Monitoring of the avifauna of the forest areas of Northern Fennoscandia exposed to emissions of industrial enterprises

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Abstract. The research allowed to describe modern species composition and population structure of bird of forests of the zone birch forests and sparse forest of the northwest part of the Murmansk region, also changes in the composition of avifauna in the process of anthropogenic transformation of the structure of forest vegetation. The diversity of bird species is reduced, but the composition of common species is preserved, however their quantitative abundance is reduced. The number of species closely related to natural woody vegetation is decreasing and the role of shrubs and birds, which feed on the exposed surface

1. Introduction
The change of the natural environment is an inherent part of life of people. One of the most large-scale types of transformation of natural components is industrial development of the territory. It covers often not only large areas, but also changes many biogeochemical processes. It leads to changes in the indigenous structure of biodiversity. In any large area, the original ecosystems undergo different forms of fragmentation, which affects not only the overall biodiversity of a particular habitat [1, 2], but also on the birds is inhabiting this territory [3, 4, 5]. The structure of habitats changes to varies on the type of transforming impact. This has influence on the structure of bird population [6, 7]. The purpose of research is description the fauna and structure of bird population of forests of zone of the birch forests and sparse forests of Northern Fennoscandia on the territories is exposed to effects of emissions of industrial enterprises of nonferrous metallurgy.

2. Region, material, methods
Murmansk region is one of the largest is developed areas of the Far North. The first deposit of copper-nickel ores was discovered in the northwestern part of this region, in Pechenga district, in 1912 [8, 9]. Only local ore with a low sulfur content was processed here until the early 1970s. During this period, the impact of emissions on ecosystems was small. In the 1970s-1980s, the ore from Norilsk was processed here., where content of sulfur was much higher, and processing of this ore was creating side effects in the form of increasing the content of oxides of sulfur in emissions [10]. There was a drying of vegetation in connection with large amounts of emissions of oxides of sulfur. This was a condition for the emergence of large forest fires. The formation of the burnt area contributed to the transformation of birch forests into "wastelands " under the influence of water and wind erosion [11, 9, 10].

The material is field researches for 2006-2018 on the stationary monitoring areas which was laid in 2006 [10, 12]. These territories are divided into three groups which various on the degree of
anthropogenic transformation of the original vegetation structure. The first group (strong degree of transformation) includes the territories adjacent to the settlement of Nickel and the city of Zapolyarny. The second group (medium degree of transformation) is the territories that are located between the upper reaches of the river Kuvernerinjoki and lake Maajarvi. The third group is territories, which have no external signs of transformation of the natural structure of forests - it is territories in the vicinity of the settlement of Pechenga.

The article summarizes the results of field ornithological studies. It is including those that have been published [10, 12, 13, 14], and archival materials. Registrations of birds were performed on permanent routes. They have been executed by transect count [15].

3. Results
This area has been studied for a long time in ornithological terms. At the beginning of the twentieth century, information about birds was collected here by Finnish researchers who characterized the avifauna of different parts of Petsamo province [16, 17, 18, 19, 20, 21]. Special ornithological researches were not carried out in this territory in the post-war period. Data about birds of all Russian part of Northern Fennoscandia were summarized in the early 1990s [22]. Active study of the fauna and of bird population in this territory was continued in the early XXI century. The last reports characterize the structure of birds communities in the typical ecosystems for the area and on the territories with different degree of transformation of vegetation structure [23, 24, 14, 25].

Avifauna of undisturbed birch forests has the most complex structure of population of birds. Basis of this avifauna are passerines (table 1). Willow Warbler *Phylloscopus trochilus*, Brambling *Fringilla montifringilla*, Common Redpoll *Acanthis flammea*, Redwing *Turdus iliacus*, Fieldfare *Turdus pilaris*, Bluethroat *Luscinia svecica* and Common Redstart *Phoenicurus phoenicurus* may be considered the most typical and the most numerous species among the birds of this group. The usual species of these forest areas are Tree Pipit *Anthus trivialis*, Hooded Crow *Corvus cornix*, Song Thrush *Turdus philomelos*, Reed Bunting *Schoeniclus schoeniclus*, Black-billed Magpie *Pica pica*, Common Raven *Corvus corax* and Great Tit *Parus major*. White Wagtail *Motacilla alba* is common on banks of small streams and water bodies. Bohemian Waxwing *Bombycilla garrulus*, Willow Tit *Parus montanus* and Siberian Tit *P. cinctus*, Common Bullfinch *Pyrrhula pyrrhula* are found in the birch forests of the territory irregularly. In addition to passerines, Common Cuckoo *Cuculus canorus*, Rough-legged Hawk *Buteo lagopus* and Willow Ptarmigan *Lagopus lagopus* are found in the birch forests of this area regularly.

