CHANGES IN BIRD COMMUNITIES THROUGHOUT SECONDARY BILBERRY PINE FOREST SUCCESSION IN SOUTH-WESTERN BELARUS

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Abstract

The article tracks the changes in the bird population during secondary succession of cleared bilberry pine forest. The field work was performed in the years 1996–2018 applying the conventional bird count methods. The study revealed that the bird species diversity in the course of succession (6 stages, 1–90 years old) increased from 10 to 45 species, total abundance – from 159.2±1.25 to 687.0±3.80 birds/km², total biomass – from 5.71±0.25 to 31.34±1.10 kg/km². The ornithological diversity included six faunal types. At the initial stages of succession the bird population comprised the European, European-Turkestan and Palearctic types of fauna. At the stage of 80–90 years old the species structure (55.6%) and the total biomass (47.7%) were dominated by the Palearctic types of fauna, and the bird population (48.6%) was dominated by the European types of fauna.

Key words: succession; bilberry pine forest; ornithological diversity; dominant; rare bird species; Belarus

Introduction

Secondary successions of vegetation and avifauna of forest ecosystems have been studied most fully. With the appearance of fresh cutting or after a fire, there is a spatial redistribution of dendrophilous species that inhabited the forests prior to the deforestation, birds of open landscapes (meadows, fields, shrubs) and forest edges. The change in the bird population in the forests is caused by a consistent succession of phytocenoses, accompanied by a change in the life forms of the dominant plants. At present the main reason for the occurrence of successions in Belarus and other regions are anthropogenic factors (forestry activities, reclamation of agricultural lands adjacent to forests) (Głowaciński 1975, 1979, 1981; Abramova 2007). Cutting down trees on large land areas changes the habitat for birds radically.

The papers devoted to secondary successions of avifauna show that the diversity of birds increases in parallel with the succession of plant communities (Novikov et al. 1956; Danilov 1958; Johnson and Odum 1975; Bednorz and

Bogucki 1982; Helle and Mőnkkőnen 1986). The successions of various bird communities in forest ecosystems in Belarus and other regions have not been sufficiently studied. This paper aims to study the successions of bird populations in bilberry pine forests in the south-western part of the Belarusian Polesie, as well as to analyze the taxonomic and faunal structure of bird communities at different stages of succession.

Material and Methods

The material for this work was collected in 1996–2018 in south-western Belarus in the Brest timber enterprise (Tomashovka, Medno and Domachevo forestries), in the Malorita timber enterprise (Pozhezhin and Malorita forestries), in the Ivatsevichi timber enterprise (Ivatsevichi and Bronnaya Gora forestries), 52º–52º30′N 23°40′–25º30′E. This territory is located in the subzones of broad-leaved pine and hornbeam-oak dark coniferous forests.

The research was conducted in bilberry pine forests *Pinetum myrtillosum*, which occupy 9.5% of the pine forests of Belarus. Pine *Pinus sylvestris* predominates in the forest stand there; in admixture to it – Silver Birch *Betula pendula* (up to 30%), Common Aspen *Populus tremula* (up to 5%) and single trees of Common Oak *Quercus robur*, Common Hornbeam *Carpinus betulus*, Common Alder *Alnus glutinosa* (Lovchiy 2012). The undergrowth contains Bird Cherry *Prunus padus*, Common Rowan *Sorbus aucuparia*, Common Hazel *Corylus avellana*, Alder Buckthorn *Frangula alnus*, and others. In the shrub-grass cover, the background consists of European Blueberry *Vaccinium myrtillus*, Lingonberry *Vaccinium vitis-idaea*, Wood Small-reed *Calamagrostis epigeios*, False Lily of the Valley *Maianthemum bifolium*, Common Bracken *Pteridium aquilinum* and others. The moss layer is dominated by *Pleurozium schreberi*, *Dicranum polysetum*, *Polytrichum commune*, *Hylocomium splendens*, and others.

