Long-term Post-fire Monitoring of the Breeding Bird Populations in the Kerzhensky State Nature Biosphere Reserve (Central Volga region, Russia)

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Abstract: In the summer of 2010, about a half of the Kerzhensky State Nature Biosphere Reserve territory suffered from a wildfire. During the 9 following years, monitoring of the bird populations in the breeding season was conducted there. Birds were counted by a route method in 6 main habitats differ in their fire burned types and also in unburned similar habitats. A total of 130 bird species were registered. In the first years after the wildfire impact, bird populations in the habitats affected by different wildfire types were similar according to the Sorensen-Chekenovsky’s index. This similarity increased to 2016. The similarity of the bird populations of burned sites has been decreasing last two years. The species richness changed in different directions. At first study years, the abundance of the breeding bird populations increased both in burnt and unburnt sites, while later this parameter decreased a bit and stabilised. Although interannual changes in indicators are still possible. The bird populations of the unburnt habitats, especially bogs, differ by lower values of indicators for the last five years. The influence of nature-climatic indicators of various months (average the monthly air temperature, the daily amount of precipitation) on the interannual dynamics of the breeding avifauna abundance was noted in only one case, out of 84 indicators. We distinguished the species (e.g. Sylvia communis) recognised as indicators of damaging by fire. Fringilla coelebs was dominant in all habitats studied, but from 2017, Anthus trivialis dominated in the severely burned birch-pine forests and on the raised bogs (burned and unburned). The most intense changes in bird populations were observed within the first five post-fire years.

1. Introduction

Wildfires arise from both natural and anthropogenic causes [1, 2]. For a long time, an interest to study the post-fire recovery processes in various natural ecosystems has existed. In this regard, Protected Areas represent important sites to study the natural processes of post-fire succession, further recovery of ecosystems and their components destroyed by wildfire [3–5].

Several authors (6–9) studied patterns of the post-fire recovery and the biogeocenose formation, including plant communities. Perera & Buse [10] concluded that wildfire is an integral part of the long-term functioning of forest biomes. Similar conclusions were also made on the basis of studies in savannas [11].

Most studies have been devoted to the invertebrates, primarily insects [e.g. 12–14], and in vertebrates – to the birds [15, 3, 16, 4, 17].

Excessive wildfires affected the Nizhny Novgorod region in the summer of 2010. Some Protected Areas also suffered from wildfire, including the Kerzhensky State Nature Biosphere Reserve (hereafter – Kerzhensky Nature Reserve). About a half of the Protected Area (about 210 km²) got burnt. During the 2011–2017 field seasons, we researched the wildfire influence and its consequences on the species richness, spatial distribution, relative abundance, and post-fire recovery dynamics of the Tetrapoda populations, including birds, in the Kerzhensky Nature Reserve. Previously, we have already published partially the results of studies devoted to some groups of Tetrapoda animals and their comparing [5, 18].
This article presents the results of the long-term monitoring of the bird populations of the Kerzhensky Nature Reserve during the breeding season, including the last two years of research (2018 and 2019).

2. Results and Discussion

The Kerzhensky Nature Reserve (total area – 467.9 km²) is located in the Nizhegorodsky region on the left bank of the Kerzhenets River, a tributary of the Volga River. The Protected Area is located at the north of the coniferous-broad-leaved forest zone. The Kerzhensky Nature Reserve is a part of wetlands included in the UNESCO International Biosphere Reserve «Nizhegorodskoye Zavolzhye». In the Kerzhensky Nature Reserve there are large areas of bogs, and young-aged and middle-aged pine (Pinus sylvestris L.) forests. During the spring-summer period, the Kerzhensky Nature Reserve regularly suffers from wildfires.

Birds were counted by a route method without limiting the count strip according to Ravkin [19] in 6 main habitats in the Kerzhensky Nature Reserve every year in the period from 16 May to 15 July 2011–2019 (unburned floodplain deciduous-spruce-pine (Tilia europaea – Picea abies – Pinus sylvestris) forests – from 2013). The birds were surveyed during the morning counting. The routes were constant. And the counting was repeated four times each breeding season, and the total accumulated length of the pedestrian routes for bird counting was 1760 km. We determined two wildfire types as follows. The first type is the surface wildfire destroying partially the shrub layer only and no damaging the tree canopy. The second type is the crown wildfire usually leading to almost complete destroy of the tree canopy and the forest floor. In addition, we included the areas non-suffering of the 2010 wildfires aiming to allow comparing the changes between burnt and unburnt areas. Also the territory of abandoned settlements burned by fires was surveyed, unfortunately these data are not considered in this article.

