ISSN 1995-4255, Contemporary Problems of Ecology, 2013, Vol. 6, No. 3, pp. 315–322. © Pleiades Publishing, Ltd., 2013.
Original Russian Text © E.A. Belskii, E.A. Belskaya, 2013, published in Sibirskii Ekologicheskii Zhurnal, 2013, No. 3, pp. 411–420.

Bird Population in Birch Forests of the Southern Urals Affected by Industrial Pollution: Report 1. Reactions of Species and the Community

E. A. Belskii and E. A. Belskaya
Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences, ul. 8 Marta 202, Yekaterinburg, 620144
e-mail: belskii@ipae.uran.ru

Abstract—The change in the summer bird population of birch forests along the gradient of pollution by emissions from the Karabash Copper Smelter (Chelyabinsk oblast) was investigated in 2009 by means of point counts. As pollution grows, the total density, species richness and diversity of bird population decrease; the proportion of hole nesters in the community decreases; and the proportion of species nesting on the ground and at the top forest canopy increases. Changes in most characteristics of bird populations are limited by the local territory (6–8 km from the plant).

Keywords: bird population, industrial pollution, Southern Urals
DOI: 10.1134/S1995425513030025

The characteristics of the bird population give important information on the state of habitats and current ecological factors [1]. It is why birds have long been used in the bioindication and environmental monitoring [2–4]. However, the responses of bird communities to industrial pollution have been studied much less than their biochemical and organismic indices. Non-ferrous smelters which emit a whole complex of ecotoxicants (heavy metals, SO_2, fluorine compounds, etc.) have been shown to affect biota most strongly among all industrial polluters [5]. The changes are the most evident in bird populations in forest ecosystems, in which environmental pollution is accompanied by the degradation of tree layer and the simplification of the phytocenotic structure. Most ecotoxicological investigations of birds have been performed in the industrial regions of Europe: in Germany, Poland, Czechia, Slovakia, Finland, and the Kola Peninsula in Russia [6–9]. The development of the Ural Region that is primarily related to the development of metallurgic industry has a tercentennial history. This region focuses a large number of plants, in the environs of which natural complexes have experienced strong degradation. Despite the broad expansion of anthropogenic landscapes in the Urals, the bird population in them has not been studied sufficiently. Most ornithological studies in this region have been carried out in reserves [10, 11], as well as in territories used for agriculture [12], forestry, and recreation [11]. The temporal dynamics of the bird fauna in the near-Ural region and the Southern Urals (Bashkortostan) related to the complex economic development of this territory has been studied at the regional level [13]. The spatial organization of the summer bird population in the Urals has been analyzed at the level of the physiographic country [14]. There is not much research devoted to the changes in bird population at the local level in the environs of the point sources of industrial pollution in the Ural Region [15]. Such investigations have not been performed in the Southern Urals.

The goal of this study is to characterize the change in the bird population of birch forests in the Southern Urals affected by industrial pollution, making an attempt to estimate the contribution of different factors to the reactions of bird communities and their separate species.

STUDY AREA, MATERIALS, AND METHODS

The Karabash Copper Smelter (ZAO 'Karabashmed') in Chelyabinsk oblast is a point source of intense industrial pollution which has been put into operation in 1910. Major pollutants are typical for ore-smelting enterprises of nonferrous metallurgy: SO_2, dust, and heavy metals. The amount of atmospheric emissions in 1970–1980 and in 2008 was 140000–360000 t per year and 9622 t, respectively [17]. The degradation of the environment near the enterprise reached such a high level that the question about closing it was raised. An industrial barren was formed in the nearest (up to 4 km) environs of the plant: there is almost no vegetation and soil has been washed away from the hill slopes near the enterprise.