During the period of secondary succession in pine forests, we have identified six stages of vegetation development: from fresh cutting to mature forest of 90 years old:

1–3 years – grassy vegetation of meadow type (recently clear-cut area);

4–9 years – clear-cut area with plantation of birch, aspen and pine trees;

10–20 years – continuous thickets of bushes, shrubs and undergrowth;

30–40 years – young pine forest;

60–70 years – mature pine forest;

80–90 years – a high preclimax forest of pine with an admixture of birch, oak and other species.

Bird counts were conducted on routes with no capacity limit with subsequent calculation of the average population density according to the average detection range of the birds.

Transect lines (200 m wide, 1–2 km long) were laid in communities at various stages of succession. The first three stages (up to 20 years) of succession were traced on the same sites, and later – on sites occupied by pine phytocenoses of different ages with the same type of conditions. The total length of the routes

covered was 450 km. Generally accepted counting techniques were used for bird inventory (Ravkin 1967; Järvinen and Väisänen, 1976; Bibby et al. 2000). Counting was performed in clear weather in the morning (1 hour after sunrise) and in the evening (stopped 1–2 hours before sunset), when birds are most active, by mapping meetings at trial sites and transects. The calculation of the abundance of birds per area unit was carried out separately by average detection ranges (voice, visual). The dominant species were those whose share in the bird community is 10% or more. Indices of species similarity, species diversity and evenness were determined by well-known methods. Stability is here understood as in Jarvinen's (1979) study: the more stable a community is, the less its properties (e.g. density, diversity, densities of individual species) vary from year to year. To measure stability, we selected the following 3 criteria

1) Coefficient of variation (*CV*%) in bird density;
2) Species diversity (Shannon's index) (*H'*);
3) Evenness of species-abundance distribution (Pielou's evenness index) (*J'*).

Latin names of birds are given according to the Clements checklist of birds of the world: v2019. Faunal types are given according to K. Voous (1962).

Results and their discussion

In the first year, in the clear-cut areas the microclimate, species composition of herbaceous vegetation and invertebrates change dramatically. At the site of fresh cutting, 10 species were counted. Here there are birds of forest edges and open spaces: Tree Pipit *Anthus trivialis*, Meadow Pipit *Anthus pratensis*, Eurasian Skylark *Alauda arvensis*, Woodlark *Lullula arborea*, Whinchat *Saxicola rubetra* and White Wagtail *Motacilla alba* (Table 1).

Some birds (Tree Pipit, Common Redstart *Phoenicurus phoenicurus*, etc.) use cuttings as feeding stations. The total abundance on average is 159.2±1.25 birds/km^2, with the dominant species (Tree Pipit, Woodlark and Yellowhammer *Emberiza citrinella*) accounting for 67.4% of the bird population and 30.0% of the species composition (Table 2). The abundance of this group of birds species varies from 18.78 to 25.24 %. Background bird species have a higher level of abundance variation (CV up to 45.53 %). The total biomass is 5.71±0.25 kg/km^2, the biomass is dominated by Grey Partridge *Perdix perdix*, Tree Pipit and Yellowhammer; these three species account for 68.6% of the total indicator.

At the stage of clear-cut area with plantation of birch, aspen and pine trees (4–9 years), birds of shrubby thickets appear: Common Whitethroat *Sylvia communis*, Eurasian Blackcap *Sylvia atricapilla*, Common Linnet *Carduelis cannabina*, Red-backed Shrike *Lanius collurio* and others. The number of species increases to 18, the total abundance is 218.8±1.28 birds/km^2. The composition of the dominant species does not change in comparison with the previous stage, they make up 56.8% of the bird population and 16.7% of the species composition. The abundance of species varies significantly (from 14.67 to 135.00 %). The abundance is more stable in Woodlark (CV = 14.67 %), Tree Pipit (CV = 17.70%) and Meadow Pipit (CV = 17.95%). An extremely high level of variation in this

parameter (more than 90%) was observed in three species: European Goldfinch *Carduelis carduelis*, Spotted Flycatcher *Muscicapa striata* and Corn Crake *Crex crex*, with their abundance less than 1.5 birds/km^2. The biomass is dominated by Grey Partridge, Tree Pipit, Woodlark and Yellowhammer, which make up 66.6% of the total biomass (6.46±0.28 kg/km^2).

