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Article

Long-term dynamics of the bird fauna and population on fallow land with degrading shelterbelts (Abakan steppe)

T.V. Zlotnikova* , E.Yu. Zhukova 

Khakassian State University named after N.F. Katanov, prospekt Lenina 90, Abakan, 655017 Russia

*tamara.zlotnikova@mail.ru

Abstract. The fauna and population of birds in the agrocenosis of the Abakan steppe changed over a 25-year period, as a result of vegetational succession, invasion of *Ulmus pumila* L. and cattle grazing. Previously 65 bird species were recorded from the area, with 23 species nesting; currently 57 species were encountered, including 22 nesting species. The overall population density during the nesting period increased 1.5 times, and decreased to 40–50% in the winter. A change in dominant taxa in the species structure occurred between the summer and winter populations. Among the nesting birds, the density of *Alauda arvensis* L., 1758 decreased, while that of *Hippolais caligata* (Lichtenstein, 1823) and *Saxicola torquata* (L., 1766) increased. *Ficedula parva* (Bechstein, 1794) and *Emberiza hortulana* L., 1758 appeared, while *Eremophila alpestris* (L., 1758) and *Emberiza citrinella* L., 1758 disappeared. The number of nesting pairs of *Pica pica* (L., 1758) and *Corvus corone* L., 1758 increased, while *Falco tinnunculus* L., 1758 and *Asio otus* (L., 1758) fluctuated depending on the abundance of rodents. *Eremophila alpestris* and *Emberiza citrinella* were not encountered in winter, and no additional species were noted. The species diversity of the summer population increased from 6.25 to 11, and that of the winter population decreased from 7 to 5.3.

Keywords: agrocenosis, invasion of small-leaved elm, birds of agricultural lands, nesting of birds, long-term changes, succession

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ORCID:

T.V. Zlotnikova, <https://orcid.org/0000-0003-0540-0399>

E.Yu. Zhukova, <https://orcid.org/0000-0003-0577-2969>

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Научная статья

Многолетняя динамика фауны и населения птиц на залежи с деградирующими полегающими лесополосами (Абаканская степь)

Т.В. Злотникова* , Е.Ю. Жукова 

Хакасский государственный университет им. Н.Ф. Катанова, 655017, Россия, г. Абакан, пр. Ленина, д. 90

*tamara.zlotnikova@mail.ru

Аннотация. В агроценозе Абаканской степи за 25-летний промежуток времени в условиях залежной сукцессии, инвазии *Ulmus pumila* L. и выпаса скота произошли изменения фауны и населения птиц: ранее обитало 65 видов птиц, 23 вида гнездились; в настоящее время встречено 57 видов, в том числе 22 гнездящихся. Общая плотность населения в гнездовой период возросла в 1.5 раза, в зимний период снизилась в 2–2.5 раза. В видовой структуре летнего и зимнего населения произошла смена доминантов. Среди гнездящихся птиц уменьшилась плотность *Alauda arvensis* L., 1758, увеличилась – *Hippolais caligata* (Lichtenstein, 1823) и *Saxicola torquata* (L., 1766). Появились *Ficedula parva* (Bechstein, 1794) и *Emberiza hortulana* L., 1758, исчезли *Eremophila alpestris* (L., 1758) и *Emberiza citrinella* L., 1758. Число гнездящихся пар *Pica pica* (L., 1758) и *Corvus corone* L., 1758 увеличилось, а *Falco tinnunculus* L., 1758 и *Asio otus* (L., 1758) – колебалось в зависимости от обилия грызунов. В зимний период не встречены *Eremophila alpestris* и *Emberiza citrinella*, новых видов не отмечено. Видовое разнообразие летнего населения увеличилось с 6.25 до 11, зимнего населения – уменьшилось с 7 до 5.3.

Ключевые слова: агроценоз, инвазия вяза мелколистного, птицы сельскохозяйственных земель, гнездование птиц, многолетние изменения, сукцессии

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ORCID:

Т.В. Злотникова, <https://orcid.org/0000-0003-0540-0399>

Е.Ю. Жукова, <https://orcid.org/0000-0003-0577-2969>

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Introduction

The Abakan steppe, which occupies the central part of the Minusinsk Basin, was mostly plowed in the mid-20th century. Arable lands were equipped with a system of shelterbelts to protect against dry winds and erosion, improve the water regime, and retain snow. In the Minusinsk Basin, shelterbelts were developed from the 1950s to the 1990s (Fomin, 1952; Zashchitnoye lesorazvedenie, 2003), and contributed to an increase in the species richness of birds due to the additional of species of the forest complex. At the end of the 20th century, agricultural practices changed: in arid steppe regions, large areas of arable land were excluded from agricultural use, and shelterbelts were not maintained. Demutation processes began on arable lands, and the forest stand of forest belts began to collapse, since even the species most resistant to local drought conditions (*Larix sibirica* Ledeb., *Betula pendula* Roth., *Ulmus pumila* L., *Populus nigra* L.) reached a critical age of 15–25 years (Kutkina, 1998).