The composition of species and representation of common species of birds is preserved almost completely in forests, which have medium degree of transformation of the typical structure of vegetation (table 1), but decreases their quantitative abundance, and some species (for example, Fieldfare) are much less often. Also, the number is reduced significantly for many species common for untouched forest areas. The distinctive features of this type of territory may be include a significant increase of the number of Willow Ptarmigan and the emergence of a "new" fairly common species – Northern Wheatear *Oenanthe oenanthe*. Thus, this territory occupies an "intermediate position" between indigenous forests and territories with strong degree of transformation according to the composition of fauna and population of birds.

The fauna and population of birds in birch forests with strong degree of transformations is undergoing significant changes compared to undisturbed birch forests, in the vicinity of the settlement of Nickel and the city of Zapolyarny (table 1). The typical species remain only Willow Warbler and Common Redpoll in both areas. Brambling, Bluethroat, Northern Wheatear, Hooded Crow, Common Raven, Redwing, Common Redstart and White Wagtail are usual species on sites adjacent to the city of Zapolyarny (table 1). In the vicinity of the settlement of Nickel the number of species that may be attributed to the usual, less relatively and they are distributed on abundance otherwise: Bluethroat, Northern Wheatear, Brambling, Redwing and White Wagtail (table 1)

Some species of birds are rare in the forests of the zone birch forests and sparse forests (table. 2). They may be divided into three groups. The first group may include birds are uncharacteristic for
forest ecosystems and living in cities and settlements Gulls Larus, Rock Pigeon Columba livia, House Martin Delichon urbica and House Sparrow Passer domesticus. These birds visit forests with strong degree of transformations and territories devoid of vegetation in search of feed.

The second group is formed by species that are rare only in the zone of birch forests and sparse forest, but in the surrounding areas these species are more common: Merlin Falco columbarius, Black Grouse Lyurus tetrix, Common Kestrel Falco tinnunculus, Rock Ptarmigan Lagopus muta, Pied Flycatcher Ficedula hypoleuca, Eurasian Siskin Spinus spinus, Common Crossbill Loxia curvirostra and Lapland Longspur Calcarius laponicus.

The last group unites the following species, rare for all this part of a territory of Northern Fennoscandia: Lesser Spotted Woodpecker Dendrocopos minor, Sand Martin Riparia riparia, Red-throated Pipit Anthus cervinus, Eurasian Jay Garrulus glandarius, Eurasian Blackbird Turdus merula, Red-flanked Bluetail Tarsiger cyanurus, Northern Wren Troglodytes troglodytes, Common Chiffchaff Phylloscopus collybita, Arctic Warbler Phylloscopus borealis, Chaffinch Fringilla coelebs, European Greenfinch Chloris chloris.

Analysis of the structure the population of bird of the surveyed areas (table 1, 2) shows that changes in the structure of vegetation areas are reflected in the species composition and quantitative abundance of birds. Abundant passerine birds may be as indicator species of condition of ecosystems.