20 species of birds were recorded in dense thickets of bushes (10–20 years old). Birds of the edges and open spaces (Meadow Pipit, Whinchat, Eurasian Skylark, Grey Partridge) begin to fall out from the community. They are replaced by birds of tree and shrub tiers. The total abundance is significantly reduced – 179.1±1.40 birds/km^2. The share of dominant species (Tree Pipit, Yellowhammer, Common Chaffinch *Fringilla coelebs*) in the total abundance is 38.1% (Table 2). The variability of abundance of this group of bird species ranges from 20.45 to 25.60 %. High variability of abundance is typical for species with low population, the abundance of which does not exceed 5 birds/km^2. The biomass is dominated by Common Blackbird *Turdus merula* and Song Thrush *Turdus philomelos*, Common Chaffinch, Yellowhammer and Tree Pipit; their share in the total biomass (5.08±0.26 kg/km^2) is 69.7%.

By 30–40 years, the bird community acquires a characteristic appearance for this type of forest, the number of species increases to 27. The total abundance is 1.3 times higher than at the previous stage. As the age of the main forest-forming species (common pine) increases, typical forest bird species begin to dominate the bird community. At this stage, Common Chaffinch dominates by abundance (50,0±3,14 birds/km^2, CV = 21,76 %). The lower the abundance, the greater the role of stochastic variations (random fluctuations), so in species with an abundance of less than 2 birds/km^2, the CV ranges from 63.30% to 119.5%. The dominant biomass species are Common Blackbird, Common Chaffinch, Fieldfare *Turdus pilaris* and Carrion Crow *Corvus corone*, which together account for 59.5% of the total biomass of the bird community.

Table 1. Population (a, birds/km²) of bird communities at different stages of secondary succession of bilberry pine forests.

Species	Age of biocenoses (years)											
	1–3		4–9		10–20		30–40		60–70		80–90	
	± x	CV	± x	CV	± x	CV	± x	CV	± x	CV	± x	CV
Motacilla alba	9.4±0.69	25.53	10.4±0.80	27.10	3.5±0.45	44.00						
Anthus trivialis	61.7±3.35	18.78	65.3±3.34	17.70	25.2±1.52	20.45	12.5±0.99	27.52	71.4±3.40	16.48	72.0±3.05	14.65
Anthus pratensis	8.4±0.68	28.09	6.5±0.65	34.30								
Saxicola rubetra	11.2±0.75	23.25	15.1±0.78	17.95								
Perdix perdix	4.7±0.62	45.53	3.2±0.56	60.93								
Alaunda arvensis	15.0±0.98	25.53	11.3±0.77	23.71								
Lullula arborea	25.0±1.40	19.56	30.6±1.38	14.67	15.4±1.15	25.84	8.2±0.82	34.33	3.0±0.59	67.66	3.2±0.58	62.50
Lanius collurio			2.6±0.45	60.00	1.8±0.39	75.50						
Emberiza citrinella	20.6±1.50	25.24	28.4±1.51	18.38	18.5±1.35	25.30						
Phoenicurus phoenicurus	2.4±0.47	67.50	5.8±0.57	34.00	3.2±0.59	63.75			4.3±0.58	47.21	10.6±1.15	37.64
Carduelis cannabina			9.7±0.83	29.70	1.0±0.30	50.54						
Carduelis carduelis			0.6±0.15	135.00	1.8±0.39	76.11						
Erithacus rubecula			7.0±0.64	31.70	10.2±0.70	23.70	5.8±0.69	41.30	10.3±0.57	19.20	14.1±0.88	21.56
Turdus philomelos			2.0±0.36	63.00	7.0±0.52	25.60	8.1±0.51	21.60	36.9±1.59	14.93	38.6±1.41	12.59
Regulus regulus									4.0±0.62	53.75	6.0±0.53	30.05
Turdus merula					13.8±1.09	27.53	16.7±1.19	24.67	18.5±1.17	21.84	20.4±1.16	19.60
Turdus pilaris							13.1±1.33	35.10	15.8±1.38	80.32	16.2±1.26	27.08
Sylvia communis			9.8±0.95	33.57	15.6±1.12	24.80	4.2±0.51	42.38				
Sylvia atricapilla			7.7±0.83	37.27	12.4±1.05	29.35	8.5±0.68	27.50	14.6±1.02	24.22	15.2±0.96	21.84
Certhia familiaris							3.6±0.59	56.34	8.2±0.64	26.42	13.8±0.0.30	23.55
Sitta europaea							2.0±0.58	101.00	5.4±0.74	29.62	2.3±0.37	56.10