The overgrowing of arable lands and the aging of forest belts affect their biotopic properties including their bird fauna, for which the fields serve as ecological channels, feeding and nesting sites. Changes occurring during demutations and the current state of lands withdrawn from agricultural circulation have been well studied only using individual components of ecosystems as an example. Thus, the structure and productivity of the vegetation cover, soil, and the state of the shelterbelt have been characterized in sufficient detail (Kutkina and Eremina, 2021; Lobanov et al., 2022; Martynova, 2019a, b; Sorokina, 2017; Varaksin and Weiss, 2016). In this context, issues of the dynamics of soil mesofauna are also discussed (Balyazin and Bessolitsyna, 2014). The features of the population and ecology of birds in agricultural landscapes has attracted the attention of many specialists (Dobrovolsky, 2016; Golovanova, 1975; Korovin, 2004; Malchevsky, 1947 and many others). In the last two decades, changes in the biological diversity of birds caused by post-agricultural succession have been actively discussed (Bolnykh and Vengerov, 2011; Korovin, 2015, 2018; Melnikov and Khruleva, 2006; Mishchenko and Sukhanova, 2007; Oparin, 2008; Sviridova et al., 2006; Shitikov, 2000 and many others), while the winter period is almost not covered.

The fauna and bird population of agricultural fields and forest belts of the Minusinsk Basin are considered in a number of works (Prokofiev, 1975, 1986, 1987, 2001; Zlotnikova, 1998, 2000, 2001, 2002a, b), but they characterize the situation of at least 20 years ago, and the response of bird species diversity to the reduction in the intensity of agriculture in the region has not been analyzed.

The aim of the study is to analyze the dynamics of bird fauna population in fallow lands with deteriorating forest belts.

Material and methods

The analysis is based on materials obtained in the periods 1998–2001, 2019, December 2021 – September 2022. The species composition, dominance structure during the nesting period and wintering period, and nesting density of dominant species were studied.

The study area of 2.6 km² is located on the left bank of the Abakan River, 25 km from the city of Abakan. Several hundred meters away are ruined stone buildings. One kilometer to the northwest are

small, partially drying lakes (up to 3 hectares in area), and three kilometers to the south and southeast is the Abakan River. The study area consists of fields where wheat and buckwheat were grown until 1999, surrounded by four-row forest belts of *Ulmus pumila* and *Ribes aureum* Pursh. In 1999, spontaneous conservation of the land was carried out. In accordance with the 4 stages of demutation of the fallow lands of Khakassia (Kutkina and Eremina, 2021), at the end of the first period of our study (2000 and 2001), the vegetation was at the weed stage, with the weeds and wormwood dominant; in the second period (2022) it was at stages 3–4, with the dominance of loose and dense sod grasses. Since 2013, sheep and goats have been grazing on this land.

The total length of the shelterbelts is 12 km, the distance between them is 300 m. The trees are planted in four rows, the distance between the rows is 2.5 m. In 1998–2001, the shelterbelts were in satisfactory condition, but the assessment of the condition of the tree stand, which we carried out in 2022 based on the Sanitary Rules¹, showed that 70–75% of the trees are classified as "severely weakened" and "drying out", and 25–30% have fallen out of the tree stand (Fig. 1). Young individuals of *Ulmus pumila* have grown between the shelterbelts by self-seeding, mainly in the form of shrubs. Near the shelterbelt, on the leeward side, the shrubs grow in a strip several tens of meters wide (Fig. 2). Their height here does not exceed one meter. At a greater distance from the forest belts, *Ulmus pumila* specimens two or more meters high grow singly and in islands. *Ribes aureum* has survived in the forest belts as single clumps, occupying no more than 5% of its original area.

The species composition of birds was studied in different seasons of the year using the route method. The routes passed both along and across forest belts, with a transect width of 50 m for small species and 100 m for large species. Calculations of density, defined as the number of bird encounters in a certain area, were made separately for each counting method (Ravkin and Chelintsev, 1990). The total length of the routes covered by transects was at least 50 km in the spring-summer period and at least 30 km in the winter for each year of study. Due to the low accuracy of transect bird counts, interval estimates are given for density. Species with a participation share in the population of $\geq 10\%$ were considered dominant in terms of numbers, and species with a participation share from 1 to 9% were considered codominants.

For large tree-nesting birds, all inhabited nests were counted, and nesting density was determined. In forest belts, nests were searched for by conducting a continuous inspection of trees and the grass tier; in fields, a continuous inspection of the grass tier was conducted on model sites. Model sites of 1 to 2 hectares in size were laid out in such a way as to cover all types of microhabitats in the fields. Nine sites were surveyed annually. Bird nesting was studied at the beginning (April–May) and end (June–July) of the nesting period.

Nesting was confirmed by sightings of singing males, birds with nesting behavior, and groups of fledglings. The nomenclature of species is given according to Stepanyan (2003). Species diversity was assessed using the Simpson Dominance index (Pesenko, 1982):

$$S = (\sum p_i^2)^{-1},$$

where S – species diversity; p_i – proportion of individuals of the i -th species.

Results and discussion

The use of agrocenoses by birds as nesting, feeding and protective stations is determined primarily by the species and spatial structure of the vegetation cover, its seasonal changes and productivity. Steppe pastures that replaced crop areas changed the ecological situation. Demutation facilitated the development of steppe phytocenoses – small-turf polydominant cereals and small-turf wormwood-cereals, which, unlike crops, are characterized by a two- and three-tiered grass cover. Shrubs of different heights further complicate the vertical structure of plant communities. The mosaic nature of the landscape, caused by the heterogeneity of the microrelief and edaphic factors, has increased due to the asynchronous nature of successional processes. Despite the destruction of some plant shoots by livestock, the vegetation cover does not undergo abrupt annual changes, as happened on arable lands during seasonal work. Most of the primary production remains in the ecosystem. These changes have implications for birds of different ecological groups.

