Biological diversity dynamics in forest biological community at Western Siberia subtaiga ecological monitoring index plot

Maria N. Kazantseva[1], *Stanislav* P. Arefyev[1], *Sergey* N. Gashev[2], *Natalia* V. Sorokina[2*], *Alena* Yu. Levykh[3], and *Nadezhda* V. Ganzherli[4]

[1]Institute of the Problems of Northern Development, Tyumen Scientific Center SB RAS, 13, Chervishevsky tract St., Tyumen, 625008, Russian Federation
[2]Department of Zoology and Evolutionary Ecology of Animals, Institute of Biology, Tyumen State University, 3, Pirogova St., Tyumen, 625000, Russian Federation
[3]Arctic Research Center of the Yamal-Nenets autonomous district, Tyumen region, Yamalo-Nenets Autonomous District, 20, Respubliki St., Salekhard, 629008, Russian Federation
[4]Department of English Philology and Translation, Institute of Social Sciences and Humanities, Tyumen State University, 6, Volodarskogo St., Tyumen, 625000, Russian Federation

Abstract. This article presents results of a 2001-2021 research into an index plot forest biological community in the Western Siberia subtaiga zone (Tyumen Region, Russia), providing data on dynamics and biological diversity of vegetation cover, fungi and terrestrial vertebrate communities. The current research analyses the influence of climate and weather conditions of certain vegetation seasons and perennial climate trends pertaining to global processes, on biodiversity. Over the observation period as a whole, the xerophily of the forest ecosystem increased.

1 Introduction

Community biological diversity indices are traditionally considered to be among the basic measures of environmental monitoring as they are closely connected to ecosystem sustainability and stability. In 2001, in a Tyumen Region subtaiga proving ground, the authors established a permanent sample plot in a forest biological community. This plot was considered key for a monitoring study of subtaiga forest biota (including plants, fungi, and vertebrate animals) [1]. The research took place from 2001 to 2021. According to the nearest weather station (Tyumen, Russia) [2], the average annual air temperature increased by 0.6º C, and the amount of precipitation decreased by 94 mm (Figure 1). The biota changes under consideration may be related to these climate trends.

* Corresponding author: natalya_sorokina@rambler.ru

 https://doi.org/10.1051/e3sconf/202339007003

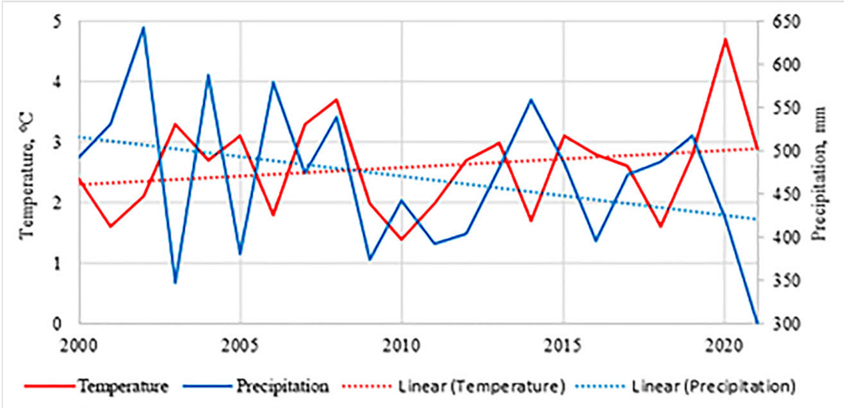

Fig. 1. The Annual Air Temperature and Precipitation Change according to Tyumen Weather Station (with Trends).

2 Materials and methods

A 0.25 ha (50x50 m) permanent sample plot (SP) was established in a grass-shrub pine forest (57°22'41" N, 66°02'59" E). This type of forest is widely spread in Western Siberia subtaiga being one of the forest vegetation zone elements. In 2001, the average age of a pine at the SP was 68 years. The forest stand was characterised by high density and fell into Class II of the Russian site index system. Apart from the main coniferous dominant species, Pinus sylvestris L., the forest stand included such parvifolliate species as Betula pendula Roth and Populus tremula L.. Over 90% of the trees were in a good condition.