Species	Age of biocenoses (years)											
	1–3		4–9		10–20		30–40		60–70		80–90	
	± x	CV	± x	CV	± x	CV	± x	CV	± x	CV	± x	CV
Troglodytes troglodytes							1.5±0.27	63.30	4.2±0.38	33.09	5.7±0.43	25.96
Fringilla coelebs					24.5±1.81	25.60	50.0±3.14	21.76	160.2±6.75	14.59	166.6±6.96	11.17
Parus major					6.3±0.53	28.86	16.8±0.96	19.88	30.6±1.49	16.83	38.7±1.58	14.30
Lophophanes cristatus							2.2±0.39	61.80	6.7±0.71	36.57	9.4±0.82	30.10
Poecile montanus					3.7±0.58	54.05	6.2±0.59	32.90	18.8±1.21	22.40	20.2±1.22	20.89
Poecile palustris									1.0±0.25	86.00	1.4±0.28	69.28
Cyanistes cyanus							1.0±0.25	86.00	2.2±0.39	61.80	2.0±0.36	63.00
Aegithalos caudatus							2.7±0.41	52.22	4.6±0.61	45.87	8.5±0.64	27.05
Phylloscopus trochilus					3.8±0.45	40.79	13.0±1.25	38.40	24.3±1.35	19.30	32.7±1.33	14.09
Phylloscopus sibilatrix					4.5±0.62	39.63	12.6±1.04	28.49	60.5±2.53	14.50	64.4±0.2.89	15.43
Phylloscopus collybita					3.7±0.58	54.05	18.2±1.06	20.10	40.6±1.48	12.58	42.5±1.57	12.80
Muscicapa striata			1.4±0.38	94.28	3.2±0.77	78.43	6.5±0.87	46.15	14.3±1.46	35.45	22.4±1.59	24.64
Ficedula parva									0.6±0.20	115.00	0.8±0.24	102.80
Ficedula hypoleuca							3.4±0.76	77.64	5.9±0.77	44.91	8.0±1.01	43.75
Oriolus oriolus							3.2±0.77	78.43	6.0±0.91	52.67	6.5±1.08	57.54
Garrulus glandarius							1.5±0.41	94.00	4.2±0.61	52.85	8.5±1.29	52.47
Corvus corone							1.8±0.45	85.50	3.4±0.79	80.59	6.2±0.81	45.16
Pica pica									1.0±0.28	96.00	1.2±0.28	12.50
Corvus corax									1.0±0.29	100.00	1.4±0.51	95.00
Columba oenas									0.5±0.19	135.00	1.0±0.25	86.00
Caprimulgus europaeus									0.3±0.11	130.00	0.4±0.14	120.00
Picus canus							1.1±0.35	119.50	1.1±0.36	111.80	0.8±0.26	130.00
Dendrocopos major							4.5±0.59	45.60	8.0±0.97	42.08	8.5±0.99	49.26