### Table 1. The occurrence of birds on fixed routes counts.

| Species/Location       | Ni        | Zp        | Vt        | Pec        |
|------------------------|-----------|-----------|-----------|------------|
| Buteo lagopus          | -         | -         | 0.04 (0.00-0.26) | 0.14 (0.00-0.33) |
| Lagopus lagopus        | 0.09 (0.00-0.60) | 0.06 (0.00-0.28) | 0.29 (0.00-1.15) | 0.09 (0.00-0.48) |
| Pluvialis apricaria    | 0.08 (0.00-0.40) | -         | 0.02 (0.00-0.26) | -           |
| Larus gentatus         | 0.01 (0.00-0.13) | 0.06 (0.00-0.69) | -         | -           |
| Larus canus            | 0.03 (0.00-0.40) | 0.03 (0.00-0.14) | -         | -           |
| Cuculus canorus        | -         | -         | 0.01 (0.00-0.15) | 0.35 (0.00-0.95) |
| Anthus trivialis       | 0.10 (0.00-0.80) | 0.09 (0.00-0.42) | 0.30 (0.00-1.83) | 0.45 (0.00-1.43) |
| Motacilla alba         | 0.21 (0.00-0.80) | 0.30 (0.00-0.57) | 0.08 (0.00-0.29) | 0.20 (0.00-0.72) |
| Pica pica              | -         | 0.06 (0.00-0.29) | -         | 0.22 (0.00-0.95) |
| Corvus cornix          | 0.01 (0.00-0.13) | 0.31 (0.00-0.86) | 0.09 (0.00-0.46) | 0.38 (0.00-0.95) |
| Corvus corax           | 0.10 (0.00-0.38) | 0.33 (0.00-1.43) | 0.17 (0.00-0.64) | 0.18 (0.00-0.48) |
| Bombycilla garrulus    | -         | 0.11 (0.00-1.14) | 0.06 (0.00-0.31) | 0.11 (0.00-0.48) |
| Phylloscopus trochilus  | 2.43 (0.00-5.63) | 2.41 (0.83-4.17) | 3.80 (0.00-7.69) | 7.65 (3.00-14.76) |
| Ficedula hypoleuca     | -         | -         | 0.02 (0.00-0.14) | 0.04 (0.00-0.24) |
| Oenanthe oenanthe      | 0.65 (0.00-1.75) | 0.54 (0.00-1.25) | 0.37 (0.00-2.31) | -           |
| Phoenicurus phoenicurus| 0.01 (0.00-0.13) | 0.26 (0.00-0.97) | 0.71 (0.00-2.15) | 0.87 (0.00-1.67) |
| Luscinia svecica       | 0.82 (0.00-2.00) | 0.67 (0.14-1.71) | 0.95 (0.13-1.85) | 1.24 (0.00-2.86) |
| Turdus pilaris         | -         | 0.04 (0.00-0.14) | 0.11 (0.00-0.92) | 1.25 (0.24-2.86) |
| Turdus iliacus         | 0.2 (0.00-0.63) | 0.28 (0.00-0.97) | 0.77 (0.29-2.92) | 1.95 (0.00-2.86) |
| Turdus philomelos      | -         | -         | 0.04 (0.00-0.26) | 0.38 (0.00-0.95) |
| Parus montanus         | -         | -         | 0.02 (0.00-0.26) | 0.11 (0.00-0.47) |
| Parus cinctus          | -         | -         | 0.05 (0.00-0.46) | 0.09 (0.00-0.47) |
| Parus major            | -         | 0.02 (0.00-0.14) | 0.06 (0.00-0.29) | 0.17 (0.00-0.71) |
| Fringilla montifringilla| 0.35 (0.00-1.38) | 0.74 (0.00-1.53) | 1.29 (0.31-3.85) | 2.63 (0.17-4.52) |
| Acanthis flammae       | 1.88 (0.00-4.75) | 2.07 (0.00-3.75) | 2.06 (0.00-4.92) | 2.56 (0.33-4.29) |
| Pyrrhula pyrrhula      | -         | 0.01 (0.00-0.14) | -         | 0.13 (0.00-0.48) |
| Schoeniclus schoeniclus| 0.05 (0.00-0.38) | 0.09 (0.00-0.50) | 0.11 (0.00-0.46) | 0.35 (0.00-1.19) |
| Calcarius laponicus    | 0.06 (0.00-0.40) | -         | -         | -           |

Explanation of symbols: Ni – Nickel, Zp – Zapolyarny, Vt – between the upper reaches of the river Kuvernerinjoki and lake Maajarvi, Pec – Pechenga. The table shows the average multi-year value (minimum-maximum).
Analysis of the similarity of the inpatient population and fauna of all bird species encountered and a model sample of 12 species (figure 1) shows that birds of this model is reflecting the degree of mutual similarity and differences of these territories well.

Table 2. Meetings of rare species of birds in the birch forests.

| Species/Location | Ni | Zp | Vt  | Pec |
|------------------|----|----|-----|-----|
| Falco columbarius|    |    | 1 (2010) |     |
| Falco tinnunculus|    |    | 2 (2016) |     |
| Lagopus muta     |    |    |       | 1 (2011) |
| Lyurus tetrax    |    |    | 2 (2014) |     |
| Larus minutus    |    |    |       | 1 (2011) |
| Delichon urbica  | 1 (2008) |    | 1 (2010) |     |
| Anthus cervinus  | 2 (2014) |    | 1 (2014) |     |
| Motacilla flava  |    |    |       |     |
| Lanius excubitor |    | 1 (2018) |    |     |
| Garrulus glandarius |    |    |       | 1 (2013) |
| Troglydotes troglodytes |    |    |       | 1 (2017) |
| Phylloscopus collybita |    | 1 (2010) |     | 1 (2015) |
| Phylloscopus borealis |    | 1 (2011) |     | 1 (2018) |
| Turdus merula    |    |    |       | 1 (2010) |
| Tarsiger cyanurus|    |    |       | 1 (2007) |
| Passer domesticus|    | 5 (2006) |    | 1 (2008) |
| Chloris chloris  |    |    | 3 (2008) | 1 (2010) |
| Spinus spinus    | 1 (2015) |    | 2 (2017) | 1 (2010) |
| Loxia curvirostra|    |    | 1 (2011) |     |