¹ Order of the Federal Forestry Agency dated 15.01.1998 No. 10 "On approval of Sanitary Rules in the forests of the Russian Federation".



Fig. 1. State of the forest belt stand 21 May, 2022. Photograph by T.V. Zlotnikova.



Fig. 2. *Ulmus pumila* growth on the leeward side of a forest belt 21 May, 2022. Photograph by T.V. Zlotnikova.

A total of 67 bird species were encountered in the fields: 65 in the first observation period and 57 in the second. A total of 25 species nested during the entire observation period: 23 species in 1998–2001, including 11 sedentary species; 22 species in 2022, including 8 sedentary species (Table 1). Changes in the composition of the nesting fauna over a 25-year period occurred due to five species. Two previously common nesting species, *Eremophila alpestris* and *Emberiza citrinella*, as well as one rare species, *Anthus campestris*, were not encountered in 2022. Two other species, *Emberiza hortulana* and *Ficedula parva*, previously not recorded at all, joined the group of nesting species. For four of them, the key role was probably played by changes in the spatial structure of the phytocenosis. The sedentary species *Eremophila alpestris* and the migratory *Anthus campestris* prefer open areas with sparse vegetation. All their nests found in the first period of research (8 and 5 nests, respectively) were located in stubble fields. The absence of these campophiles in the 2022 surveys may be due to the increase in the height, density and tiers of the grass cover and a decrease in the area of open territories. For the dendrophiles *Emberiza hortulana* and *Ficedula parva*, suitable nesting conditions were formed due to the development of tree growth. The disappearance of the previously common and widespread *Emberiza citrinella* is most likely not associated with a change in habitat conditions in a particular territory, since in the Minusinsk Basin in the last five years the species has been noted only in a few cases.

Table 1. Species composition of nesting birds. Nature of stay: n – nesting migratory, s – sedentary; “–” – species not found.

No.	Species	Nature of stay	
		1998–2001	2022
Order Falconiformes			
Family Falconidae			
1	<i>Falco tinnunculus</i> L., 1758	n	n
Order Galliformes			
Family Phasianidae			
2	<i>Perdix dauurica</i> (Pallas, 1811)	s	s
3	<i>Coturnix coturnix</i> (L., 1758)	n	n
Order Strigiformes			
Family Strigidae			
4	<i>Asio otus</i> (L., 1758)	s	s
Order Upupiformes			
Family Upupidae			
5	<i>Upupa epops</i> L., 1758	n	n
Order Passeriformes			
Family Alaudidae			
6	<i>Eremophila alpestris</i> (L., 1758)	s	–
7	<i>Alauda arvensis</i> L., 1758	n	n

No.	Species	Nature of stay	
		1998–2001	2022
Family Motacillidae			
8	<i>Anthus campestris</i> (L., 1758)	n	–
9	<i>Motacilla flava</i> L., 1758	n	n
Family Corvidae			
10	<i>Pica pica</i> (L., 1758)	s	s
11	<i>Corvus corone</i> L., 1758	s	s
12	<i>Corvus corax</i> L., 1758	s	s
Family Sylviidae			
13	<i>Acrocephalus dumetorum</i> Blyth, 1849	n	n
14	<i>Hippolais caligata</i> (Lichtenstein, 1823)	n	n
15	<i>Sylvia curruca</i> (L., 1758)	n	n
16	<i>Phylloscopus collybita</i> (Vieillot, 1817)	n	n
Family Muscicapidae			
17	<i>Ficedula parva</i> (Bechstein, 1794)	–	n
18	<i>Saxicola torquata</i> (L., 1766)	n	n
19	<i>Oenanthe oenanthe</i> (L., 1758)	n	n
Family Paridae			
20	<i>Parus major</i> L., 1758	s	s
Family Passeridae			
21	<i>Passer montanus</i> (L., 1758)	s	s
Family Fringillidae			
22	<i>Carduelis carduelis</i> (L., 1758)	s	w
Family Emberizidae			
23	<i>Emberiza citrinella</i> L., 1758	s	–
24	<i>Emberiza cioides</i> J.F. Brandt, 1843	s	s
25	<i>Emberiza hortulana</i> L., 1758	–	n
Total number of species		23	22
including nesting migratory		12	13
sedentary		11	8

To assess the changes in the bird population density, we used the data from 1999 (when the arable land was converted into a fallow land, and the shelterbelts were in a satisfactory condition) and 2022 (under conditions of the completion of demutation processes and degradation of shelterbelts). The overall population density of nesting period birds increased one and a half times (Table 2). The density of *Emberiza cioides*, *Hippolais caligata* and *Saxicola torquata* increased 2–4 times; it remained approximately at the same level for *Passer montanus*, *Pica pica* and *Corvus corone*. A halving in density was observed for *Alauda arvensis*. As a result of these changes, three species changed their rank from the dominant group, which included four species in 1999, moving to the codominant group. The exception is *Passer montanus*, which remains one of the most numerous species.