Over the period from 2001 to 2021, we held six censuses of the composition and abundance of wood-decaying fungi (aphyllophoroid macromycetes destroying the major part of coarse woody debris). The fungi community was analysed with the help of aphyllophoroid fungi Betula-complex [3], where each species has its own coordinates in a system of environmental factors (substrate condition, hydrothermal regime, succession).

Using conventional geobotanical methods [4], we performed four complete descriptions of herbaceous vegetation on the SP at five permanent 10 x 10 m quadrats. In order to describe the biological community's floristic composition more thoroughly, we also performed route censuses.

Communities of terrestrial vertebrates were studied with the help of conventional methods: at the study plots and on census routes [5-7]. There were three such surveys performed.

3 Results and findings

The trees, being an ecosystem engineer of the forest biological community, exercise a decisive influence on its structure and functional features. Changes occuring in the composition and condition of the aborescent stratum inevitably lead to adjustment of all community components.

Over the monitoring period, the forest stand condition deteriorated considerably. The number of healthy trees dropped by 23%. In 2021, dead trees and wood debris account for over a quarter of the initial number of trees in the stand. A probable reason for degradation may be climate aridification whose ramifications are clearly evident in the subtaiga forests at the southern border of forest vegetation. At the same time, driven by the growth of healthy trees, the forest stand density remained high; the Russian site index changed to Class I.

3.1 Lignicolous micobiota diversity monitoring

The fungi are an integral part of environmental complexes and account for a considerable share of biological diversity. The Red Data Book of the Tyumen Region (2020) lists 20 fungi species, 14 of which are wood decaying ones. The fungi communities species composition and structure are sensitive to changes in the environment and biota.

In total, there were 207 individuals coming from 47 aphyllophoroid macrofungi species (Figure 2). The species include widely spread boreald and forest steppe ones characteristic of Western Siberia south. Although the forest stand is almost a pure pinery with a mixture of deciduous trees, there were only 6 fungi species (20 specimens) on P. sylvestris, and 24 (72) on B. pendula, 15 (51) on P.tremula, 12 (58) on Salix L.; since 2014 3 fungi species (6 specimens) have been registered on Sorbus aucuparia L.

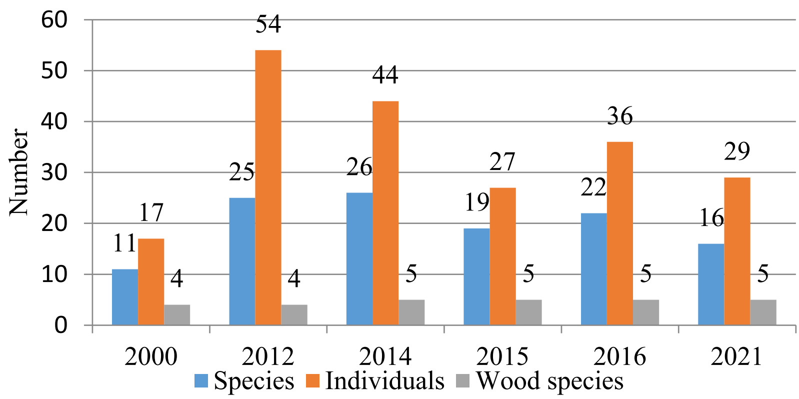

Fig. 2. The Change in Wood-Decaying Fungi Species Diversity and Abundance on the SP from 2000 to 2021.

Fungi species diversity and abundance substantially changed from year to year; an increase in general fungi abundance led to a growth in the number of their species (R = 0.92). According to 2001 May census, the lowest values (17 individuals from 11 species) were registered for the fungi that developed in 2000, a year with average climate conditions. The highest values (54 individuals from 25 species) were registered in a droughty and hot 2012, after a dry year of 2011. Judging by the indicator fungi subsystem of the Betula-complex, by 2012 the share of drought-resistant species (Daedaleopsis tricolor (Bull.) Bondartsev & Singer, Plicaturopsis crispa (Pers.) D.A. Reid, Picipes badius (Pers.) Zmitr. & Kovalenko, etc.) has grown by 12% (Figure 3), the share of fungi characteristic of closed forests (Fomitopsis betulina (Bull.) B.K. Cui, M.L. Han & Y.C. Dai, etc.) decreased by 12%. There appeared fungi characteristic of drying and disturbed forest stands (Irpex lacteus (Fr.) Fr., Metuloidea murashkinskyi (Burt) Miettinen & Spirin, Phlebia tremellosa (Schrad.) Nakasone & Burds., etc.). They accounted for 25% of the wood-decaying community species (Figure 4).

