Pyrogenic transformation of old pine forests in the Middle Volga Integrated Biosphere Reserve and its effect on the nesting birds

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Abstract. The effects of the pyrogenic transformation of old pine forests of the Middle Volga Integrated Biosphere Reserve on the nesting birds were studied, based on the original surveys performed in 2006–2009. The changes of the breeding ornithological fauna’s parameters were traced during the restoration of the lower tiers of vegetation after local lower fires. The response of particular species and guilds of nesting birds to the changes in nesting conditions due to a single bottom fire was determined, as well as the changes in the total number of nesting birds and in the number of particular guilds of nesting birds during the vegetation recovery after the fire. The bird species vulnerable to the changes in nesting conditions were identified. The relationship between post-pyrogenic vegetation restoration processes in old pine forests and the species composition and ecological preferences of birds nesting was shown.

1. Introduction

Ground fires are usual in the old pine forests of the northern part of the Middle Volga Integrated Biosphere Reserve. Their area is usually insignificant, but they occur regularly. Therefore, the area of the pine forests of the reserve having never been affected by the ground fire is quite small. The transformation of grass and bush tiers is the basic effect of ground fire on the old pine forests. Bush tier is usually oppressed or destroyed and grass tier is destroyed as a result of even a single fire. The thin-barked trees of the second tier and pine undergrowth are also damaged. Transformation of the vegetation of these tiers changes the nesting conditions for birds. In the forests, exposed to lower-tier fires, the changes in the species composition and in the abundance of particular species and guilds of nesting birds are registered. The study analyzes the effects of various single lower-tier fires, differed by the time passed from fire incident, on nesting birds of the old pine forests. The changes in the parameters of the avifauna along with the transformation of vegetation were studied for the temporal series, from the areas with no fire to the areas characterized by the maximum time passed from fire incident. The role of nesting birds in the bush vegetation restoration is shown.

2. Material and methods

The field surveys were performed in the spring-summer period of 2006–2009 in the northern part of the Middle Volga Integrated Biosphere Reserve (Stavropol Pine Forest). The nesting birds of old pine forest ecosystems were the study objects. The pristine ecosystems were initially classified as the
linden (*Tilia*)-goutweed pine forests. Due to the ground fires and subsequent restoration of vegetation, they have undergone a transformation of the lower tiers. This has changed significantly the nesting conditions for the birds and thus influenced the species composition and abundance of the nesting birds.

We studied the state of the forest ecosystems affected by local ground fires. The state of vegetation and the changes of the nesting avifauna of the forest areas that had undergone the ground fire were estimated for each canopy tier separately. The fire impact on the vegetation was assessed on standard geobotanical sites, five sites per each study area [1, 2]. The avifauna was studied by the route method with a fixed width of the accountable area [3].

The areas where local ground fires occurred once, but at different times, were compared. The total anthropogenic background in the compared areas was the same, since the areas were adjacent to each other and were at approximately the same distance from the pollution sources. Vegetation parameters were compared for six areas: (1) the area of the unburned pine forest, (2) the area where the fire occurred 1-2 years before the year of study, (3) ibid., 3-4 years before, (4) ibid., 5-6 years before, (5) ibid., 15-16 years before, and (6) the area where the fire occurred not less than 30-35 years before the year of study. Nesting avifauna was studied at four areas: (1) the area of the unburned pine forest, (2) the area where the fire occurred 3-4 years before the year of study, (3) ibid., 15-16 years before, and (2) the area where the fire occurred not less than 30-35 years before the year of study. For the areas, affected by local ground fire, this event should occur at least once prior to our study. In order to study the nesting birds, we selected the areas where it was possible to perform an accounting route with a length of at least 500-600 m and width of 100 m. Five one-time counts were conducted for each area. According to the results of the birds count, the total abundance and population density of particular species of nesting birds was calculated, as well as the population density of each guild of nesting birds. Significance of the differences was determined by the Fisher test (F-test) at a significance level of 5% (P = 0.05).

3. Results and discussion

Even local ground fires may significantly transform the original ecosystem of the old pine forest and change drastically the nesting conditions for birds there. As the grass tier is burned down and the bushes and undergrowth are dying after the fire had passed, the protective conditions of the nesting biotope is reducing, so the number of potential ecological niches reduces as well. However, the restoration processes of the vegetation of the lower canopy tiers are very rapid. Within a few years after a single ground fire, the vegetation density of the grass layer is restored to reference values, and then even exceeds them (table 1). In this case, the species composition of the vegetation of this tier can change significantly. Meantime, there is a gradual progressive restoration of the bush layer and undergrowth taking place along the restoration of the grass layer.