The ornithopopulation of the 2022 nesting period is characterized by a high density of dendrophile *Emberiza hortulana*, campophiles *Hippolais caligata* and *Saxicola torquata*, as well as sclerophiles *Passer montanus*. *Hippolais caligata* and *Saxicola torquata*, which prefer tall-grass vegetation, were common before, but they nested along the edges of fields, in places where steppe plant species and weeds grow. Only in these areas was there sufficient plant debris left to conceal the nests, and tough dry stems of herbaceous plants, which served as perches for the birds. The cessation of agricultural work contributed to the widespread restoration of the steppe litter and the preservation of dead wood (Figs. 1, 2), which increased the ecological capacity of the lands for campophiles. In 2022, nests were distributed more evenly throughout the entire territory. The decrease in the density of *Alauda arvensis* and the loss of the dominant position of this species in the bird population most likely resulted from the development of woody vegetation. Using other agrocenoses as an example, it was found that *Alauda arvensis* and *Eremophila alpestris* leave habitats when the fragmentation of open spaces and the length of forest edges increase (Korovin, 1986). *Passer montanus* is a species closely associated with anthropogenically modified territories. These birds readily feed both in agricultural fields and near grazing flocks, flying up to 3 km from the feeding site to the nest (Polevoi vorobey, 1981). In open habitats, the number of sparrows is often limited by the availability of suitable places for nesting. In the studied fields, sparrows nest and roost in the numerous inhabited and uninhabited magpie nests, so the change in land use did not significantly affect the density of the species during the nesting period.

The nesting bird population of the first observation period was dominated by species that nested on the ground – 43% (including 27% – *Alauda arvensis*), in trees – 24% and closed-nesting (magpies in nests) – 22%. In the second period, the proportions of these groups were 55, 14 and 16%, respectively. Among the trophic groups in both periods, species feeding on both insects and plant food (larks, buntings, sparrows) predominated: 54% in the first period and 55% in the second. The proportion

Table 2. Main characteristics of the bird population during the nesting period.

Characteristics	Period of study	
	May – June 1999	May – June 2022
Number of individuals per 1 km ²	70–100	120–150
Dominants (share of participation, %)	<i>Alauda arvensis</i> (27) <i>Passer montanus</i> (22) <i>Pica pica</i> (13) <i>Corvus corone</i> (11)	<i>Emberiza hortulana</i> (17) <i>Passer montanus</i> (12) <i>Hippolais caligata</i> (12) <i>Saxicola torquata</i> (10)
Codominants (share of participation, %)	<i>Emberiza cioides</i> (5) <i>Saxicola torquata</i> (5) <i>Hippolais caligata</i> (4) <i>Perdix dauurica</i> (2)	<i>Alauda arvensis</i> (9) <i>Emberiza cioides</i> (7) <i>Pica pica</i> (7) <i>Corvus corone</i> (6) <i>Ficedula parva</i> (4) <i>Sylvia curruca</i> (4) <i>Falco tinnunculus</i> (1)

of insectivorous birds increased sharply: from 9% in 1999 to 30% in 2022 due to *Hippolais caligata*, *Saxicola torquata* and *Ficedula parva*. The proportion of omnivores, on the contrary, decreased from 24 to 13%. Herbivorous birds comprised no more than 2% over the entire observation period, and predatory birds no more than 1%.

The results of the census of inhabited nests are shown in Fig. 3. Before the conservation of the arable land, in 1998 and 1999, the number of nesting pairs of corvids did not change. In 1999, the birds built new nests near the previous year's ones. Cases of *Pica pica* building a new nest directly above the old one were recorded, when the roof of the previous nests served as a support for the new nest. A case of nesting in the previous year's nest was noted. These facts indicate the stable existence of populations in stable environmental conditions. Of the diurnal birds of prey, *Falco tinnunculus* nested in small numbers in 1998 and 1999, laying eggs in old magpie nests. The owl *Asio otus* was not recorded on the site during this period.

The 1999 harvest remaining in the fields probably led to an increase in the number of small mouse-like rodents and improved the trophic base for birds of prey and omnivores. A study of the diet of corvids in this area in 1999–2000 showed that 30% of *Pica pica* pellets and 100% of *Corvus corone* pellets contained wheat grains, and 18% of *Pica pica* pellets contained bones of small mouse-like rodents (mainly juveniles) (Zlotnikova, 2000, 2002a). In addition, 2001 and 2002 were “mouse” years for the entire Abakan steppe, and birds of prey nested in high numbers in other studied habitats (Ekimov and Zlotnikova, 2001). The increase in food availability during this period probably resulted in an increase in the number of nesting pairs of *Corvus* and *Falco tinnunculus*, as well as the appearance of nesting *Asio otus*, which settled in old magpie nests. This effect was observed for at least two years after the cessation of agricultural work (Fig. 3).