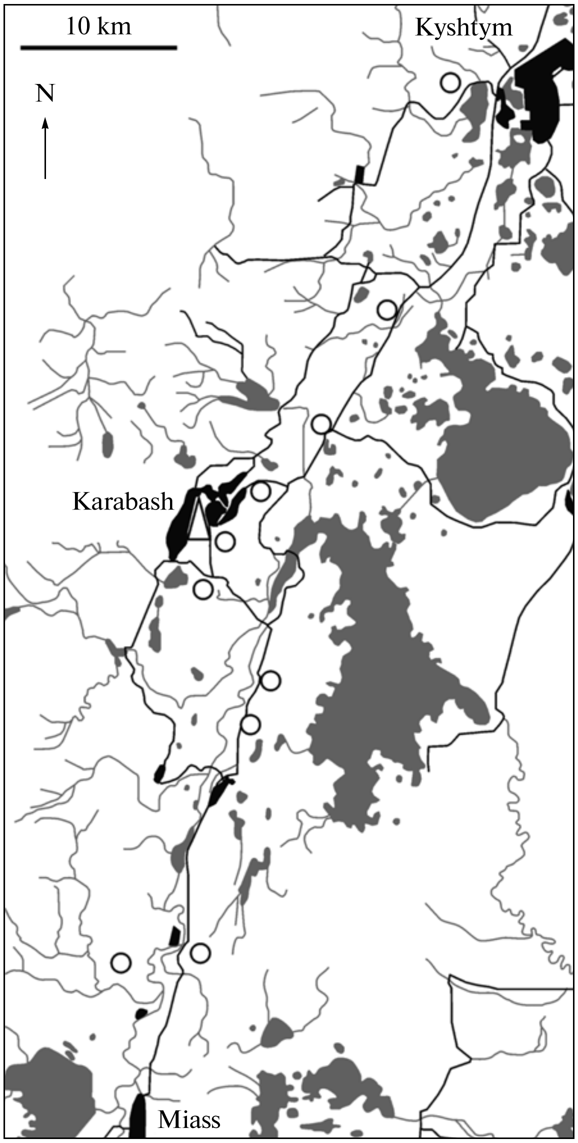

Fig. 1. Schematic map of the region under investigation in the environs of the Karabash Copper Smelter (triangle) with study sites indicated (small circles).

Soil [16], soil algae, vascular plants [16, 18–20], lichens [21], soil invertebrates [22], leaf-eating insects [16], and small mammals [23, 24] were the objects of ecotoxicological investigations in this region. As we know, ornithological studies have not been carried out here.

The city of Karabash is in a valley elongated in the meridian direction along the Ilmen Ridge. The heights of uplands are 250–600 m above sea level. Soils (brown mountain-forest and forest soils, gray soils, mountain–forest and mountain-podzol chernozems) are rubbly and thin. The climate is continental, moderately cold. The average monthly January temperature is from −16 to −17°C, and the average monthly July temperature is +18°C. The duration of the vegetation period is 160–170 days. The annual precipitation is 430 mm. The height of the snow cover is 40 cm [25]. According to geobotanic zoning, this territory is part of the subzone of pine–birch southern taiga forests [26]. The major types of forests are herb pineries and secondary grass-herb birch forests. We carried out the investigations in birch forests (*Betula pendula* Roth is dominant in the stand; there are also *B. pubescens* Ehrh., *Pinus sylvestris* L., *Populus tremula* L., *Tilia cordata* Mill, and *Larix sibirica* Ledeb.).

Four zones of pollution were distinguished based on previous studies [16, 19, 21]. Ten study sites were selected by us in the following zones: (1) the background zone: a herb birch forest at the age of 90–100 years; three sites 26 km south of the smelter (in the Ilmen Reserve), 27 km to the south, and 32 km to the northwest. (2) Buffer zone: a herb birch forest at the age of 90–100 years; four sites at a distance of 9 and 12 km to the south and 11 and 18 km to the northwest. (3) Impact zone: dead-cover birch forest at the age of 60–70 years; two sites 3 and 5 km northwest of the plant; (4) Industrial barren (the western slope of the Zolotaya Mountain): one site 1 km east of the plant; trees are few in number and only remained in gullies, the field layer has a form of separate spots, the greater part of the surface is bald, soil was washed away, and a branched net of gullies with a depth of up to 3 m arose due to erosion. The location of the study sites is shown in Fig. 1.

The nesting bird population was censused from May 20 to June 12, 2009. The method of point counts was used [27, 28]. Four constant count points, the coordinates of which were fixed using a GPS navigator, were selected at each study site. The distance between points averaged (±SE) (296 ± 15) m ($n = 34$), which excluded the possibility of counting one bird twice. This permitted us to consider each point to be a true replication.

Counts were made at each site four times per season with an approximately weekly interval by one observer. Censuses were made at three or four sites in one morning. The order of visiting the sites was changed so that it would be possible to differentiate the spatial variation in the registered indices from the temporal one. Censuses were carried out between 5 and 9 a.m. local summer time in dry weather at a wind intensity of no more than 3 points according to the Beaufort scale and air temperature no lower than +6°C. The duration of a census in one point was 5 min. When making counts, birds noted both by voice and visually were all registered. In calculations it was assumed that a singing male, a female and a male observed together, one female, or an active nest or brood = 1 pair. The total number of point counts was 160.