Table 1. Plant population density in the old pine forests in the areas differed by the time passed from fire event.

| Density of vegetation by tiers | Time passed from the ground fire |
|-------------------------------|----------------------------------|
|                               | No fire | 1-2 years | 3-4 years | 5-6 years | 15-16 years | 30-35 years |
| Grass tier, sprouts per 1 m²  | 17.3    | 62.3      | 20.7      | 101.3     | 157.0       | 148.2       |
| Bush tier, plant specimens per 1 ha | 1,593.6 | 46.4      | 430.4     | 1,961.6   | 4,096.0     | 4,392.0     |
| Undergrowth tier, plant specimens per 1 ha | 4,428.8 | 76.8      | 2,547.2   | 2,227.2   | 2,048.0     | 2,126.4     |

The transformation of the lower tiers affects both the abundance and the species composition of nesting birds.

As a result of the changes in the vegetation of pine forests exposed to ground fires, the peculiarities of formation of the breeding avifauna are quite specific. Analysis of the changes in the total population density revealed that the latter decreased during the first years after the fire, then recovered as the
undergrowth and bush layers formed, and then increased up to the values significantly exceeding those observed before the fire (table 2).

The primary decrease and the subsequent increase in bird abundance is due to the bird species nesting in the open spaces. The most significant changes in population were registered for the guild of birds nesting openly and mainly in the lower tiers. After a sharp decrease in the first years after the fire, the number of birds of this guild increases rapidly. The guild of birds nesting openly and predominantly in the upper and middle tiers of old pine forests changes slightly its abundance in the first several years after the fire event, but increases significantly after several years. The abundance of birds nesting in hollows remains stable in the first years after the fire, then decreases and reaches its minimum in 15-20 years after the fire; finally, it begins to grow slowly and reaches the reference values in 30-35 years.

**Table 2. The structure of the breeding avifauna of old pine forests**

| Guild of birds                                      | Population density, pairs per 1 km², after the ground fire |
|-----------------------------------------------------|----------------------------------------------------------|
|                                                     | No fire | after 3-4 years | after 15-16 years | after 30-35 years |
| Birds nesting openly and predominantly in the lower tiers | 145.8   | 87.5            | 179.2            | 283.3            |
| Birds nesting openly and predominantly in the upper and middle tiers | 173.6   | 150.0           | 162.5            | 283.4            |
| Birds nesting in hollows                           | 104.1   | 118.7           | 75.0             | 111.1            |
| Total                                               | 423.5   | 356.2           | 416.7            | 677.8            |

The difference in the total bird abundance per guild was reliable in the compared areas, but no significant differences were found when comparing the abundances of particular bird species. This was due to the small size of the areas affected by the ground fire, in particular, the size of such areas were comparable to the size of the nesting area of the registered species. However, the analysis of changes in species composition revealed similar patterns as observed when analyzing the bird abundance per guild. In the first years after the fire event, only three bird species of the lower tier were registered during surveys (table 3). These were the species nesting exclusively on the ground. Only after 15-16 years passed after the fire, when the bush tier has restored significantly, the species belonging to the guild of birds of the lower tiers (i.e., nesting in the bushes and undergrowth) have appeared, e.g. these were warblers (*Sylvia* spp.). This guild reached its highest species diversity in the pine forests after the dozens of years after the fire event. Meantime, this guild was mostly represented by the species of sparse forests, woodland edges, and open forests. The bird species of the guild, preferring dense woods, such as Eurasian blackcap (*Sylvia atricapilla* L.) and thrush nightingale (*Luscinia luscinia* L.) disappeared from pine forests affected by fire, they appeared only after 30-35 years passed after the fire event. Only two species of the sixteen representatives of this guild, the common chiffchaff (*Phylloscopus collybitus* Vieill.) and the tree pipit (*Anthus trivialis* L.), turned out to be quite eurytopic; they were found in all the transformed areas as well as in the initial sites (unaffected by fire).

There are only two commonly eurytopic species, common chaffinch (*Fringilla coelebs* L.) and carrion crow (*Corvus corone* L.), in the guild of birds nesting mostly openly and in the upper and middle canopy tiers of the old pine forests. The pine forests transformed by fire turn out to be completely unfavorable for nesting of such species of this guild as icterine warbler (*Hypolais icterina* Vieillot.) and fieldfare (*Turdus pilaris* L.). These species appeared again only after a dozens of years have passed after the fire.