In the steppe Trans-Urals, the reduction of functioning agrocenoses led to a decrease in the number of nests of corvids in forest belts (Korovin, 2018). In our model agrocenosis, with successional changes, the nesting density of corvids tended to increase: in 2019 and 2022, compared to the indicators at the beginning of observations, it increased by 2–3 times. At the same time, *Pica pica* remained dominant. The increase in the number of nesting pairs of corvids may be associated not only with a change in the phytocenosis, but also with the grazing of small cattle on the fallow land. It is known that herd animals attract some birds, as they facilitate their foraging, trampling the high grass, contributing to an increase in the number of bloodsucking insects, parasites and coprophages. Carcasses of domestic ungulates

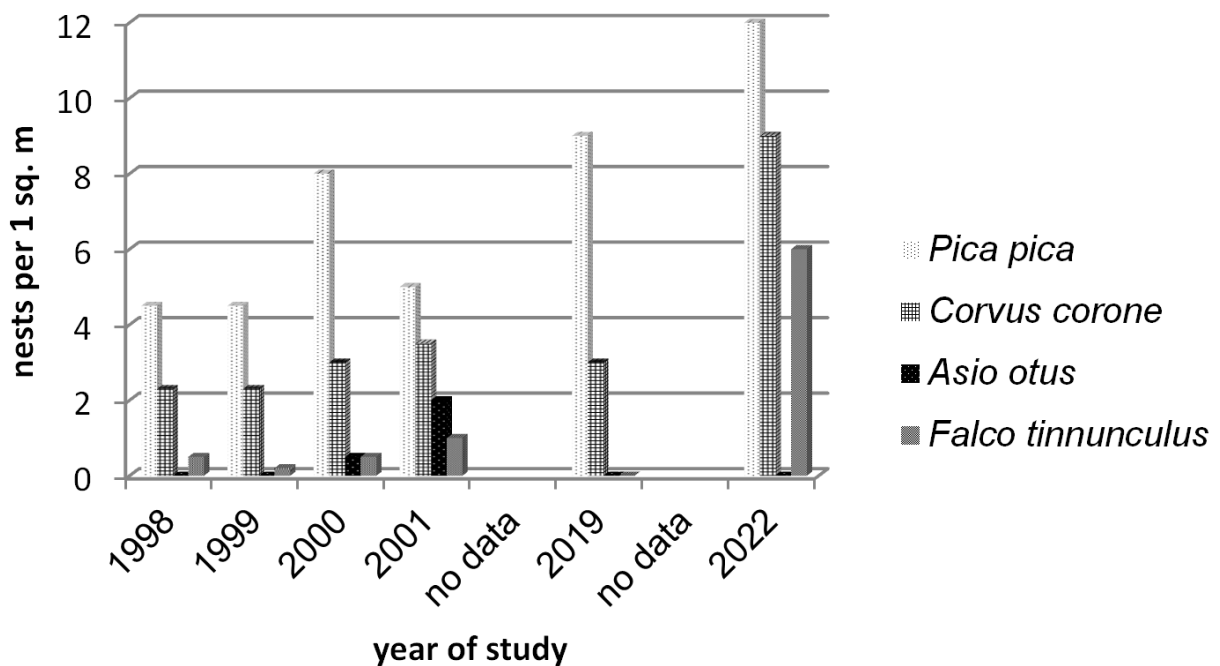


Fig. 3. Density of nesting birds in the study area.

remained on the pastures, which also serve as a source of food: during one of the counts, the remains of two sheep were found, which were fed on by magpies.

A comparison of the number of inhabited nests of corvids between the first and second observation periods and the summer population density of these species, determined during transect counts, showed a discrepancy in the changes. In 2022, the number of pairs nesting in the agrocenosis was greater than in 1999, and the density, defined as the number of bird encounters in a certain area, was similar (*Corvus corone* – 9 and 8 individuals per 1 km² in 1999 and 2022, respectively, *Pica pica* – 11 and 10 individuals per 1 km²). We assume that in the second observation period, the birds, following grazing animals, expanded their foraging territories, which were previously limited to crop areas.

The number of nesting pairs of *Falco tinnunculus* in 2022 also increased many times compared to 1998. No nests of the long-eared owl were recorded at the sites in 2022. *Falco tinnunculus* and *Asio otus* are closely associated with agricultural lands, which they use as nesting and feeding stations. Among the various types of anthropogenically modified landscapes, *Falco tinnunculus* prefers to hunt in pastures (Pererva, 1990). In the diet of this species, gray voles, which predominate in areas disturbed by humans, exceed "wild food" by 3–4 times (Shepel, 1988). The appearance of fallow lands probably improves the trophic situation for these bird species. Thus, in the steppe zones of the Trans-Urals, the agricultural crisis led to a fourfold increase in the number of nesting pairs of *Falco tinnunculus* and an almost twofold increase in *Asio otus* (Korovin, 2018). Research conducted by us in 2022 on adjacent fallow and virgin lands also showed an increase in the number of nesting pairs of *Falco tinnunculus* and a relatively low nesting density of *Asio otus* (unpublished data). Therefore, the observed dynamics of nesting of vole-eating birds most likely reflects not only local processes.

Agrocenoses are used as feeding grounds not only by nesting birds, but also by visiting species. This becomes especially noticeable in non-nesting seasons, when the proportion of birds penetrating from neighboring biotopes increases. The drying forest stand of forest belts attracts insectivorous species. Small mammals that use forest belts as temporary survival stations (Senotrusova, 2017) attract birds of prey. The food value of agrocenoses changes significantly during seasonal agricultural work. In fields with stubble residues or after pre-sowing cultivation, natural plant and animal ground feeds become more accessible, and the lost part of the harvest remains. During the ripening and harvesting of grain, mammals are concentrated in the fields.