The density of the bird population was estimated using the following formula [27]:

$$D = 3Nc^2/\pi,$$

where D is the density of the bird population, pairs/km^2; N is the number of counted pairs. Since the

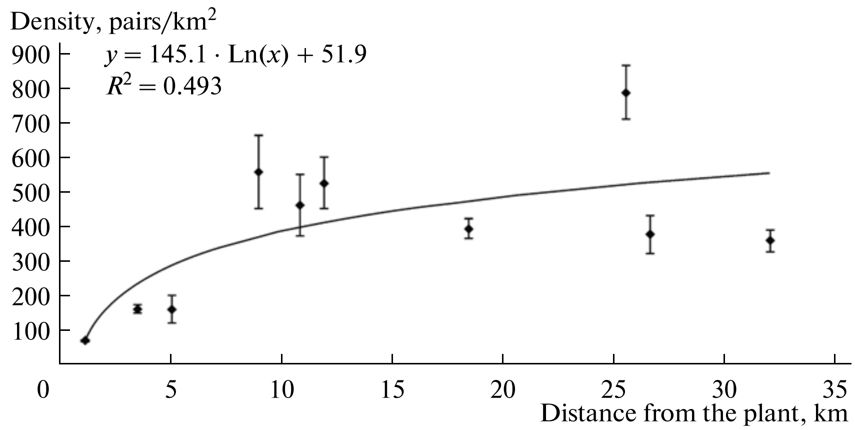

Fig. 2. Change in the total density of the bird population in birch forests (pairs/km^2, mean ± SE) along the gradient of pollution by emissions from the Karabash Copper Smelter.

singing activity of birds never reaches 100%, the number of pairs per point that was equal to the maximum value from four counts was used; *c* is the species-specific factor (article [28], Table 1, column "E") and $\pi = 3.14$.

The total density of the bird population was obtained by summing up the densities of all observed species. However, the species in which the number of observed pairs totaled no less than ten in all counts were only used to compare the species richness in different zones. The vegetation layers preferred for nesting are classified according to V.D. Zakharov [11], and bird species are named according to L.S. Stepanyan [29, 30].

RESULTS AND DISCUSSION

The total density of the bird population in a birch forest significantly decreases as pollution grows (see Table 1); the dependence can be expressed by the logarithmic equation (Fig. 2). This index was at the background level in the buffer zone, 3.2 times smaller in the impact zone and 7.4 times smaller in the industrial barren. Species diversity decreases as pollution grows. The Shannon diversity index in the impact zone and in the industrial barren is much smaller than the background one. The total number of counted species decreased by an order of magnitude along the pollution gradient (see Table 1). The average number of species in counts decreased as pollution grew; however, differences from the background level were significant only in the impact zone and in the industrial barren (by a factor of 2.8 and 9.4 smaller, respectively). Consequently, the pairwise comparison of the integral indices of the bird population in different zones (the Mann–Whitney *U*-test) shows that the impact zone and industrial barren only differ from the control significantly.

The responses to the industrial pollution differ between species. Let us consider only the changes in the background–buffer–impact zone series, i.e., sites with the remained woody vegetation. The population of the industrial barren is very poor; the wheatear *Oenanthe oenanthe* L. nests here and the magpie *Pica pica* L. and raven *Corvus corax* L. seldom fly here.

As pollution grows, the density of the population significantly decreases in the chaffinch *Fringilla coelebs* L. (the comparison of the background and impact zones, the Mann–Whitney test $U = 11.5$, $p = 0.0013$), willow tit *Parus montanus* Bald. ($U = 12.0$, $p = 0.005$), pied flycatcher *Ficedula hypoleuca* Pall. ($U = 12.5$, $p = 0.006$), robin *Erithacus rubecula* L. ($U = 16.0$, $p = 0.014$), tree pipit *Anthus trivialis* L. ($U = 10.0$, $p = 0.003$), great tit *Parus major* L. ($U = 20.0$, $p = 0.03$), song thrush *Turdus philomelos* Brehm ($U = 8.0$, $p = 0.002$), and chiffchaff *Phylloscopus collybita* Vieil ($U = 16.0$, $p = 0.014$). In the buffer zone, the abundance is greater as compared to other zones in the spotted flycatcher *Muscicapa striata* Pall. (the comparison of the buffer and background zones, $U = 11.5$, $p = 0.0013$), blackcap *Sylvia atricapilla* L. and garden warbler *S. borin* Bodd. (comparison of the buffer and impact zones, $U = 27.5$, $p = 0.025$ and $U = 28.0$, $p = 0.027$, respectively), and scarlet grosbeak *Carpodacus erythrinus* Pall. ($U = 55.5$, $p = 0.021$). The yellowhammer *Emberiza citrinella* only grows in abundance in the impact zone ($U = 25.0$, $p = 0.034$). The abundance does not change significantly in the greenish warbler *Phylloscopus trochiloides* Sund., great spotted woodpecker *Dendrocopos major* L., redstart *Phoenicurus phoenicurus* L., crossbill *Loxia curvirostra* L., and cuckoo *Cuculus canorus* L. However, the trend towards the decrease in abundance in the impact zone is noted in these species (except the cuckoo).