In the guild of cavity nesters, the European robin (*Erithacus rubecula* L.) was the most vulnerable to the forest transformation caused by fire; this species has never been found in the areas of the old pine forests affected by fire.
Table 3. Species composition of nesting birds of the old pine forests affected by fire

| Species                               | Presence of the species on a site after the ground fire event (years passed) |
|----------------------------------------|--------------------------------------------------------------------------------|
|                                        | No fire | 3-4 years | 15-16 years | 30-35 years |
| **Birds nesting openly and predominantly in the lower canopy tiers** |          |            |              |             |
| Phylloscopus collybitus Vieill.        | +        | +          | +           | +           |
| Phylloscopus trochilus L.              | +        | -          | +           | +           |
| Phylloscopus sibilatrix Bechst.        | +        | -          | -           | -           |
| Anthus trivialis L.                   | +        | +          | +           | +           |
| Emberiza citrinella L.                | +        | -          | +           | +           |
| Luscinia luscinia L.                   | +        | -          | -           | +           |
| Locustella flaviatilis Wolf.          | -        | +          | -           | +           |
| Turdus iliacus L.                     | -        | -          | -           | +           |
| Sylvia atricapilla L.                 | +        | -          | -           | +           |
| Sylvia borin Bodd.                    | -        | -          | +           | -           |
| Sylvia curruca L.                     | -        | -          | +           | -           |
| Sylvia communis Latham.               | -        | -          | -           | +           |
| Sylvia nisoria Bechst.                | -        | -          | -           | +           |
| Acrocephalus palustris Bechst.         | -        | -          | +           | -           |
| Lanius cristatus L.                   | -        | -          | -           | +           |
| Erythrina erythrina Pall.             | +        | -          | -           | +           |
| **Birds nesting openly and predominantly in the upper and middle canopy tiers** |          |            |              |             |
| Fringilla coelebs L.                  | +        | +          | +           | +           |
| Hypolais icterina Vieillot.           | +        | -          | -           | +           |
| Chloris chloris L.                    | -        | -          | -           | +           |
| Carduelis carduelis L.                | -        | +          | -           | +           |
| Turdus pilaris L.                     | +        | -          | -           | +           |
| Turdus philomelos Brehm.              | +        | -          | -           | +           |
| Oriolus oriolus L.                    | -        | +          | +           | +           |
| Corvus corone L.                      | +        | +          | +           | +           |
| Pica pica L.                          | -        | -          | +           | +           |
| **Birds nesting in hollows**           |          |            |              |             |
| Parus major L.                        | +        | +          | +           | +           |
| Parus montanus Baldenstein.           | +        | +          | +           | +           |
| Muscicapa striata Pall.               | +        | -          | -           | +           |
| Ficedula hypoleuca Pall.              | -        | -          | -           | +           |
| Ficedula parva Bechst.                | +        | -          | -           | +           |
| Phoenicurus phoenicurus L.            | +        | +          | +           | +           |
| Erithacus rubecula L.                 | +        | -          | -           | -           |
| Sitta europaea L.                     | -        | +          | -           | +           |
| Jynx torquilla L.                     | -        | +          | +           | +           |
| Dendrocopos major L.                  | +        | -          | -           | +           |
| Dryocopus martius L.                  | -        | +          | +           | +           |
| Passer montanus L.                    | -        | -          | -           | +           |
| Apus apus L.                          | -        | -          | -           | +           |

The great tit (Parus major L.), the willow tit (Parus montanus Baudenstein), and the common redstart (Phoenicurus phoenicurus L.) were the hollow-nesting species characterized by the widest range of nesting biotopes. Such representatives of this guild as black woodpecker (Dryocopus martius L.) and the Eurasian wryneck (Jynx torquilla L.) were also attracted by the areas of pine forests, transformed by fires.
In turn, the birds influence greatly the post-pyrogenic regeneration of vegetation in pine forests. This is especially true for shrub vegetation. Most of the plant specimens found in the areas renewed after fire belong to ornithochoric species (table 4).