All bird observation data were loaded into the database of the Zoomonitoring laboratory in the Institute of the Systematics and Ecology of Animals of RAS. The staff of this laboratory executed the processing of obtained data. We have considered abundance (density), biomass and other indicators applied in Noskova et al. [5], Lebedinskii et al. [18]. The biomass calculation was given according to Dementiev & Gladkov [20]. To estimate of the interannual similarity of the bird populations of different habitat types we calculated the Sorensen-Chekanovsky index. In the analysis of the connection of the breeding avifauna abundance with nature-climatic indices (the average monthly air temperature and the daily sum of the precipitation), we used Spirman's rank correlation coefficient (rS). A total of 14 long-term series of indicators (for April, May, separately the second half of May, June, the first and second half of June and the entire breeding season) were analyzed. Only one rS index of 84 ones obtained has reliable value. Statistical data processing was carried out in MS Excel 2003 and StatSoft Statistica v6.0.

2.1. The interannual dynamic of the species richness

During the breeding season, we recorded 130 bird species from 37 families and 14 orders, comprising 72% of resident bird species of the Reserve [21]. According to census data the species number was varying between 81 and 98 in different years. Thus, 31 % of them were registered every year, another 28 % – almost every year, and 14 % were noted at once.

After the 2010 wildfire impact, we revealed the main tendencies and some regional patterns of the bird population trends in the Kerzhensky Nature Reserve. Due to the tree fallout observed after the wildfire impact, the heterogeneity of the study area increased in general. In the forests affected by the surface wildfires, it promoted both an increase in the species number and size of bird populations during the breeding season (Figure 1, 2).
Figure 1 – Long-term post-fire dynamics of the species number of the breeding birds population in different habitats of the Kerzhensky State Nature Biosphere Reserve. Labels: 1 – severely burnt (after the crone wildfire) birch-pine forests, 2 – lightly burnt (after the surface wildfire) birch-pine forests, 3 – unburnt birch-pine forests, 4 – unburnt floodplain deciduous-spruce-pine forests, 5 – burnt bogs, 6 – unburnt bogs.

Figure 2 – Long-term post-fire dynamics of the cumulative abundance (a, b) and biomass (c, d) of the breeding bird populations in different habitats of the Kerzhensky State Nature Biosphere Reserve. Labels: 1 – severely burnt (after the crone wildfire) birch-pine forests, 2 – lightly burnt (after the surface wildfire) birch-pine forests, 3 – unburnt birch-pine forests, 4 – unburnt floodplain deciduous-spruce-pine forests, 5 – burnt bogs, 6 – unburnt bogs.
The crown wildfire resulted in the decrease in ornithological indicators (species numbers, size of populations) during the first post-fire year. However, the intense overgrowing of these sites with Epilobium angustifolium L. encouraged breeding the birds of forest edges and of dry valleys during the second post-fire year. It consequently doubled the species number. During the summers, the highest species numbers were recorded more frequently on the fire-damaged sites (excluding the area of abandoned settlement) than on the unburnt sites.

At the same time the regional peculiarities of the changes in bird fauna were revealed in the fire-affected sites. During the breeding season, following bird species were concluded to be indicators of the fire-affected sites. There were Sylvia communis Latham, 1787, Acrocephalus dumetorum Blyth, 1849, A. palustris (Bechstein, 1798), Motacilla alba Linnaeus, 1758, and Lanius collurio Linnaeus, 1758. These bird species were more numerous or even predominant in the fire-affected sites, while they never were abundant in unburnt forests. For example, in burnt areas, we observed more frequently Motacilla alba and Lanius collurio than others species-indicators.

The abundance of birds inhabiting the forest edges had increased in the burnt sites of the Kerzhensky Nature Reserve only by the second post-fire year. It is concerned mainly Anthus trivialis (Linnaeus, 1758), Muscicapa striata (Pallas, 1764), and Phylloscopus trochilus (Linnaeus, 1758). During the 2019 breeding season, these bird species still prevailed on the burnt sites, comprising 50–59 % of the total bird abundance. In lightly burned birch-pine (Betula pendula – Pinus sylvestris) woods the forest bird species often predominated (in 2011, 2012, 2016–2018). On the unburnt sites, the proportion of the forest-confined species increased up to 77 % of the total abundance value during 2015–2017. It was noted decreasing during the last two years of surveys, down to 51 % in 2019.