The dominance structure of the community changes as pollution grows. The degree of dominance (the Berger–Parker index) increases (see Table 1). In the background territory, chaffinch (22.0% of the total density), willow tit (13.2%), greenish warbler (8.9%), pied flycatcher (7.8%), robin (6.3%), and tree pipit (5.4%) dominate. In the buffer zone chaffinch (20.3%),

Table 1. Density of the bird population in birch forests (mean ± SE) in different zones of pollution by emissions from the Karabash Copper Smelter, pairs/km^2

Species, index	Zone				H*	p	Vegetation layer preferred for nesting**	Type of feeding***
	Background	Buffer	Impact	Industrial barren				
1	2	3	4	5	6	7	8	9
Fringilla coelebs L.	98.2 ± 5.5 [a]	91.4 ± 3.7 [a]	63.5 ± 4.6 [b]	0 [b]	22.6	<0.001	t	i
Parus montanus Bald.	67.2 ± 16.5 [a]	21.0 ± 8.0 [a]	0 [b]	0 [a]	15.3	0.002	h	i
Phylloscopus trochiloides Sund.	54.8 ± 13.7 [a]	52.3 ± 9.3 [a]	22.4 ± 10.9 [ab]	0 [b]	8.7	0.034	g	i
Ficedula hypoleuca Pall.	32.2 ± 5.7 [a]	42.7 ± 6.1 [a]	3.7 ± 3.7 [b]	0 [b]	20.5	<0.001	h	i
Erithacus rubecula L.	26.0 ± 6.2 [a]	4.3 ± 3.0 [b]	0 [b]	0 [b]	16.2	0.001	h	i
Anthus trivialis L.	25.6 ± 3.5 [a]	34.6 ± 2.6 [a]	5.8 ± 2.8 [b]	0 [b]	24.6	<0.001	g	i
Parus ater L.	22.4 ± 8.0	6.7 ± 4.6	0	0	–	–	h	i
Parus major L.	20.1 ± 5.1 [a]	21.6 ± 7.0 [a]	0 [b]	0 [ab]	8.9	0.031	h	i
Certhia familiaris L.	17.5 ± 9.1	4.4 ± 4.4	0	0	–	–	h	i
Muscicapa striata Pall.	15.0 ± 10.1 [a]	61.9 ± 10.8 [b]	22.5 ± 14.7 [ab]	0 [a]	11.5	0.009	l	i
Sylvia atricapilla L.	10.3 ± 3.4 [ab]	13.3 ± 2.6 [a]	2.2 ± 2.2 [b]	0 [b]	9.9	0.020	l	i
Sitta europaea L.	10.2 ± 6.9	3.8 ± 3.8	0	0	–	–	h	i
Turdus philomelos Brehm	10.1 ± 1.4 [a]	6.0 ± 1.9 [a]	–	0 [ab]	15.6	0.001	l	i
Dendrocopos major L.	9.7 ± 3.5 [a]	13.1 ± 3.0 [a]	2.9 ± 2.9 [a]	0 [a]	6.9	0.077	h	i
Turdus iliacus L.	9.6 ± 4.4	0	0	0	–	–	l	i
Coccothraustes coccothraustes L.	8.0 ± 8.0	0	0	0	–	–	l	g
Garrulus glandarius L.	7.3 ± 4.9	0	0	0	–	–	t	e
Turdus pilaris L.	7.0 ± 3.6	0	0	0	–	–	t	i
Ficedula parva Bechst.	7.0 ± 4.7	2.6 ± 2.6	0	0	–	–	h	i
Phylloscopus collybita Vieil.	6.8 ± 1.6 [a]	7.3 ± 1.2 [a]	–	0 [b]	16.1	0.001	g	i
Phoenicurus phoenicurus L.	6.0 ± 2.3 [a]	5.2 ± 1.5 [a]	3.0 ± 2.0 [a]	0 [a]	3.2	0.358	h	i
Locustella fluviatilis Wolf	5.1 ± 5.1	0	0	0	–	–	g	i
Emberiza citrinella L.	3.7 ± 2.5 [a]	4.1 ± 2.2 [a]	16.6 ± 5.5 [b]	0 [ab]	8.4	0.038	g	g
Hippolais icterina Vieil.	3.5 ± 3.5	15.8 ± 5.3	0	0	–	–	t	i
Sylvia borin Bodd.	3.3 ± 1.7 [ab]	8.3 ± 2.0 [a]	0 [b]	0 [ab]	10.4	0.016	l	i
Spinus spinus L.	3.0 ± 2.2	0	0	0	–	–	t	g
Buteo buteo L.	2.7 ± 1.8	1.0 ± 1.0	0	0	–	–	t	p
Turdus viscivorus L.	2.5 ± 1.3	3.1 ± 1.2	1.3 ± 1.3	0	–	–	t	i
Fringilla montifringilla L.	2.4 ± 2.4	0.9 ± 0.9	0	0	–	–	t	i
Zoothera dauma Lath.	1.9 ± 1.3	0	0	0	–	–	t	i

Table 1. (Contd.)