Table 4. Population density of shrubs in the old pine forests in the areas affected by fire.

| Population density of a group of shrub species, specimens per 1 ha | Time passed after the ground fire event |
|---------------------------------------------------------------|----------------------------------------|
|                                                               | No fire | 1-2 years | 3-4 years | 5-6 years | 15-16 years | 30-35 years |
| Low ornithochorous:                                           |         |           |           |           |             |             |
| common hazel (Corylus avellana), broom (Chamaecytisus ruthenicus) | 1,001.6 | 0         | 35.2      | 94.4      | 1,472.0     | 1,428.6     |
| Ornithochorous, originally present: spindle tree (Euonymus verrucosus), bird cherry (Prunus padus), rowan (Sorbus aucuparia), alder buckthorn (Frangula alni), fly honeysuckle (Lonicera xylosteum) | 592.0   | 46.4      | 395.2     | 740.8     | 1,024.0     | 1,384.0     |
| Ornithochorous, introduced after fire: European dwarf cherry (Prunus fruticosa), nanjing cherry (Prunus tomentosa), common cotoneaster (Cotoneaster integrerrimus) | 0       | 0         | 0         | 1,126.4   | 1,600.0     | 1,579.4     |

Low ornithochorous shrub species prevail in the pristine areas (unaffected by fire), and the species distributed mainly by birds dominate absolutely in the areas affected by the fire during the first years after this event.

4. Conclusion

The transformation of the old pine forests has an ambiguous effect on both the species composition and the abundance of nesting birds. In the first years after single ground fires, the conditions that are generally unfavorable for nesting birds are formed in the areas affected by fire. This is manifested as a decrease both of the species richness and of the total abundance of nesting birds. The guild of birds nesting mainly openly in the lower tiers of the forest, especially the birds nesting in bushes and undergrowth, suffers much more than the representatives of other guilds.

If the fire does not occur again in the coming years, the grass layer not only recovers, but becomes denser. On the affected site, favorable conditions are formed for the birds of the lower canopy tiers, nesting mainly on the ground. The population density of this guild increases in comparison with the initial density in the pristine forest.

Primarily, this increase is due to the species of birds that prefer sparse forests, such as tree pipit (Anthus trivialis) and yellowhammer (Emberiza citrinella). In pristine areas, these species may either be completely absent or may have a very low population density.

If the fires do not occur again, the overgrowth of the burning area with shrubs and young trees forms favorable conditions for the birds of the lower tiers, preferring to nest on bushes and in undergrowth. Again, there are many species of the sparse forests in this group, namely, common whitethroat (Sylvia communis), garden warbler (Sylvia borin), and red-backed shrike (Lanius collurio).

The restoration and growth of the shrub layer and undergrowth after a ground fire reduces the illumination in the lower tiers. Therefore, the number of open-forest bird species nesting openly in the lower tiers attracted by the changed conditions decreases gradually. In the overgrown forests, species preferring dense forests appear; these are the birds that inhabited this area before the fire, i.e. thrush nightingale (Luscinia luscinia) and the Eurasian blackcap (Sylvia atricapilla).

Birds that prefer to nest openly are more eurytopic in the upper and middle tiers than the representatives of other ecological groups. For example, common chaffinch (Fringilla coelebs) can nest in the lower tiers (shrubs and undergrowth), as well as in higher tiers (in the tree canopy),
including the trees of the first tier. Since the changes occurring under the influence of fires affect mainly the lower tiers, the transforming effect of local grassroots fires does not affect drastically the diversity of this group. Surely, the potential number of nesting habitats is also decreasing for this group, but even strong ground fires do not completely destroy their nesting conditions. That is why there is no noticeable decrease in abundance of the open-nesting bird guild of the upper and middle tiers of the pine forests after fires.

The conditions formed in the old pine forests 15-16 years after the fire are unfavorable for hollow-nesting birds. In the old pine forests, thin-bored foliage trees of the second tier, which die after the fire and fall out of the stand, are the main suppliers of hollows. The number of hollow-nesting birds in the old pine forests after ground fires decreases after some time and recovers up to the reference values only after 30-35 years after the fire event.

Not all the species of nesting birds are able to stand the pyrogenic transformation of their nesting sites. A number of species disappear from the areas affected by fire and do not appear again even after the complete restoration of vegetation. The observed increase in the species richness of nesting birds in the areas affected by fire, especially in the guild of birds of the lower tiers, is explained by the local nature of ground fires. Areas of varying degrees of pyrogenic transformation have a small size, they are adjacent to each other and to unaffected (pristine) areas. The combination of such areas forms a kind of ecotone, where the number of ecological niches for nesting birds increases. In the old pine forests, affected by repeating ground fires, the birds with different requirements for nesting conditions find their optimal niche.

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