2.2. The change of the most numerous breeding birds

Based on the abundance values during the breeding season Fringilla coelebs Linnaeus, 1758 absolutely predominated in all habitats. Its abundance was up to 45 % in unburnt sites and up to 34 % in burnt areas (Table 1). Actually, this species had no co-dominants in the unburnt forests. In the burnt sites and in the unburnt bogs, Anthus trivialis was a co-dominant of Fringilla coelebs (both species had up to 24 % of total abundance). These two bird species predominated also in the burnt forest sites in the Oka State Nature Biosphere Reserve and the Balakhna depression. In the latter case, Anthus trivialis was recorded prevailing more frequently than Fringilla coelebs [4, 17].

| Year | Habitat types | Frequent species |
|------|---------------|-----------------|
|      |               | 2011            | 2012            | 2013            |
|      |               | Fringilla coelebs (28), Anthus trivialis (12), Phylloscopus trochilus (11) | Fringilla coelebs (24), Anthus trivialis (20), Fringilla coelebs (16) | Fringilla coelebs (24), Anthus trivialis (14) |
|      |               | Fringilla coelebs (34), Phylloscopus collybita (10) | Fringilla coelebs (31), Anthus trivialis (17) | Fringilla coelebs (24), Anthus trivialis (14) |
|      |               | Fringilla coelebs (45) | Fringilla coelebs (28), Parus montanus (12) | Fringilla coelebs (34), Fringilla coelebs (20) |
|      |               |                  | Fringilla coelebs (20), Anthus trivialis (11) | Fringilla coelebs (23) |
|      |               |                  | Fringilla coelebs (25), Anthus trivialis (11) | Fringilla coelebs (27), Anthus trivialis (18), Parus montanus (12) |

Table 1. The most numerous breeding birds observed in the Kerzhensky State Nature Biosphere Reserve after the 2010 wildfire (% of total bird abundance)
In the burnt sites of the Kerzhensky Nature Reserve, Sylvia communis and (in some years) Phylloscopus trochilus (both species averaged to 11–17% of the total abundance) were recognized as co-dominants during the fourth and fifth years after the wildfire affect. In the fourth year after the 2010 wildfire (i.e. 2014), Sylvia communis predominated also in the Oksky State Nature Biosphere Reserve, where this species shared its dominance status together with Erithacus rubecula (Linnaeus, 1758). The increased abundance of these species, together with Phylloscopus trochilus, may be caused by the development of Betula pendula Roth undergrowth on the fire-damaged sites [4].

Since 2017, Anthus trivialis has predominated (up to 20% of total abundance) in the severely burned birch-pine forests and on the bogs (burned and unburned) in the Kerzhensky Nature Reserve and Phylloscopus trochilus has permanently accompanied in the burnt sites (up to 17%).

### 2.3. The interannual dynamics of the total abundance and biomass

The abundance and biomass of the breeding birds were noted increasing with subsequent stabilization both on burnt and on unburnt sites during the first post-fire years. Although interannual changes in indicators are still possible. At the same time, virtually the lowest values of indicators of bird populations were registered in the unburnt sites, especially bogs. The exception was 2018, when the lowest values of indicators of the bird populations were noted in the burnt sites and floodplain forests.

| Year | Dominant Species | Subordinate Species | Silvia communis | Fringilla coelebs | Phylloscopus trochilus | Anthus trivialis |
|------|------------------|---------------------|----------------|-------------------|----------------------|------------------|
| 2014 | Fringilla coelebs | (18), Anthus trivialis (14), Sylvia communis (11) | (21) | (29) | (16), Silvia communis (12) | (17), Anthus trivialis (20) |
| 2015 | Fringilla coelebs | (18), Anthus trivialis (14), Sylvia communis (13) | (16), Anthus trivialis (13), Parus montanus (10) | (30) | (18), Anthus trivialis (14), Silvia communis (12) | (24), Anthus trivialis (19), Parus montanus (12) |
| 2016 | Fringilla coelebs | (21), Anthus trivialis (18) | (25), Anthus trivialis (13), Phylloscopus trochilus (11) | (34), Parus montanus (13) | (16), Anthus trivialis (14) | (32), Anthus trivialis (18) |
| 2017 | Anthus trivialis | (19), Fringilla coelebs (17), Phylloscopus trochilus (17) | (30), Anthus trivialis (13) | (43) | (20), Fringilla coelebs (18), Phylloscopus trochilus (12) | (19), Fringilla coelebs (16) |
| 2018 | Anthus trivialis | (18), Phylloscopus trochilus (16) | (14), Anthus trivialis (11), Fringilla coelebs (10), Phylloscopus trochilus 10 | (27), Phylloscopus sibilatrix (11) | (22) | (14), Parus montanus (12) |
| 2019 | Anthus trivialis | (18), Phylloscopus trochilus (12), Fringilla coelebs (11) | (15), Phylloscopus trochilus (10) | (27), Parus major (14) | (16), Anthus trivialis (11), Fringilla coelebs (11) | (24), Fringilla coelebs (23) |
| Average | | (15), Anthus trivialis (15) | (25), Anthus trivialis (14), Phylloscopus trochilus (10) | (33) | (17), Anthus trivialis (12) | (26), Anthus trivialis (17) |