The species composition of birds that do not nest in the area but were repeatedly noted feeding on the sites during the nesting and post-nesting period, is given in Table 3. There were 21 species of visiting birds noted in the first period, and 16 in the second. These are mainly insectivorous (8 species), predatory (6 species), and birds that feed on both plant and animal food (4 species).

All visiting species nest in neighboring biotopes: in the forested areas of the Abakan River floodplain, along coastal cliffs, in populated areas and livestock farms, and in virgin steppe areas. For dendrophilous insectivorous species (tits and woodpeckers), the system of forest belts serves as ecological corridors.

Table 3. Species composition of visiting birds during the nesting and post-nesting period (April – September).

No.	Species	Period of study	
		1998–2001	2022
Order Anseriformes			
Family Anatidae			
1	<i>Tadorna ferruginea</i> (Pallas, 1764)	+	+
Order Falconiformes			
Family Accipitridae			
2	<i>Milvus migrans</i> (Boddaert, 1783)	+	+
3	<i>Circus cyaneus</i> (L., 1766)	+	+
4	<i>Accipiter nisus</i> (L., 1758)	+	+

No.	Species	Period of study	
		1998–2001	2022
5	<i>Buteo buteo</i> (L., 1758)	+	–
	Family Falconidae		
6	<i>Falco peregrinus</i> Tunstall, 1771	+	–
	Order Gruiformes		
	Family Gruidae		
7	<i>Anthropoides virgo</i> (L., 1758)	+	–
8	<i>Columba rupestris</i> Pallas, 1811	+	+
9	<i>Cuculus canorus</i> L., 1758	+	–
	Order Piciformes		
	Family Picidae		
10	<i>Dendrocopos minor</i> (L., 1758)	+	+
	Order Passeriformes		
	Family Hirundinidae		
11	<i>Riparia riparia</i> (L., 1758)	+	+
12	<i>Hirundo rustica</i> L., 1758	+	+
	Family Laniidae		
13	<i>Lanius cristatus</i> L., 1758	+	+
	Family Corvidae		
14	<i>Corvus monedula</i> L., 1758	+	+
	Family Muscicapidae		
15	<i>Phoenicurus phoenicurus</i> (L., 1758)	+	+
	Family Paridae		
16	<i>Parus montanus</i> Baldenstein, 1827	+	+
17	<i>Parus ater</i> L., 1758	+	+
	Family Sittidae		
18	<i>Sitta europaea</i> L., 1758	+	+
	Family Fringillidae		
19	<i>Fringilla coelebs</i> L., 1758	+	–
20	<i>Carduelis caniceps</i> Vigors, 1831	+	+
21	<i>Acanthis cannabina</i> (L., 1758)	+	+
	Total number of species	21	16

Visitors were encountered mainly singly or in small flocks. Differences in the number of species recorded in the two periods are probably due to different durations of observations. The nature of stay of three species with single encounters in the nesting and post-nesting period has not been determined: *Tadorna tadorna* (L., 1758), *Garrulus glandarius* (L., 1758), and *Fringilla montifringilla* L., 1758.

In winter, the number of birds and their distribution over the territory are determined primarily by the food supply. Snow cover creates limitations for herbivorous birds feeding on the ground and vole-eating predators. The climatic features of the central part of the Minusinsk Basin – little precipitation in winter and frequent winds (Galakhov, 1964; Mosolova et al., 2016) that blow away snow – facilitate foraging in open areas. Arable lands can remain open for several weeks in the winter months and are cleared of snow earlier than other areas. Fallow areas with a permanent grass cover, litter and undergrowth of shrubs retain snow better, but the cover is never deep. Snow has little effect on foraging of birds feeding on trees and dry tall stems of plants.

The results of winter bird counts are presented in Tables 4 and 5. The species composition has changed little over 25 years: of the 33 species encountered in the first period, three were not recorded in the second period. These are two common sedentary species, *Eremophila alpestris* and *Emberiza citrinella*, as well as *Lanius excubitor*, which was only observed a few times in 1998–2001. No new species were recorded in 2022.

The winter bird population density decreased more than twofold in the second study period (Table 5). *Passer montanus* remained the most numerous wintering species, but its density decreased. The winter population in 1998–1999 was mainly made up of herbivorous species – 54% (buntings, finches, *Perdix dauurica*) and species feeding on both plant and animal food – 25% (*Passer montanus*). The proportion of omnivores was 10%, insectivores – 3%. In the winter of 2021–2022, the predominant species were those feeding on both plant and animal food – 40%, plant food – 23%, and insectivores – 12%. The proportion of omnivores was 6%. Birds of prey accounted for less than 1% in both periods.

The changes that occurred are linked to food availability. Wintering finches, buntings and passerines, which form the basis of the winter population, previously fed on seeds on tall stems of weedy plants not covered with snow – wormwood, goosefoot, hemp and other weeds, as well as on open areas of harvested fields, where the seeds of cultivated and weed plants remain. With the transformation of the agrocenosis into a steppe community and the appearance of shrubs, open areas disappeared, the territories occupied by weeds decreased. There was a deterioration in the trophic situation for seed-eating birds feeding on the ground and on weeds.