Species	Age of biocenoses (years)											
	1–3		4–9		10–20		30–40		60–70		80–90	
	± x	CV	± x	CV	± x	CV	± x	CV	± x	CV	± x	CV
Dryocopus martius									1.8±0.76	90.00	2.0±0.58	101.80
*Dendrocopos medius**									2.0±0.61	105.50	2.4±0.69	100.00
Bonasa bonasia									1.6±0.55	118.75	3.7±0.58	54.60
Scolopax rusticola									1.9±0.56	102.63	2.0±0.65	112.00
*Ciconia nigra**									0.5±0.18	124.00	0.7±0.22	108.60
Cuculus canorus									1.0±0.30	102.00	1.2±0.32	91.70
*Crex crex**	0.8±0.26	112.10	1.4±0.40	99.70								
Accipiter gentilis									1.0±0.33	112.90	1.1±0.35	110.90
Accipiter nisus									1.4±0.41	102.10	1.6±0.46	99.37
Buteo buteo									1.0±0.38	132.00	0.8±0.32	140.00
Falco subbuteo *									0.6±0.21	123.30	0.5±0.20	142.00
Pernis apivorus									0.8±0.27	116.20	0.9±0.31	118.90
Number of species	10		18		20		27		45		45	
Total abundance, birds/km^2	159.2±1.25		218.8±1.28		179.1±1.40		228.9±1.94		606.0±3.56		687.1±3.80	
Total biomass, kg/km^2	5.71±0.25		6.46±0.28		5.08±0.26		8.39±0.30		25.71±0.93		31.32±1.10	
Species diversity (H')	2.67		3.36		3.86		4.10		3.99		4.14	
Evenness of species-abundance distribution (J')	0.80		0.81		0.89		0.86		0.73		0.75	

Note: * – species listed in the Red Book of the Republic of Belarus (2015)

Table 2. Dynamics of bird species dominance in bilberry pine forests in summer during succession (% of total abundance and total biomass).

Species	Indicator	Age of biocenoses (years)					
		1–3	4–9	10–20	30–40	60–70	80–90
Anthus trivialis	abundance	38.8	29.8	14.1	-	11.8	10.5
	biomass	24.9	23.2	11.4	-	-	-
Emberiza citrinella	abundance	12.9	13.0	10.3	-	-	-
	biomass	10.8	13.2	10.9	-	-	-
Lullula arborea	abundance	15.7	14.0	-	-	-	-
	biomass	-	10.4	-	-	-	-
Fringilla coelebs	abundance	-	-	13.7	21.8	26.4	24.2
	biomass	-	-	10.6	13.1	13.7	11.7
Phylloscopus sibilatrix	abundance	-	-	-	-	10.0	-
	biomass	-	-	-	-	-	-
Perdix perdix	abundance	-	-	-	-	-	-
	biomass	32.9	19.8	-	-	-	-
Turdus merula	abundance	-	-	-	-	-	-
	biomass	-	-	26.6	19.5	-	-
Turdus philomelos	abundance	-	-	-	-	-	-
	biomass	-	-	10.2	-	10.6	-
Turdus pilaris	abundance	-	-	-	-	-	-
	biomass	-	-	-	15.6	-	-
Corvus corone	abundance	-	-	-	-	-	-
	biomass	-	-	-	11.3	-	10.4

A further increase in the main total indicators (number of species, abundance, biomass) was observed in the middle-aged forest (60–70 years). At this stage, the bird community is enriched with new species, and the abundance of birds in the bilberry pine forest increases. The total abundance reaches 606.0±3.56 birds/km^2, the total biomass is 25.71±0.93 kg/km^2. The bird population is dominated by Common Chaffinch (160,2±6,75 birds/km^2, CV = 14,59 %), Tree Pipit (71,4±3,40 birds/km^2, CV = 16,48 %) and Wood Warbler *Phylloscopus sibilatrix* (60,5±2,53 birds/km^2, CV = 14,50 %). By total abundance, they account for 48.2%. A group of species with low abundance (1–10 birds/km^2) is formed by 26 species, most of them characterized by high rates of abundance variability (CV up to 118.75 %). This indicator is especially high (up to 135.00 %) for rare species with an abundance of less than 1 bird/km^2. By biomass, Common Chaffinch (13.7%) and Song Thrush (10.6%) dominate.

At the stage of the preclimax forest (80–90 years), these indicators are slightly higher (Tables 1 and 2). The total abundance is 687.1±3.80 birds/km^2 and the biomass is 31.32±1.10 kg/km^2. The abundance is dominated by Common Chaffinch

(166,6±6,96 birds/km^2, CV = 11,17 %) and Tree Pipit (72,0±3,05 birds/km^2, CV = 14,65 %), while the biomass is dominated by Common Chaffinch and Carrion Crow (Table 2).