Species, index	Zone				H*	*p*	Vegetation layer preferred for nesting**	Type of feeding***
	Background	Buffer	Impact	Industrial barren				
1	2	3	4	5	6	7	8	9
Loxia curvirostra L.	1.7 ± 0.4 ^{a}	0.9 ± 0.4 ^{a}	0.7 ± 0.5 ^{a}	0 ^{a}	5.5	0.140	t	g
Pyrrhula pyrrhula L.	1.6 ± 1.6	1.2 ± 1.2	0	0	–	–	t	g
Phylloscopus sibilatrix Bechst.	1.5 ± 1.5	0	0	0	–	–	g	i
Phylloscopus trochilus L.	1.3 ± 1.3	3.8 ± 1.7	1.9 ± 1.9	0	–	–	g	i
Carpodacus erythrinus Pall.	1.2 ± 1.2 ^{a}	8.1 ± 2.3 ^{b}	5.4 ± 2.6 ^{ab}	0 ^{ab}	7.6	0.056	l	g
Cuculus canorus L.	0.5 ± 0.1 ^{a}	0.5 ± 0.1 ^{a}	0.4 ± 0.2 ^{ab}	0 ^{b}	7.4	0.060	–	i
Corvus cornix L.	0.5 ± 0.3	0.1 ± 0.1	0.2 ± 0.2	0	–	–	t	e
Cuculus saturatus Blyth	0.2 ± 0.1	0.1 ± 0.1	0	0	–	–	–	i
Oriolus oriolus L.	0.2 ± 0.2	0.2 ± 0.2	0	0	–	–	t	i
Corvus corax L.	0.1 ± 0.05	0	0	0.1 ± 0.1	–	–	t	e
Scolopax rusticola L.	0	13.6 ± 13.6	0	0	–	–	g	i
Tetrastes bonasia L.	0	13.1 ± 13.1	0	0	–	–	g	g
Acrocephalus dumetorum Blyth	0	6.1 ± 3.3	0	0	–	–	l	i
Parus caeruleus L.	0	3.9 ± 3.9	0	0	–	–	h	i
Strix aluco L.	0	3.8 ± 3.8	0	0	–	–	h	p
Sylvia communis Lath.	0	1.7 ± 1.7	0	0	–	–	l	i
Turdus merula L.	0	1.1 ± 1.1	0	0	–	–	l	i
Jynx torquilla L.	0	0.7 ± 0.4	0	0	–	–	h	i
Motacilla alba L.	0	0	7.0 ± 7.0	0	–	–	g	i
Pica pica L.	0	0	0.6 ± 0.6	1.3 ± 1.3	–	–	t	e
Oenanthe oenanthe L.	0	0	0	66.9 ± 0.0	–	–	g	i
Total density, pairs/km^2	507.9 ± 233.4 ^{a}	484.3 ± 157.5 ^{a}	160.1 ± 53.1 ^{b}	68.3 ± 2.7 ^{b}	24.8	<0.001	–	–
Average number of species in counts	14.1 ± 4.0 ^{a}	12.8 ± 2.9 ^{a}	5.0 ± 1.5 ^{b}	1.5 ± 1.0 ^{b}	25.5	<0.001	–	–
Total number of species in counts	40	39	17	3	–	–	–	–
Shannon diversity index	2.221 ± 0.313 ^{a}	2.174 ± 0.214 ^{a}	1.192 ± 0.307 ^{b}	0.071 ± 0.142 ^{b}	25.4	<0.001	–	–
Berger–Parker index	0.237 ± 0.057 ^{a}	0.231 ± 0.056 ^{a}	0.473 ± 0.147 ^{b}	0.981 ± 0.037 ^{b}	25.1	<0.001	–	–

Note: The values within a line that are designated with different letters differ significantly ($p < 0.05$) from each other (the Mann–Whitney *U*-test);
* The Kruskal–Wallis test ($df = 3$, $n = 40$). (–) No comparison of abundance in different zones was performed owing to the small number of registrations (less than 10 pairs).
** Vegetation layers preferred for nesting: (t) top canopy, (h) holes, (l) lower layer, and (g) ground.
*** Type of feeding: (e) euryphagous feeding, (g) grain-eating, (i) insect-eating, and (p) predation.

