites in different types of forests, using the South Ural region as an example.

2. Methods

The analysis of species diversity in forest communities at different stages of restorative successions was based on 180 geobotanical relevés conducted in native forests, at logging sites and in secondary forests of the South Ural region (SUR) during the 2001–2017 time period. The plot sizes of geobotanical relevés varied from 100 to 400 m^2. Sites with a highly affected ground cover due to summer or fall logging that were left for natural reforestation, as well as ones where planted forests were lost due to a lack of care, were used for relevés. The dates at which recent logging took place were determined based on data from forest inventories. The age of tree stands in secondary forests at older logging sites was determined by taking core samples using the Haglöf increment borer at each lot. Tree ring counts were conducted in accordance with standard dendrochronological methods [4] in laboratory conditions. Geobotanical relevés were stored in a TURBOWIN [5] database. Data was then imported into JUICE 7.0 [6] software that was used to classify vegetation using the Braun–Blanquet approach and K. Kopecký's and S. Hejný's deductive method [7, 8]. A chronosequence method – a concept of highlighting well-defined stages of succession within a temporal sequence of plant communities at the clear-cutting sites – was also used [9]. After identifying a succession sequence for each unit that represented vegetation communities of logging sites of different ages, alpha-diversity indexes were calculated (reflecting the average number of species within a unit).

Analysis of species diversity at different stages of post-logging succession in cool-temperate dark-coniferous forests with a predominance of nemoral and hemi-boreal floristic elements (alliance *Aconito septentrionalis-Piceion obovatae* Solomeshch et al. ex Martynenko et al. 2008 of class *Asaro europaei-Abietetea sibiricae* Ermakov, Mucina et Zhitlukhina 2016), nemoral broad-leaved forests (alliance *Aconito septentrionalis-Tilion cordatae* Solomeshch et al. 1993 of class *Carpino-Fagetea* Jakucs ex Passarge 1968), hemiboreal light-coniferous forests (alliance *Trollio europaea-Pinion sylvestris* Fedorov ex Ermakov et al. 2000 of class *Brachypodio pinnati-Betuletea pendulae* Ermakov, Korolyuk et Lashchinsky 1991) and boreal light-coniferous forests (alliance *Dicrano-Pinion sylvestris* (Libbert 1933) Matuszkiewicz 1962 of class *Vaccinio-Piceetea* Br.-Bl. in Br.-Bl., Sissingh et Vlieger 1939) of the SUR was conducted using these data.

3. Results

The forests of the SUR are characterized by a high ecological and syntaxonomical diversity. This is caused by the effects of altitudinal zonation and the diversity of natural terrain; the location of the region at the intersection of Europe and Asia and forests and steppes; and the complex history of vegetation dynamics in the region during the Pleistocene and Holocene epochs [10, 11]. The area of the SUR forests has decreased by 40% during the last three centuries due to the extensive exploitation of these woodlands. Presently, the vast majority of forests in the region is represented by a relatively young secondary tree stand less than 50–70 years old on average.

The main trends in changes to species diversity during restorative successions are shown in Figure 1. It is known that the most significant changes in biodiversity take place during the initial stages of succession and that they slow down in the final stages of the process. Moreover, the trends of changes in species diversity vary greatly in different types of forests. After logging in broad-leaved and cool-temperate dark-coniferous forests, there is a sharp increase in the lightening of the ground cover and, in the first years in the regeneration niches formed by disturbance, a large number synanthropic species. In this case, the projective cover of the herb layer increases significantly, along with biodiversity levels, which reach up to 50–70 plant species per plot (Stage 1).

Most of the species are represented by ruderal bi– and perennial species from the class *Artemisietea vulgaris* Lohmeyer et al. in R. Tx. 1950 *Taraxacum officinale* F.H. Wigg., *Cirsium setosum* (Willd.) Besser, *Picris hieracioides* L., *Artemisia absinthium* L. et al.) and segetal species of the class *Stellarietea mediae* R. Tx. et al. ex von Rochow 1951 (*Sonchus arvensis* L., *Lactuca tatarica* (L.) C.A. Mey., *L. serriola* L., *Erigeron acris* L.). They are accompanied by clear-cutting community species of the class *Epilobietea*