Thus, each of the 6 selected stages of succession is characterized by certain dominant species (Table 2). As the cuttings are overgrown with young saplings, birds of open ecosystems disappear or become scarce, and they are not recorded at later stages of succession. On the contrary, tree and shrub birds (typical warblers, warblers, Common Chaffinch, etc.) become numerous. In mature pine forest and high preclimax forest Common Chaffinch dominates.

At various stages of succession, there are bird species belonging to 11 orders (Table 3). At all stages of succession, the Passeriform birds predominate, accounting for 66.8–100.0% of the species diversity. At the fifth and sixth stages of succession, the Accipitriformes and the Piciformes are in the second place in terms of the number of species (8.9% each). The Passeriform birds also dominate the bird population (in terms of abundance and biomass).

Table 3. Participation of bird species of different orders in species diversity, total abundance and total biomass (%) at different stages of succession of bilberry pine forests.

Orders	Indicator	Age of biocenoses (years)					
		1–3	4–9	10–20	30–40	60–70	80–90
Galliformes	number of species	10.0	5.6	-	-	2.2	2.2
	abundance	3.0	1.5	-	-	0.3	0.5
	biomass	32.9	19.8	-	-	2.4	4.5
Ciconiiformes	number of species	-	-	-	-	2.2	2.2
	abundance	-	-	-	-	0.1	0.1
	biomass	-	-	-	-	5.8	6.7
Accipitriformes	number of species	-	-	-	-	8.9	8.9
	abundance	-	-	-	-	0.7	0.6
	biomass	-	-	-	-	9.9	8.4
Falconiformes	number of species	-	-	-	-	2.2	2.2
	abundance	-	-	-	-	0.1	0.1
	biomass	-	-	-	-	0.5	0.4
Columbiformes	number of species	-	-	-	-	2.2	2.2
	abundance	-	-	-	-	0.1	0.1
	biomass	-	-	-	-	0.5	0.9

Caprimulgiformes	number of species	-	-	-	-	2.2	2.2
	abundance	-	-	-	-	0.1	0.1
	biomass	-	-	-	-	0.1	0.1
Gruiformes	number of species	10.0	5.6	-	-	-	-
	abundance	0.5	0.6	-	-	-	-
	biomass	2.2	3.4	-	-	-	-
Charadriiformes	number of species	-	-	-	-	2.2	2.2
	abundance	-	-	-	-	0.3	0.3
	biomass	-	-	-	-	2.1	1.8
Cuculiformes	number of species	-	-	-	-	2.2	2.2
	abundance	-	-	-	-	0.2	0.2
	biomass	-	-	-	-	0.4	0.4
Piciformes	number of species	-	-	-	7.4	8.9	8.9
	abundance	-	-	-	2.5	2.1	2.0
	biomass	-	-	-	5.6	5.8	5.0
Passeriformes	number of species	80.0	88.8	100.0	92.6	66.8	66.8
	abundance	96.5	97.9	100.0	97.5	96.0	96.0
	biomass	64.9	76.8	100.0	94.4	72.5	71.8

At different stages of successions, 3 species were found included in the Red Book of the Republic of Belarus (2015): Eurasian Hobby *Falco subbuteo* (category IV), Corn Crake (category III), Black Stork *Ciconia nigra* (category III). 25 bird species registered during the study are of international conservation significance (SPEC), including Corn Crake (category I), Woodlark and Common Redstart (category II), Eurasian Skylark, Red-backed Shrike *Lanius collurio*, Spotted Flycatcher and Grey-headed Woodpecker *Picus canus* (category III) (European birds of conservation concern... 2017).

The ecological structure of bird communities changes parallel to the succession of vegetation cover (Figure 1). In the first stage (recently clear-cut area), ground-nesting birds predominate, with the exception of the Common Redstart, which collects food on the ground. Later the number of birds building nests on the ground or immediately above it gradually decreases, at the fifth and sixth stages of succession, the share of this group is 22.2%. This trend is not typical for birds that nest in bushes.