Table 2. Distribution of birds by layers preferred for nesting in different zones of pollution by emissions from the Karabash Copper Smelter (mean ± SE)

Vegetation layer preferred for nesting	Proportion of the total density, %			Density, pairs/km^2		
	Zone					
	Background	Buffer	Impact	Background	Buffer	Impact
Top canopy	29.0 ± 2.7	25.0 ± 1.7	44.7 ± 5.9 *	132.7 ± 11.6	114.7 ± 7.2	66.4 ± 5.6 **
Holes	44.3 ± 3.1	27.2 ± 2.4 **	4.9 ± 2.0 **	218.2 ± 29.9	133.8 ± 15.8 *	9.6 ± 4.2 **
Lower layer	8.9 ± 2.3	22.5 ± 2.2 **	14.5 ± 7.5	57.5 ± 22.6	106.6 ± 12.0	30.2 ± 17.0
Ground	17.8 ± 2.2	25.3 ± 2.7 *	35.9 ± 7.3 *	98.7 ± 18.7	128.9 ± 22.9	53.7 ± 11.7 *

Note: The cuckoos and industrial barren are excluded. *The differences from the background index are significant at $p < 0.05$ (F is the Fisher test and t is the Student test; ** $p < 0.001$.

spotted flycatcher (12.8%), greenish warbler (10.5%), pied flycatcher (9.4%) and tree pipit (7.6%) dominate. In the impact zone, the number of dominants decreased to four: chaffinch (43.1%), greenish warbler (14.7%), yellowhammer (11.6%), and spotted flycatcher (10.4%). In the industrial barren, there is the only nesting species: the wheatear.

An analysis of bird distribution by the vegetation layers preferred for nesting showed that the proportion of hole-nesting birds decreased and the proportion of birds that build nests at the top canopy and on the ground grew as pollution increased. Meanwhile, the absolute density of the population in all the mentioned ecological groups decreases in the impact zone as compared to the background one (Table 2).

The decrease in the total density and reduction in the species richness and diversity of the bird population in polluted areas are typical of many impact regions with high industrial load. An analogous picture was noted in the environs of large nonferrous metallurgy enterprises in the Middle Urals [15], in the Kola Peninsula [8], and in the mountains of Central Europe [6]. The total density of the bird population was not reduced near the Harjavalta Cu-Ni smelter as compared to background area in 2001, however, the average number of species in counts was 16% smaller, and the Shannon diversity index was 9% lower [9]. Near Karabash (even if the industrial barren is not taken into account), the total density of the population, average number of species in counts, and Shannon index decreased as compared to background area by factors of 3.2, 2.8, and 1.9, respectively (see Table 1). A less evident pollution effect in Harjavalta as compared to other factories is likely due to the lesser pollution level: the total emissions came to about 3000 t [31] in the year 2000, which preceded the counts; meanwhile, they were three times greater in Karabash in 2008 [17]. However, the effect of emissions from the Karabash smelter on the bird population should be noted as being local, although strongly pronounced. The total density of the bird population and number of species significantly differ from the control only at a radius of 6–8 km from the plant.

The reactions to the anthropogenic impact in many bird species depend on their ecological specificity. The proportion of typical forest species in the bird population was shown to decrease in polluted areas [6–9, 15]. This decrease is caused by the lack of nesting places as a result of the degradation of the tree layer, increased trouble near the source of emissions, and reduction in the food supply for specialized species. Tits and pied flycatchers (hole nesters), thrushes (which feed mainly on soil invertebrates including earthworms), and a number of others disappear from the population or decrease in abundance by a factor of more than 8 in the environs of Karabash. The increased abundance of the spotted flycatcher in the buffer zone in comparison with the background one is due to its preference for sparse forests with an open space under or between tree crowns [32]. Some thinning of a tree stand in the buffer zone is favorable for this species. The proportion (in total density) of typical forest species in the region under investigation decreases from 73% in the control to 59% in the impact zone.

The abundance of ecologically plastic species that nest in bushes, in the underbrush, and on the ground is known to depend insignificantly on pollution [6–9, 15]. This reaction is demonstrated in the environs of Karabash by the greenish warbler and redstart. The decrease in the abundance of chiffchaff in the impact zone as compared to the background one may be due to the degradation and impairment of the protective properties of the field layer, where this species builds nests. The greatest density at the intermediate pollution level is reached by the garden warbler, blackcap, and scarlet grosbeak, which nest in bushes and in the underbrush, often at forest edges.

The growth in the abundance of the yellowhammer and wheatear is explained by their biotopic preferences. These are species that live in open habitats and nest on the ground (the yellowhammer) and in ground cavities (the wheatear), and the degradation of forest is favorable for them. The wheatear feeds on invertebrates, gathering them from the ground surface, and avoids densely grassed sites. Its distribution in the study area is limited by the industrial barren, where there is almost no vegetation.