Explanation of symbols: Ni – Nickel, Zp – Zapolyarny, Vt – between the upper reaches of the river Kuvernerinjoki and lake Maajarvi., Pec – Pechenga. The table shows the number of birds was encountered on permanent study area (year of meeting)

Figure 1. Comparison of the territories with different degree of transformation of vegetations structure by fauna and population of all birds which are found here and model species. Explanation of symbols: Ni – Nickel, Zp – Zapolyarny, Vt – between the upper reaches of the river Kuvernerinjoki and lake Maajarvi., Pec – Pechenga.
Analysis of the dynamics of changes in the number of model species of birds on different territories allows to divide them into several groups (figure 2, 3). The first group include species, who have an quantitative abundance gradually increases from strongly transformed sites to the native structure of vegetation areas: Willow Warbler, Brambling, Bluethroat, Fieldfare, Redwing, Reed Bunting, Tree Pipit, Common Redstart. The second group is formed by species for which certain areas with certain signs of transformation of vegetation structure are more preferable: Common Redpoll, White Wagtail, Hooded Crow. The third group is formed by the species are attracted to areas with severely disturbed vegetation structure – the Northern Wheatear. Analysis of changes in the abundance of model species of bird in different time periods shows that most of them in last year’s by an increase in the number (figure 2, 3), which occurs in all territories and does not depend on proximity to enterprises. This may indicate a gradual restoration of the bird population structure of previously disturbed areas and the absence of a pronounced negative impact of enterprises even on the adjacent areas.

**Figure 2.** The change in the abundance of the model species of birds in the birch forests on permanent study area. Explanation of symbols: black line - trend line, $y$ - equation of trend line, $r$ - coefficient of correlation of distribution of the number on permanent study area for 2006-2012 and 2013-2018, $R^2$ - value of reliability of approximation, Ni – Nickel, Zp – Zapolyarny, Vt – between the upper reaches of the river Kuvernerinjoki and lake Maajarvi., Pec – Pechenga.
Figure 3. The change in the abundance of the model species of birds in the birch forests on permanent study area. Explanation of symbols: black line - trend line, y - equation of trend line, r - coefficient of correlation of distribution of the number on permanent study area for 2006-2012 and 2013-2018, R² - value of reliability of approximation, Ni – Nickel, Zp – Zapolyarny, Vt – between the upper reaches of the river Kuvernerinjoki and lake Maajarvi., Pec – Pechenga.

4. Conclusions
The research of long-term changes in the composition and structure of bird population may be used as model of monitoring of changes structure forests. The avifauna of undisturbed birch forests has the most complex population structure. The diversity of species of birds is reduced usually in the range from undisturbed to highly transformed forest ecosystems, but the composition of abundant species is preserved, however their number is reduced. Analysis of the distribution of model species among the monitoring sites shows that the species-indicators of normal condition of the structure of forest vegetation may serve Redwing, Willow Warbler, Brambling, Common Redstart, Fieldfare and Tree Pipit. Species-indicators of fragmentation and sparsity of vegetation may be a White Wagtail, Northern Wheatear and Hooded Crow.