The following 2014 and 2015 were cool and moist and promoted tree growth. The fungi abundance reduced to 27, number of species – to 19. The share of drought-resistant forest steppe species dropped to a minimum (17%). Species characteristic of the drying tree stands were not registered, while the share of the forest species reached its maximum of 54%. There appeared a hydrophylous Antrodiella semisupina (Berk. & M.A. Curtis) Ryvarden. In the hot and droughty years of 2016 and 2021, the fungi diversity increased again, but to a lesser extent than in 2012. The indicator Betula-complex has considerably changed. The share of forest fungi went down to a minimum of 17%; the share of fungi characteristic of open forests and drought-resistant fungi rose to a maximum of 72 and 56%, respectively; fungal indicators of drying forest stand account for 11%. Thus, with a high enough crown density, the 2021 condition of the forest stand is similar to that of forest steppe.

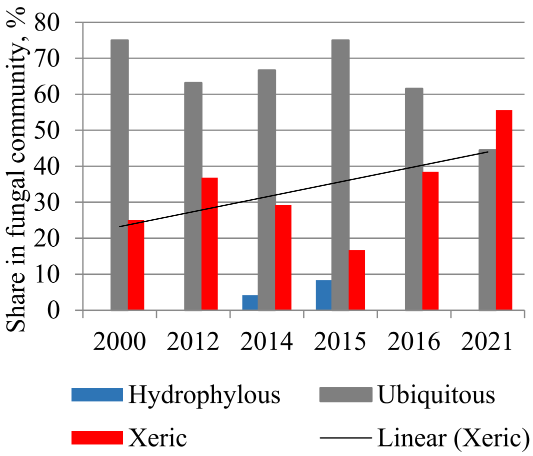

Fig. 3. The Change in Fungal Indicators of Hydrothermal Regime at the SP (in the Betula-Complex).

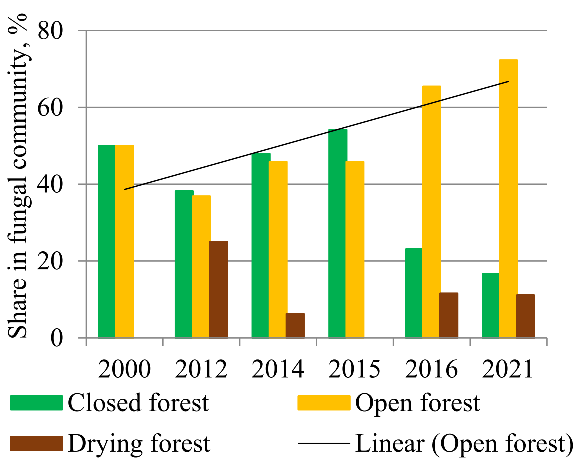

Fig. 4. The Change in the Number of Fungal Indicators of the Forest-Stand Condition on the SP (in the Betula-Complex).

Therefore, with predictable fluctuations of fungal biota in the years of diverse weather and climate conditions, the 2000-2021 trend shows an increase of species diversity and abundance of xerophile wood-decaying fungi. This is in line with climate trends and corroborates our previous findings [8].

3.2 The condition and diversity of grass and shrub layer

The grass and shrub layer at the SP is well developed, its foliage cover is high (about 90%) and shows little variation from year to year. Mean species saturation is 22 species per quadrat.

 https://doi.org/10.1051/e3sconf/202339007003

Over the monitoring period, 79 species of vascular plants coming from 64 genra and 30 families were registered. Figure 5 shows the data split by year.