A change in the nesting-layer distribution of birds in polluted areas was also observed in other investigated regions. The proportion of the species that nest on the ground and in ground cavities grew in the environs of the Middle Ural Copper Smelter from 33% in the background to 54% in the impact zone [15]; near the Severonikel Combine (Monchegorsk) it grew from 39 to 63%, respectively (calculated from [8]). In the deciduous forests of Southern and Middle Urals, as well as in the northern taiga, the proportion of hole nesters in the bird population abruptly decreases in the polluted territory (by factors of 9, 2.2, and 2.4, respectively). The proportion of other groups in the community can vary differently in different regions. The relative abundance of birds that nest at the lower forest layer does not significantly vary along the pollution gradient in the compared regions. The proportion of birds that nest at the top canopy decreases in the Middle Urals, almost does not change in the environs of Monchegorsk, and grows in the environs of Karabash. This effect is likely due to the distinctions in the responses to the pollution of vegetation at different forest layers in these regions. The field layer has been transformed to the greatest extent in the environs of Karabash, and the tree layer is the last to disappear [18]. In the northern taiga and Middle Urals, the tree layer is, in contrast, the first to fall out and the field layer is more stable [5, 33]. Surely if the analysis includes not only the forest sites of the Southern Urals, but also the industrial barren, all groups, except for ground nesters, can be seen to disappear from the community.

CONCLUSIONS

Environmental pollution by emissions from the Karabash Copper Smelter leads to a decrease in the total density and species richness and diversity of the bird population in birch forests. As the pollution grows, the proportion of hole nesters decreases and the proportion of the species that nest on the ground and at the top forest canopy increases. Meanwhile, the absolute abundance decreases in all groups. The changes in the indices of the bird population are limited by the local territory (6–8 km from the plant). The wheatear is the only species typical of open habitats which nests in the industrial barren, where there is almost no vegetation.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research (grant 13-04-01229), the Program for the Development of Leading Scientific Schools (NSh-5325.2012.4), and the Presidium of the Russian Academy of Sciences (the program "Living Nature," project 12-P-4-1026).

REFERENCES

1. Ravkin, Yu.S., *Prostranstvennaya organizatsiya naseleniya ptits lesnoi zony: Zapadnaya i Srednyaya Sibir'* (Spatial Organization of Avian Population in Forest: Western and Central Siberia), Novosibirsk: Nauka, 1984.
2. *Bioindication of Pollution of Terrestrial Ecosystems,* Schubert, R., Ed., Moscow: Mir, 1988.
3. Koskimies, P., Birds as a tool in environmental monitoring, *Ann. Zool. Fenn.*, 1989, vol. 26, pp. 153–166.
4. Lebedeva, N.V., *Ekotoksikologiya i biogeokhimiya geograficheskikh populyatsii prits* (Ecotoxicology and Biogeochemistry of Geographical Bird Populations), Moscow: Nauka, 1999.
5. Vorobeichik, E.L., Sadykov, O.F., and Farafontov, M.G., *Ekologicheskoe normirovanie tekhnogennykh zagryaznenii nazemnykh ekosistem* (Ecological Standardization of Technogenic Pollution of Terrestrial Ecosystems), Yekaterinburg: Nauka, 1994.
6. Flousek, J., Impact of industrial emissions on bird populations breeding in mountain spruce forests in Central Europe, *Ann. Zool. Fenn.*, 1989, vol. 26, no. 3, pp. 255–263.
7. Lemberk, V., Srovnavani ornitocenoz smrkovych lesu Krkonos podle stupne poskozeni imisemi, *Opera Corcontica*, 1989, no. 26, pp. 131–143.
8. Gilyazov, A.S., Air pollution impact on the bird communities of the Lapland biosphere reserve, in *Proc. Int. Workshop "Aerial Pollution in Kola Peninsula", April 14–16, 1992*, Apatity, 1993, pp. 383–390.
9. Eeva, T., Koivunen, V. and Hakkarainen, H., Population densities of forest birds in a heavy metal pollution gradient, *Avian Sci.*, 2002, vol. 2, pp. 227–236.
10. Livanov, S.G., Seasonal dynamics of the Central Ural bird population, *Sib. Ekol. Zh.,* 2002, vol. 9, no. 5, pp. 549–564.
11. Zakharov, V.D., *Bioraznoobrazie naseleniya ptits nazemnykh mestoobitanii Yuzhnogo Urala* (Biological Diversity of Birds in Land Habitats of Southern Ural), Miass: Il'men. Gos. Zapoved. UrO Ross. Akad. Nauk, 1998.
12. Korovin, V.A., *Ptitsy v agrolandshaftakh Urala* (Birds in Agricultural Landscapes of Ural), Yekaterinburg: Ural. State. Univ., 2004.
13. Il'ichev, V.D. and Fomin, V.E., *Ornitofauna i izmenenie sredy (na primere Yuzhno-Ural'skogo regiona)* (Bird's Fauna and Environmental Changes (by Example of South Ural Region)), Moscow: Nauka, 1988.
14. Livanov, S.G., Korovin, V.A., and Kochanov, S.K., The spatial organization of the summer bird communities in the Urals, *Sib. Ekol. Zh.*, 2004, vol. 11, no. 4, pp. 527–537.
15. Belskii, E.A. and Lyakhov, A.G., Response of the avifauna to technogenic environmental pollution in the southern taiga zone of the Middle Urals, *Russ. J. Ecol.*, 2003, vol. 34, no. 3, pp. 181–187.
16. Kozlov, M.V., Zvereva, E.L., and Zverev, V.E., *Impacts of Point Polluters on Terrestrial Biota,* Dordrecht: Springer, 2009.
17. *Kompleksnyi doklad o sostoyanii okruzhayushchei prirodnoi sredy Chelyabinskoi oblasti v 2008 godu* (Comprehensive Report on Environment in Chelyabinsk