Note: 1 – the habitat was not surveyed.
The comparison of interannual post-fire dynamics in the numbers of breeding bird species has revealed some comparable changes in the avifauna of unburnt birch-pine forests, burnt bog, both severely and lightly burnt birch-pine forests, as well as unburnt bog and unburnt floodplain forests for seven post-fire years. For the first two mentioned habitats, an almost twofold increase in abundance of the bird species was observed in the second year after the fires. Then, we noted the indicators increasing in all four habitats in the third year. However, the indicators of these bird species declined in the fourth year, whilst these hardly changed in total within the next three years. The last two years have seen differences in the abundance of the bird populations.

Such simultaneous changes in the abundance have been caused by both the weather conditions of a particular year, as well as by the vegetation successions on the burnt sites. For example, the avifauna structure in unburnt birch-pine forests seemed to be similar with one in burnt bogs, where the birch formed homogeneous dense undergrowth having grown since the first post-fire year. The severely and lightly burnt birch-pine forests alternate mosaically with each other. Therefore, interannual post-fire dynamics of the bird species abundance was similar within these habitats. The influence of nature-climatic indicators of various months (average the monthly air temperature, the daily amount of precipitation) on the interannual dynamics of the breeding avifauna abundance was noted in only one case (out of 84 indicators). The reliable negative link was revealed between the long-term dynamics of the abundance of the bird population of burned bogs and the average monthly air temperature of the second half of May $r_S = -0.71$ ($p$-level<0.05).

According to the Sorenson-Chekanovsky’s index, the avifauna of the forest sites and bogs affected by fired was similar in the first post-fire years, because these habitats stochastically alternate with each other (Figure 3).

Over the next period, this similarity was increasing to 2016, especially between the avifauna in the burnt bogs and the severely burnt birch-pine forests [5]. The maximum of the similarity between lightly burned birch-pine forests and burned bogs was evident only in 2016. However, the similarity of the bird populations of burned sites has been decreasing for the last two years.

![Figure 3](image)

**Figure 3** – Long-term post-fire dynamics similarity of breeding bird populations of the burnt sites in the Kerzhensky State Nature Biosphere Reserve after the 2010 wildfire. Labels: 1 – severely burnt (crone wildfire) birch-pine forests and burnt bogs, 2 – severely burnt (crone wildfire) and lightly burnt (surface wildfire) birch-pine forests, 3 – lightly burnt (surface wildfire) birch-pine forests and burnt bogs.

### 3. Conclusions

On the basis of the above-mentioned results, we can draw the following conclusions.

The 2010 wildfire had a significant impact on the bird populations in the Kerzhensky Nature Reserve, as did on the rest of the Tetrapoda fauna [18]. In comparison with other groups of the Tetrapoda birds were the least vulnerable to the wildfire effect, because they are capable to actively avoid it. They were able to inhabit the burnt areas, and come back again, once the appropriate breeding conditions were restored or even improved, because of the succession specifics.
The wildfire caused species redistribution, multidirectional dynamics of the abundance indicators and replacement of the dominants in the study site. In the burnt areas, we identified bird species being considered as indicators of wildfire impact. These species were more abundant in burnt sites in comparison with similar unburnt sites, where they never or only occasionally predominated. These bird species-indicators were Sylvia communis, Acrocephalus dumetorum, A. palustris, Motacilla alba, and Lanius collurio.

The avifauna of the forest sites and bogs affected by fired was similar in the first post-fire years due to their mosaic structure. This similarity was increasing to 2016, but on the contrary has been decreasing for the last two years.

Coordinated changes in the abundance of the bird populations in different habitat types have been most likely caused by the vegetation successions after wildfires. The reliable relationship (rS) between the interannual dynamics of abundance of the bird populations and nature-climatic indicators (average monthly air temperature, daily amount of the precipitation) in breeding period was noted in only case out of 84.

The recovery rates of each species abundance in the concerning Tetrapoda groups were different [18]. The formation of the post-fire bird communities took 4–5 years. During this period, the most intense changes occur in the bird populations. Wildfires occur with a certain frequency in this area, so the processes of the avifauna restoration are periodically repeated. At the same time, they manifest both common succession patterns and regional features.

4. Acknowledgements

The authors express their gratitude to the staff of the Kerzhensky State Nature Biosphere Reserve for allowing them to carry out this research. We are also grateful to Yu.A. Sorokina, L.N. Odrova, S.V. Strizhova and S.V. Bakka for their help in collecting field data.

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