Herbivorous birds feeding in trees in winter: *Turdus pilaris*, *T. ruficollis*, *T. atrogularis*, *Bombycilla garrulus* were often recorded in the model territories in both study periods. Despite the invasive migration strategy, they were not numerous here. In the studied shelterbelts, trees die off and almost do not produce seeds. In the adjacent agrocenoses, part of the field-protective and roadside shelterbelts are formed by *Betula pendula*, *Populus nigra*, *Malus baccata* (L.) Borkh., some of which are currently in satisfactory condition. On the fallow lands between the shelterbelts, tree growth of these species and the shrub sea buckthorn *Hippophaë rhamnoides* L. has also formed, forming dense clumps of up to 500 m² in the relief depressions. Herbivorous birds feed on the fruits and seeds of these woody plants: in places where sea buckthorn grows, mixed flocks of thrushes of several dozen and hundreds of individuals were encountered. It is likely that it was from such territories that small flocks of thrushes and *Bombycilla garrulus* penetrated into the stands formed by *Ulmus pumila*.

Wintering birds of prey remained the same. These are the sedentary species *Asio otus* and *Buteo lagopus* and *Nyctea scandiaca* migrating to the Minusinsk Basin for the winter. All of them are predominantly vole-eaters and gravitate towards open spaces with areas devoid of snow. Birds of prey were few in number – during winter censuses only single individuals of *Buteo lagopus* and *Nyctea scandiaca* were noted. *Asio otus* was not visually noted in winter, but two winter perches were observed. The pellets collected under the perches were dominated by bone remains of *Microtus gregalis* (Pall., 1779) (Zlotnikova, 2000).

Variations in species diversity indirectly indicate changes in the ecological quality of the environment and the sustainability of a particular community (Magarran, 1992). Thus, during the restoration of the ecosystem from arable land to loose and dense sod cereal steppe, the species diversity of the nesting bird population increased significantly – from 6.25 to 11. Since the number of nesting species has hardly changed, the increase in the indicator is due to the increase in the evenness of the numbers of different species. Similar trends were identified in the steppes of the Voronezh and Saratov regions, the Urals

Table 4. Species composition of wintering birds. Nature of stay: w – only winters; s – sedentary.

No.	Species	Nature of stay	
		December – February 1998–2001	December 2021 – February 2022 r
Order Falconiformes			
Family Accipitridae			
1	<i>Buteo lagopus</i> (Pontoppidan, 1763)	w	w
Order Galliformes			
Family Phasianidae			
2	<i>Perdix dauurica</i> (Pallas, 1811)	s	s
Order Strigiformes			
Family Strigidae			
3	<i>Nyctea scandiaca</i> (L., 1758)	w	w
4	<i>Asio otus</i> (L., 1758)	s	w
Order Piciformes			
Family Picidae			
5	<i>Dendrocopos major</i> (L., 1758)	w	w
6	<i>Dendrocopos leucotos</i> (Bechstein, 1803)	w	w
7	<i>Dendrocopos minor</i> (L., 1758)	w	w
8	<i>Picoides tridactylus</i> (L., 1758)	w	w
Order Passeriformes			
Family Alaudidae			
9	<i>Eremophila alpestris</i> (L., 1758)	s	–
Family Laniidae			
10	<i>Lanius excubitor</i> L., 1758	w	–
Family Corvidae			
11	<i>Pica pica</i> (L., 1758)	s	s
12	<i>Corvus corone</i> L., 1758	s	s
13	<i>Corvus corax</i> L., 1758	s	s
Family Bombycillidae			
14	<i>Bombycilla garrulus</i> (L., 1758)	w	w
Family Muscicapidae			
15	<i>Turdus ruficollis</i> Pallas, 1776	w	w
16	<i>Turdus atrogularis</i> Jarocki, 1819	w	w
17	<i>Turdus pilaris</i> L., 1758	w	w

No.	Species	Nature of stay	
		December – February 1998–2001	December 2021 – February 2022 r
Family Aegithalidae			
18	<i>Aegithalos caudatus</i> (L., 1758)	w	w
Family Paridae			
19	<i>Parus palustris</i> L., 1758	w	w
20	<i>Parus montanus</i> Baldenstein, 1827	w	w
21	<i>Parus ater</i> L., 1758	w	w
22	<i>Parus cyanus</i> Pallas, 1770	w	w
23	<i>Parus major</i> L., 1758	s	s
Family Sittidae			
24	<i>Sitta europaea</i> L., 1758	w	w
Family Passeridae			
25	<i>Passer montanus</i> (L., 1758)	s	s
Family Fringillidae			
26	<i>Carduelis carduelis</i> (L., 1758)	s	w
27	<i>Acanthis flammea</i> (L., 1758)	w	w
28	<i>Uragus sibiricus</i> (Pallas, 1773)	w	w
29	<i>Pyrrhula pyrrhula</i> (L., 1758)	w	w
30	<i>Coccothraustes coccothraustes</i> (L., 1758)	w	w
Family Emberizidae			
31	<i>Emberiza citrinella</i> L., 1758	s	–
32	<i>Emberiza cioides</i> J.F. Brandt, 1843	s	s
33	<i>Plectrophenax nivalis</i> (L., 1758)	w	w
Total number of species		33	30
including wintering		22	23
sedentary		11	7

Табл. 5. Main characteristics of the bird population in winter.