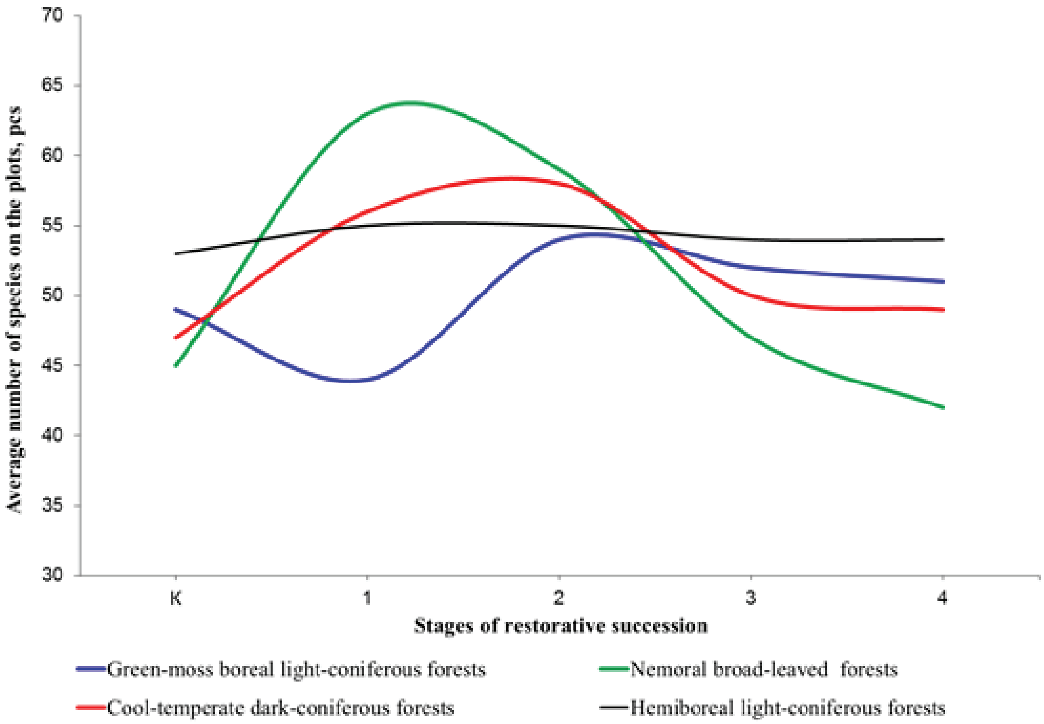

Figure 1: Trends in changes to species diversity in the clear-cutting of different forest types: K – native forest. Source: Authors' own work.

angustifolii Tüxen et Preising ex von Rochow 1951, meadow species of the class *Molinio-Arrhenatheretea* R. Tx. 1937, pastureland species of the class *Polygono-Poëtea* Rivas-Martínez 1975 corr. Rivas-Martínez et al. 1991 and meso- and thermophilous forest edge species of the classes *Galio-Urticetea* Passarge ex Kopecký 1969 and *Trifolio-Geranietea* Th. Müller 1962.

In the following years, during the recovery of tree stands (Stage 2) and the closure of the canopy (Stages 3 and 4), synanthropic species are replaced by native species of the forest communities; phytodiversity declines and almost reaches the level of native forests. Therefore, the so-called parabolic trend of changes in species diversity takes place, which is also observed in the dark-coniferous forests of other regions [12, 13].

The parabolic trend is also observed at clear-cutting sites in boreal green-moss light-coniferous forests, but it goes in a different direction. During the early years of succession (Stage 1), boreal undershrubs and herbs (*Vaccinium myrtillus* L., *Vaccinium vitis-idaea* L., *Linnaea borealis* L., *Lycopodium annotinum* L., *Platanthera bifolia* (L.) Rich. et al.) disappear from communities due to a sharp increase in insolation; the moss canopy decreases. Then, species typical for grass forests become more abundant [14]. As a result, species diversity increases due to the appearance of light demander plants of grass forests (Stage 2), and then decreases when the tree canopy closes and secondary birch forests are formed (Stage 3 and 4).

A different trend in changes to species diversity is observed at clear-cutting sites in hemiboreal light-coniferous forests (class *Brachypodio-Betuletea*). The main background phytocenoses in these areas is *Calamagrostis arundinacea* (L.) Roth, which also dominate native forests.

After logging, the reed grass demonstrates explerent features by expanding and conquering the newly available habitat. This expansion of reed grass is typical for most types of hemiboreal forests in the Urals [15]. Due to the rapid expansion, reed grass occupies the majority of the habitat and prevents the invasion of synanthropic species into the phytocenosis [16]. *Calamagrostis arundinacea* dominates during the entire period of restorative succession, from the first year to the final stages of secondary birch and aspen forests. As a result, the species diversity in these types of logging sites does not change and the trend remains linear.

4. Conclusion

Trends of species diversity changes manifest themselves in different ways during each of the stages of 'native forest – logging – secondary forest' succession sequence. In broad-leaved, cool-temperate dark-coniferous and boreal light-coniferous forests, changes of species diversity follow the parabolic trajectory during the restorative successions at the sites of clear-cutting. This is caused by the introduction of invasive synanthropic species at the early stages of succession.

A linear trend in changes to species diversity is observed in the succession sequences of all four types of forests during selective, strip cuttings or winter logging, when the ground cover is disturbed slightly or remains undisturbed. As a result, only the coenotic role of the native forest species changes in the succession sequence 'native forest – logging – secondary forest'. The contribution of invasive species to the succession processes is not significant.

The results of this study will become of the basis for the prognosis of natural vegetation restorative of forests main types of the South Ural region and development of recommendations for the optimization of logging system in forestry and monitoring of their condition.

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