Oblast in 2008), Podtesov, G.N., Ed., Chelyabinsk, 2009.

18. Chernen'kova, T.V., Stepanov, A.M., and Gordeeva, M.M., Changes in structure of forest phytocenoses caused by technogenesis, *Zh. Obshch. Biol.*, 1989, vol. 1, no. 3, pp. 388–394.
19. Stepanov, A.M., et al., *Kompleksnaya ekologicheskaya otsenka technogennogo vozdeistviya na ekosistemy yuzhnoi taigi* (Comprehensive Ecological Assessment of Technogenic Effect on Ecosystems of Southern Taiga), Moscow: Tsentr Probl. Ekol. Prod. Lesov, 1992.
20. Chernen'kova, T.V., *Reaktsiya lesnoi rastitel'nosti na promyshlennoe zagryaznenie* (Response of Forest Plants to Industrial Pollution), Moscow: Nauka, 2002.
21. Purvis, O.W., et al., Lichen biomonitoring near Karabash smelter town, Ural Mountains, Russia, one of the most polluted areas in the world, *Proc. R. Soc. London, Ser. B*, 2004, vol. 271, pp. 221–226.
22. Nekrasova, L.S., Influence of copper-smelting industry on soil mesofauna, *Russ. J. Ecol.*, 1993, no. 5, pp. 83–85.
23. Chernousova, N.F., Influence of copper-smelting industry emissions on ecological and physiological features of common vole, in *Zhivotnye v usloviyakh antropogennogo landshafta* (Animals in Anthropogenic Landscape), Sverdlovsk, 1990, pp. 83–90.
24. Mukhacheva, S.V., Davydova, Y.A., and Kshnyasev, I.A., Responses of small mammal community to environmental pollution by emissions from a copper smelter, *Russ. J. Ecol.,* 2010, vol. 41, no. 6, pp. 513–518.
25. Chikishev, A.G., Physical and geographical zoning of Ural region, in *Problemy fizicheskoi geografii Urala* (Physical Geography of Ural Region), Moscow: Mos. Gos. Univ., 1966, pp. 7–84.
26. Kolesnikov, B.P., Vegetation of Chelyabinsk oblast' related to the geographical zoning, *Tr. Il'menskogo Gos. Zapov. im. V.I. Lenina*, 1961, no. 4, pp. 63–85.
27. Järvinen, O., Estimating relative densities of land birds by point counts, *Ann. Zool. Fenn.*, 1978, vol. 15, pp. 290–293.
28. Järvinen, O. and Väisänen, R., Correction coefficients for line transect censuses of breeding birds, *Ornis Fenn.,* 1983, vol. 60, pp. 97–104.
29. Stepanyan, L.S., *Sostav i raspredelenie ptits fauny SSSR: Nevorob'innye* (Composition and Distribution of Bird Fauna of USSR: Non-Passeriformes), Moscow: Nauka, 1975.
30. Stepanyan, L.S., *Sostav i raspredelenie ptits fauny SSSR: Vorob'inoobraznye* (Composition and Distribution of Bird Fauna of USSR: Passeriformes), Moscow: Nauka, 1978.
31. Eeva, T., et al., Environmental pollution has sex-dependent effects on local survival, *Biol. Lett. (London, U. K.)*, 2006, vol. 2, pp. 298–300.
32. *Ptitsy Ryazanskoi Meshchery* (Birds of Ryazan Meshchera), Khlebosolov, E.I., Ed., Ryazan: Golos Gubernii, 2008.
33. Chernen'kova, T.V., Biogeocenotic approach to the evaluation of the condition of forest ecosystems under anthropogenic influence, *Acta Biol. Hung.,* 1986, no. 37 (1), pp. 47–53.

Translated by L. Solovyova