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References
[1] Fahrig, L. Effects of habitat fragmentation on biodiversity // Annual Reviews of Ecology and Systematics 34, 2003: P. 487-515.
[2] Fischer J., Lindemayer B. David. landscape modification and habitat fragmentation: a synthesis // Global Ecology and Biogeography. 2007, 16 (3): P. 265-280.
[3] Andren, H. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review // Oikos 71, 1994: P. 355-366.
[4] Hinsley, S.A., R. Pakeman, P.E. Bellamy, and I. Newton. Influences of habitat fragmentation on bird species distributions and regional population sizes // P. Roy. Soc. Lond. B. Bio. 263, 1996; P. 307-313.
[5] Mortelliti A., Amori G., Capizzi D., Rondinini C., Boitani L. Experimental design and taxonomic scope of fragmentation studies on european mammals: current status and future priorities // Mammal Review. 2010. T. 40. № 2. C. 125-154.
[6] Helzer C.J. and Jelinski D.E. The relative importance of patch area and perimeter-area ratio to grassland breeding birds // Ecological Applications, 1999. 9, 1448.: 12 p.
[7] Lehikoinen A., Helle I., Klemola E., Mäntyniemi S., Kuikka S., Pitkänen H. Evaluating the impact of nutrient abatement measures on the ecological status of coastal waters: a bayesian network for decision analysis // International Journal of Multicriteria Decision Making. 2014. T. 4. № 2. P. 114-134.
[8] Copper-Nickel deposits of Pechenga (resp. Editor N. P. Laverov). Proceedings of Institute of IGEM RAS. New series. Vol. 2. - Moscow: GEOS, 1999, 236 p.
[9] Pechenga: an attempt at encyclopedia of local lore. (author-composer V. A. Matsak). – Murmansk: Educational center "well-wishers", Publishing house "Dobrohot", 2005, 1008 p.
[10] Kola mining and metallurgical company ( “Nickel” and “Zapolyarny” industrial sites): The impact on the Land ecosystems // Ryazan: "Golos Gubernii", 2012. - p. 1-92.
[11] Mukina N. V. Nikonov V. V. Biogeochemical cycles in the forests of the North under man-caused of air pollution conditions. // Apatity: Publishing house of Kola scientific center RAS, 1996, part 1, 213 p.; part 2. 192 p.
[12] Polikarpova N.V. Zatsarinny I. V., Isaeva L. G., Lukina N. V. Khlebosolova O.A. The condition of terrestrial ecosystems in the north-west of the Kola Peninsula, including the territory of the reserve "Pasvik" // Thvetnye metally. 2013. № 10 (850). P. 95-101.
[13] Zatsarinny I. V., Sobchuk I. S., Varyukhin V. S., Efremova E. S. Fauna and population of birds in the valleys of small rivers in the northwest of the Murmansk region. // The Russian Journal of ornithology. 2016. Vol. 25. Express issue 1315. P. 27-2741.
[14] Zatsarinny I. V., Buzun, V. A., Bolshakov A.A., Bychkov M. V., Shavrina, U. Y., Gribova M. O., The avifauna of the zone of birch forests and sparse forest in the northwest of the Murmansk region // The Russian Journal of ornithology. 2018. Vol. 27. In press.
[15] Ravkin E. S., Chelintsev N. D. Methodical recommendations on transect counts of bird population in nature reserves // Organization of research research in nature reserves and national parks. Moscow. 1999. P. 143-155.
[16] Merikallio E. Petsamon Heinäsaarten lintuluettelo // Ornis Fennica 1 (1), 1924.: P. 2-7.
[17] Merikallio E. Emberiza citrinella Petsamossa // Ornis Fennica 3 (2), 1926.: P. 39-41.
[18] Merikallio E. Petsamon Heinäsaarten lintuluettelon täydennys // Ornis Fennica 11 (2), 1934.: P. 56-59.
[19] Carpenter J. 1927. Om Buteo l. lagopus förekomst och forplantning m. m. i Petsamo // Ornis Fennica 4 (1), 1927: P. 19-20.
[20] Keltikangas V., Harala A. Eräitä tietoja havaintoja Luttojoen eteläpuolisen Petsamon alueen linnustosta // Ornis Fennica 15 (4), 1938.: P. 104-107.
[21] Ottow. J. Ein Beitrag zur Vogelwelt des Petsamogebietes und seiner Grenzgebiete // *Ornis Fennica* **26**(4), 1949.: P. 98-116.

[22] Bianchi V. V., Kokhanov, V. D., Koryakin A. S., Krasnov Y. V., Panava T.D., Tatarinkov I. P., Chemyakin R. G., Shklyarevich F. N., Shutova E. V. Birds of Kola White Sea region // *The Russian Journal of ornithology*. 1993. **2**(4). P. 491-586.

[23] Khlebosolov E. I., Khlebosolova O.A., Makarova O. A., Polikarpova N. V. The structure of avian population in the mountain ecosystems of the Northwestern Kola Peninsula // *Animal ecology, evolution and systematics*. Ryazan, 2006. Pp. 22-30.

[24] Khlebosolov E. I., Makarova O. A., Khlebosolova O. A., Polikarpova N. V. Zatsarinny I. V. The birds Of Pasvik. Ryazan, 2007. - 175 p.

[25] Zatsarinny, I. V., Sobchuk I. C., Bulychev, I. A., Varyukhin, V. S., Efremova E. S. Modern species composition and bird population of birch forests, birch forest zone and the woodland North-West of the Murmansk region in the breeding period // *The Russian Journal of ornithology*. 2016a. Vol. **25**. Express-issue 1317. P. 2795 – 280.