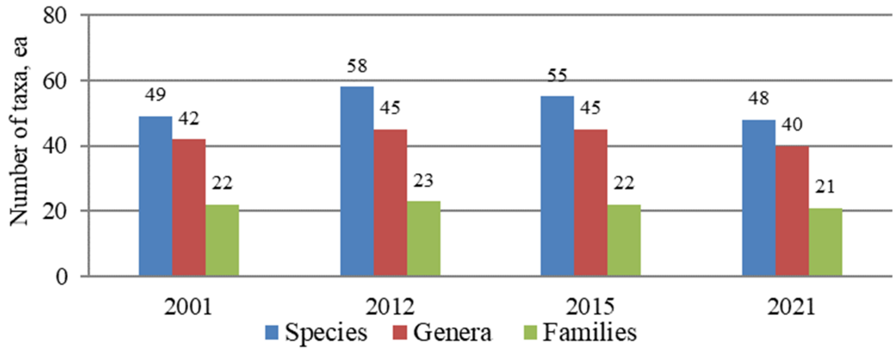

Fig. 5. Taxonomic Richness of Grass and Shrub Layer on the SP by Years.

The species richness was highest in 2012 and gradually declined thereafter. The following seven main taxa are always in the list of the most numerous families: Poaceae, Pyrolaceae, Ericaceae, Rosaceae Fabaceae, Apiaceae, Asteraceae. These families account for over 63% of the floristic list of all the research years.

The species of the SP grass and shrub layer vary from year to year. Floristic similarity gradually decreases compared to that of 2001. In 2012 it was almost 75% (Sørensen index), an in 2012 it was only 66%. This fact evidences directed changes in the plant community species structure. The correlations changes in plant groups from different latitudes attest to the same (Figure 6).

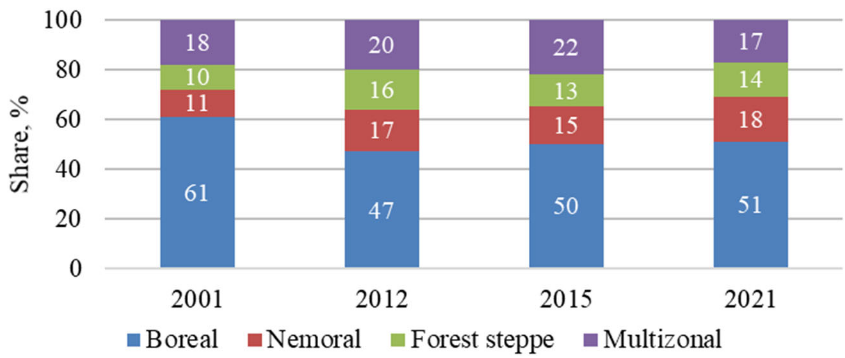

Fig. 6. The Distribution of Plant Species across Latitude Range Types on the SP by Years.

In 2012 the share of boreal plants decreased considerably (by 14%) as compared to 2001. At the same time, the share of nemoral and forest steppe species grew, as they flourished in more suitable weather and climate conditions exploiting their strengths. We regestered the same trend for suburban forests of Tyumen [9]. The nemoral species react primarily to climate warming, and the xerophile forest steppe species indicate an increase in climate dryness. Such latitude groups correlation in SP plant community mostly persists in the subsequent monitoring and may be considered a consequence of continuing global climate changes, namely of an increase in climate aridity.

3.3 Terrestrial vertebrates

Three monitoring periods (2001, 2010, and 2021) showed presence of four vertebrate classes (Amphibia, Reptilia, Aves and Mammalia) in terrestirial vertebrate communities, but there were only one species coming from each of the first two: Rana arvalis Nilsson, 1842 and Zootoca vivipara Lichtenstein, 1823, respectively. It should be noted that R. arvalis was registered only in 2001 and 2010 at a rate of three and one individuals per 1 km of the route. Z. vivipara was registered in all the tree periods with the abundance of 1, 2 and 4 individuals per 1 km of the route respectively. Thus, over the period under study, the share of hydrophylous species declined, while the share of xerophile species of herpetofauna increased.

Over the three periods, the total number of species in bird and mammal communities was 27 and 12, respectively. Over the research period, the number of registered species from both classes gradually decreased along with a decrease of relative abundance of both birds (from 291 to 92 individuals/km2), and mammals (from 18.6 to 9.5 specimen/100 trap-days). At the same time, the share of phytivorous birds in the community decreased, and omnivores were registered only in 2001. Nevertheless, there is an opposite pattern obesrved when the species domitating in number change from Sylvia borin Boddaert, 1783 and Phylloscopus trochiloides Sundevall, 1837 to Fringilla coelebs L., 1758. This, to our mind, may be caused by a decreasing shade density due to crown defoliation and partial tree loss. As a result, we registered an increase in insect species variety with a decrease of hydrophilous and sciophilous species (e.g., Culicidae, etc.)