Характеристика	Period of study	
	December 1998 – February 1999	December 2021 – February 2022
Number of individuals per 1 km ²	240–270	100–130
Dominants (share of participation, %)	<i>Passer montanus</i> (25) <i>Emberiza citrinella</i> (19) <i>Acanthis flammea</i> (13)	<i>Passer montanus</i> (40) <i>Emberiza cioides</i> (10) <i>Parus major</i> (10)
Codominants (share of participation, %)	<i>Uragus sibiricus</i> (8) <i>Emberiza cioides</i> (8) <i>Corvus corone</i> (7) <i>Perdix dauurica</i> (4) <i>Pica pica</i> (3) <i>Parus palustris</i> (3) <i>Turdus pilaris</i> (2)	<i>Uragus sibiricus</i> (8) <i>Pica pica</i> (3) <i>Turdus pilaris</i> (3) <i>Corvus corone</i> (3) <i>Perdix dauurica</i> (2) <i>Parus palustris</i> (1) <i>Parus cyanus</i> (1)

(Bolnykh and Vengerov, 2011; Korovin, 2015; Oparin, 2008). The authors associate the increase in bird species diversity with changes in plant height and the area of projective cover of phytocenoses. The species composition of the bird population of the restored steppes in these regions and the Minusinsk Basin is also similar: the basis of the population is *Hippolais caligata*, *Alauda arvensis*, *Emberiza hortulana*, *Saxicola rubetra* (*S. torquata* in the Abakan steppe). The features of the studied community are the high abundance of *Passer montanus*, observed throughout the year, and a decrease in the number of *Alauda arvensis* as a result of demutation of the steppe ecosystem. The species diversity of the winter population has decreased slightly (from 7 to 5.3) due to an increase in the proportion of *Passer montanus* against the background of a sharp decrease in the number of other species, mainly herbivores and omnivores.

Succession processes in model agrocenoses continue. Pasture load slows down, but does not stop, the overgrowing of fields with shrubs. The problem of *Ulmus pumila* invasion on fallow lands in Khakassia is known and widely covered. Special studies have shown that to some extent (crown density 0.1–0.2) shrubs have a positive effect on the state of the phytocenosis, increasing its productivity by up to 1.5 times compared to open fallows. A further increase in crown density leads to a decrease in species diversity and productivity of phytocenoses, and with complete density, productivity decreases to a twentieth or less (Martynova, 2018, 2019a, b; Martynova and Lobanov, 2015).

These changes affect the bird population. In the South Minusinsk Depression there are arable lands where agriculture ceased 30 or more years ago, almost completely overgrown with *Ulmus pumila*. According to our reconnaissance estimates, the crown density here is more than 0.7, the grass cover is single- or double-tiered, with a projective cover of less than 50%. During the nesting period, 3-5 bird species were recorded here, concentrated mainly along the edges. If the current trends persist, the transformation of the vegetation cover may lead to negative changes in the fauna and bird population.

Conclusions

In a model agrocenosis with forest belts of *Ulmus pumila* and *Ribes aureum*, transferred to a fallow land 25 years ago, a forest-steppe landscape was formed as a result of self-seeding of *Ulmus pumila*. The territory is currently used for grazing small cattle. Long-term succession processes, changes in the nature of land use and population dynamics have led to changes in the fauna and bird population.

In 1998–2001, 65 bird species were encountered in the fields, 23 species were nesting. In 2022, 57 species were recorded, including 22 nesting ones. The overall population density during the nesting period increased by 1.5 times. A change in dominants occurred: the density and proportion of *Alauda arvensis* decreased, the leading position was occupied by the previously unnoticed *Emberiza*

hortulana, as well as *Hippolais caligata* and *Saxicola torquata*. *Eremophila alpestris* and *Emberiza citrinella* completely disappeared from the nesting population, *Ficedula parva* appeared. The number of nesting pairs of *Pica pica* and *Corvus corone* increased. Nesting of *Falco tinnunculus* and *Asio otus* depended on the abundance of rodents.

The species diversity of the summer population increased from 6.25 to 11. In the nesting bird population, ground-nesting species prevailed in both observation periods (43% and 55%, respectively), and in terms of diet, species feeding on both insects and plant food prevailed (54% and 55%). The proportion of insectivores increased (from 9 to 30%), while that of omnivores decreased (from 24 to 13%).

There were 21 species of visiting birds recorded in the first period, and 16 in the second. All these species nest in neighboring biotopes. In the winter of 1998–2001, 33 species of birds were recorded, in the winter of 2021–2022 – 30 species. The usual *Eremophila alpestris* and *Emberiza citrinella* disappeared, no new species were recorded. The density of the winter bird population decreased to 40–50% of previous levels, mainly due to the absence of *Emberiza citrinella* and *Acanthis flammea*, with *Parus major* becoming one of the dominants. The species diversity of the winter population decreased from 7 to 5.3. The ecological structure of the ornithocenosis changed: the proportion of herbivorous species decreased from 54 to 23%, and the proportion of species feeding on both plant and animal food (*Passer montanus*) increased from 25 to 40%.

As in the period of land cultivation, the bird population is currently represented mainly by eurybiont species and is characterized by high species diversity. Birds have close trophic links with adjacent territories. The changes are due to the transformation of the species and spatial structure of phytocenoses (cultivated plants and weeds are replaced by steppe species, fields are overgrown with shrubs, habitats are fragmented), the transition of arable land to pastures, as well as population trends of birds and small mammals, occurring both at the level of a specific agroecosystem and at the subregional level.

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