



Forest fires increase variability of soil macrofauna communities along a macrogeographic gradient



A.Yu. Gorbunova^a, D.I. Korobushkin^a, A.S. Zaitsev^{a,b}, K.B. Gongalsky^{a,*}

^a A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Leninsky pr., 33, Moscow, 119071, Russia

^b Institute of Animal Ecology, Justus-Liebig-University, Heinrich-Buff-Ring 26, 35392 Giessen, Germany

ARTICLE INFO

Article history:

Received 30 September 2016

Received in revised form

31 March 2017

Accepted 1 April 2017

Available online 22 April 2017

Handling Editor: Thibaud Decaens.

Keywords:

Boreal forest

Deciduous forest

Mediterranean

Wildfire

Belowground macroinvertebrates

Spatial variance

ABSTRACT

We assessed the impact of forest fires on macrofauna taxonomic richness, abundance and total biomass in 20 forests burnt five years ago and 20 respective control plots along a 3000-km-long north-south transect in European Russia that covered five major forest types (Mediterranean and broadleaved forests, southern, middle, and northern taiga). In parallel we assessed basic soil abiotic parameters in these stands. Within forest type, the spatial variance of macrofauna total biomass was 1.8 times higher in the burnt forests than in the controls. Due to this increase of variance in the burnt forests, the main effect of forest type on soil macrofauna parameters was generally weaker. Among different soil abiotic parameters, higher level of uniformity of macrofaunal community parameters between different forest types was explained by the labile P and N content in the soil, water-holding capacity and soil moisture. Presence of open areas within the burnt forests seems to be the leading driver of the increased similarity of soil macrofauna communities across different forest types. Forest fires thus act as a powerful force that raises within-forest-type soil macroinvertebrate beta-diversity and associated biomass fluctuations. At the same time burning reduces soil macrofauna gamma-diversity due to increased faunistic similarity between different forest types. This has potentially important implications for the functioning of soil macroinvertebrate communities in the pyrogenic forests and its dependency on macroclimatic conditions.

© 2017 Elsevier Masson SAS. All rights reserved.

1. Introduction

The effect of forest fire on soil macroinvertebrate communities is very hard to predict. Due to high microspatial variability of the fire intensity and severity, neighboring areas of the forest floor may be damaged to a different degree [6]. Less burned or even completely unburned patches may exist within a burned area. This phenomenon increases patchiness and ecological niche availability for immigrating species on the forest floor [20]. It remains unknown whether this habitat patchiness is similar or not in the different forest types. Interaction of regional gradients and local effects of fire on habitat heterogeneity with respect to soil macrofauna has not been addressed yet. Understanding such interactions may strongly modify our knowledge on the both taxonomic and functional response of soil macrofauna to burning [5]. Some preliminary expectations about these interactions are based on observations of fire effects on soil macrofauna in different forest types, which are

associated with the appearance of open areas within burnt stands [2]. This potentially enables macrofauna taxa typical for the open landscapes (e.g. grasslands) to invade burnt forests [9,16]. We thus hypothesize that: (i) soil macrofauna communities in the burnt forests will be more variable at the local level regardless of the forest type; and (ii) this will result in the reduction of the role of macrogeographic gradients in determining their taxonomic distinctness in the pyrogenic forests across vast areas. To test these hypotheses we performed a large-scale field study on a 3000 km-long transect in the Russian Plain, which hosts the prominent macrogeographic gradient. The clear advantages of this region are the uniform topography and well-studied environmental and edaphic parameters distribution.

2. Material and methods

The study area covers almost the entire diversity of forest types represented in the European part of Russia (Supplementary Material, Fig. S1) [14]. The material was collected at the 3000-km long transect in five forest types: 1) Mediterranean forests (MF), the

* Corresponding author.

E-mail address: gongalsky@gmail.com (K.B. Gongalsky).

Black Sea coast of the Krasnodar Region; 2) broadleaved forests (BF), the Voronezh and Lipetsk Regions; 3) southern taiga (ST), the Moscow and Tver Regions; 4) middle taiga (MT), the Republic of Karelia and the Leningrad Region; 5) northern taiga (NT), the Murmansk Region.

To synchronize sampling from the ecological point of view, we sampled respective forest types at the annual mean date of the bird cherry tree (*Prunus padus* L.) flowering, which happens in late spring. This approach for ecological synchronization of field work is routinely used in soil zoological studies across extensive climatic gradients (see e.g. Ref. [7]). We started from the southernmost sampling area (Mediterranean forests) on April 30, 2015, and sampled each forest type with a 10-day lag moving northwards. For the same reason the time lag between the two northernmost forest types, middle taiga and northern taiga, was 20 days [19].

In each of the five sampled forest types, 4 pairs of plots (burnt and control) were selected. Each day we sampled simultaneously only one pair of plots. Normally, the burnt forest and adjacent unburnt forest (control) were located 250–500 m apart from each other. In total, 20 burned areas and 20 unburned control plots were sampled. To avoid possible bias of results due to factors which were not controlled within this study (e.g. vicinity of industrial facilities, large water bodies, big cities) we selected sites in the remote areas within each forest type and invested a lot into studying four replicating forest stands located far from each other. Only forest types typical for respective ecoregion were selected for sampling. Unfortunately, exact burning dates were not available for the selected forests, neither from the forestry departments records nor from the satellite imagery which we examined during the burnt plots selection process. For detailed geobotanical descriptions of the sites refer to the project website [21] and [3].