Mammal community showed a decline of Soricidae family (from four to one, the most adapted species – Sorex araneus) and to a lesser extent of Arvicolidae, on top of Sciuridae family species loss and emerging Muridae species, not registered before that. As for the voles, there are no meadow voles of Microtus genus anymore, and in red-backed voles of Clethrionomys genus, the dominance of a more xerophile Clethrionomys ritulus has doubled as comparred to Clethrionomys glareolus. All these facts may indicate xerophytization of the terrestrial vertebrates habitats [10]. The processes of structural change in bird and small mammal communities found their way into biological diversity indices dynamics (Table 1).

Table 1. Biological Diversity Indices of Terrestrial Vertebrates (Birds/Mammals) over the Years of Research.

Biological diversity index	2001	2012	2021
Margalef species richness index	8.93 / 7.09	9.00 / 4.20	6.62 / 4.09
Shannon diversity index	3.71 / 2.35	3.79 / 2.21	3.10 / 2.04
Simpson's diversity index	0.91 / 0.74	0.91 / 0.75	0.85 / 0.72
Simpson's dominance index	0.095 / 0.26	0.094 / 0.25	0.15 / 0.28
Share of rare species	0.30 / 0.34	0.18 / 0.13	0.24 / 0.10
Resistant sustainability	1.32 / 1.18	1.32 / 1.56	1.40 / 1.52
Resilient sustainability	22.97 / 8.16	22.97 / 8.67	15.94 / 7.22

The table analysis bears witness of a decrease in Shannon richness and Simpson's diversity indices with a concurrent growth of Simpson's dominance index and rare species index. As for the integral characteristics, there is an understandable increase of resistant sustainability of bird and mammal communities, with its declining resilient component. Thus, we may say that the share of most adapted to the conditions but less plastic forms grows [12, 13].

4 Conclusions

Our findings afford a conclusion that the composition, condition, and dynamics of biological diversity of different groups of organisms in the subtaiga grass-and-shrub pine forest is mostly determined by weather and climate conditions of a certain growing season, as well as by perennial climate trends prompted by global processes. On the whole, over the monitoring period, the subtaiga forest biological community showed a growing similarity to forest steppe forest communities.

References

1. S. N. Gashev et al., Bulletin of Ecology, Forestry and Landscape Science **3**, 11-23 (2002)
2. Weather and climate. (2020). URL: http://www.pogodaiklimat.ru/monitor.php?id=28367 (accessed 25.03.2022)
3. S. P. Arefyev, *Systemic analysis of lignicolous mycobiota* (Nauka Press, Novosibirsk, 2010)
4. V. M. Poniatovskaya, *A survey abundance and peculiarities of species distribution in natural plant communities Field Geobotany* (Nauka Press, Moscow-Leningrad, 1964) **3**, pp. 209-289
5. Y. S. Ravkin, *To the bird census method in forest landscapes Nature of foci of tick-borne encephalitis in Altai* (Nauka Press, Novosibirsk, 1967), pp. 66-75
6. V. V. Kucheruk, N. A. Nikitina, *Main tasks and results of mammal tagging in USSR. Results of tagging of mammals* (Nauka Press, Moscow, 1980)
7. S. N. Gashev, *Methodology of complex assessment of communities and populations condition of dominant or indicator species of small mammals, amphibians and fish: guidelines* (Tyumen State University, Tyumen, 2005)
8. S. P. Arefiev, M. N. Kazantseva, Mycology and Phytopathology **50(1)**, 5-13 (2016)
9. M. N. Kazantseva, Environmental monitoring and biodiversity **1(11)**, 47-51 (2016)
10. S. N. Gashev, *The impact of oil pollution on the fauna and ecology of small mammals of the Middle Ob Region: Doctor's Thesis in Biology* (Sverdlovsk: Institute of Ecology and Natural Resources of Ural Branch of Academy of Sciences of USSR, 1991)
11. S. N. Gashev, *Mammals in the of ecological monitoring system (Tyumen Region)* (Tyumen State University Press, Tyumen, 2000)
12. S. N. Gashev, *Systems Ecology Lectures: study guide* (Tyumen State University, Tyumen, 2007)