A number of environmental and biotic variables were identified at each forest plot. Among the ecosystem parameters we measured the total mass of lying twigs with a diameter of more than 4 cm and the projective cover of berry bushes. Among climatic parameters we used annual mean temperature. Among soil parameters we measured: depth of the litter layer, pH (H₂O), water holding capacity (WHC, in %), content of elements and their ratios: labile C, N and P, total C and N. Detailed method descriptions for abiotic parameters are provided in Refs. [3,6] and on the project's website [21]. In this paper we used the same dataset of environmental parameters as in Ref. [6] to explain observed trends in the macrofaunal community abundance, diversity and trophic structure, and the detailed descriptions of the methods can be found in the same paper and are not duplicated here.

We obtained five soil samples with the steel corer of 20 cm in diameter, down to the depth of 15 cm to account for soil macrofauna. The soil samples were delivered to the laboratory in cool boxes at a temperature of ca. +10 °C and were processed within 2–3 days after delivery. Extraction of macrofauna was performed using Tullgren extractors into a mixture of alcohol, water and ethylene glycol in a ratio of 80:15:5, for 4 days, the time sufficient to make soil reach air-dry condition. To extract earthworms from the soil, the formaldehyde method was applied [15]. Three 1 × 1 m square areas were selected at each plot. All litter was thoroughly hand-sorted and all earthworms collected. After that, 10 L of a 4% formaldehyde solution was sprayed over the area. All emerging earthworms were collected during 30 min after application of the irritant and fixed in separate jars in 95% alcohol. Animals were sorted out from the samples under the binocular microscope and identified under the light microscope. All taxa were identified at the family level, and the following groups were identified at the species level: Araneae, Isopoda, Chilopoda, Diplopoda, Elateridae larvae. Biomass of soil macrofauna was estimated by direct weighing. Animals were lyophilized in a Labconco FreeZone 1

freeze-dryer for a day. Then the animals were weighed on a Mettler Toledo MX6 balance with an accuracy of 1 µg. The number of animals in the analysis ranged from 1 or a few individuals for rare taxa and up to 10 for numerous taxa. Biomass was expressed in g dry weight m⁻². Taxa with biomass exceeding 7% of the total at a plot were considered dominants, and 1% were considered subdominants.

The abundance and biomass of soil macrofauna are given as the mean value for burnt and control plots per forest type ($n = 4$) ± standard error of the mean (SE). Samples within each plot ($n = 5$) were considered pseudo-replicates, and were only used to form a mean value per plot. To assess the variability of soil macrofaunal communities, two metrics were applied. First, we looked at the variability of abundance and biomass across 4 replicate plots within each treatment and forest type. For this, we calculated the ratio of maximum to minimum value of biomass across control and burnt areas within each forest type. Second metric is based on the assumption that unstable conditions after fires result in a less predictable community structure. For this, we counted the number of dominant and subdominant taxa.

The taxonomic composition of soil invertebrate communities was compared using the ordination method [17]. We calculated the matrix of samples from the biomass of macrofauna families. The similarity matrix was processed by multidimensional scaling (MDS). The optimum number of basic axes was determined by the comparison of the actual and theoretical stress values. The obtained coordinates of points in the multidimensional space were used for assessing the value and significance of difference between samples taken from different plots using discriminant factor analysis (DFA), the significance of results was estimated by Wilks' Lambda. When the discriminant analysis confirmed the significant differences between the plots, the linear Pearson correlation between the ratio of contribution to the total macrofauna biomass (%) of separate taxa in samples and the coordinates of these samples on the significant canonical axes were calculated. Samples with total biomass of macrofauna equal to zero and with taxonomic richness equal or below 2 were excluded from the analysis.

Correlations between the biomass of dominant taxa of soil macrofauna and environmental variables including burning treatment were visualized using principal component analysis (PCA). In the PCA, the abiotic factors were selected as active variables, while invertebrate taxa were selected as passive ones. All statistical analyses were performed using Statistica 8.0 software.

3. Results

The taxonomic composition of soil macrofauna communities in control plots from different forest types differed in the multidimensional space of the canonical analysis (Wilks' Lambda = 0.035, $F = 27.99$, $p < 0.0001$) along two significant axes (Fig. 1A). The first axis (60.0% of explained variance) defined the difference between the deciduous forest types (Mediterranean and broadleaved forests) and the boreal forests (southern, central and middle taiga), the second one (32.0% of explained variance) differentiated the latter three forest types from each other. Also, burnt forests bore significantly lower biomass of soil macroinvertebrates as compared with the respective controls in three forest types: Mediterranean forests ($F = 5.0$, $p = 0.001$), broadleaved forests ($F = 3.8$, $p = 0.005$) and northern taiga ($F = 2.5$, $p = 0.040$) (Supplementary material, Table S1). The differences between burned and control plots in middle taiga were insignificant ($F = 2.3$, $p = 0.059$). The discrimination of control communities from each other was primarily determined by the high relative biomass of unique taxa with the distribution limited to the single forest type (Supplementary material, Table S2). Along with the effect of forest type, fires led to the

Download English Version:

<https://daneshyari.com/en/article/5744218>

Download Persian Version:

<https://daneshyari.com/article/5744218>

[Daneshyari.com](https://daneshyari.com)