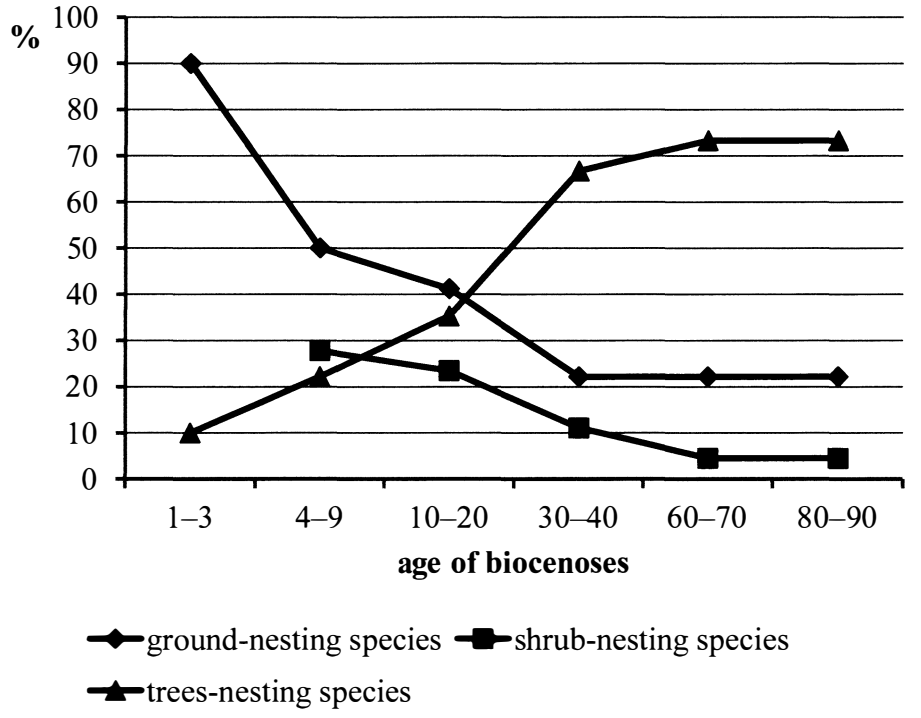

Figure 1. The distribution of bird species according to the levels of nesting in bilberry pine forests of different age.

On the contrary, the number of bird species building nests in the shrub and tree layer increases with the age of the main forest-forming species and reaches the maximum at the last two stages – 33 species (73.3%). In the high preclimax pine forest, birds populate all levels: there are birds that nest and forage on the ground, on fallen trees or dead wood, on shrubs and undergrowth, many species nest in hollows and crowns of trees, where they forage.

At the stages of recently clear-cut area (1–3 years) and clear-cut area with plantation of birch, aspen and pine trees (4–9 years), 3 types of fauna are represented in bird communities: European, European-Turkestan and Palearctic (Figure 2). The population is dominated by species of the European-Turkestan type of fauna (41.1–41.7% of the total abundance, 48.8–57.8% of the total biomass), in terms of the number of species, European-type species lead the way (38.9–50.0). Starting from the 10–20-year-old succession stage, the bird community is dominated by a complex of Palearctic faunal types (45.0–60.1% of the number of species, 35.9–48.6% of the total abundance, 49.7–65.7% of the total biomass). The participation of European faunal types in the species diversity and abundance of bird communities decreases with the development of succession (50.0–24.4%) and the share of birds in the total abundance increases (30.0–48.3% respectively). At the last two stages of succession, there are 6 types of fauna. The main contribution to the structure of bird communities is made by the Palearctic and

European types of fauna, the Holarctic type is represented by 2 species (Northern Goshawk *Accipiter gentilis* and Common Buzzard *Buteo buteo*), the Siberian and Afro-Eurasian types – by 1 species each (respectively, Hazel Grouse *Tetrastes bonasia* and Eurasian Golden Oriole *Oriolus oriolus*). The participation of birds of these three types of fauna in the species structure is no more than 4.4%, in the population of birds it does not exceed 1.5%, in the total biomass it is no more than 6.5%. Bird complexes of the Holarctic, Siberian and Afro-Eurasian faunal types make up no more than 4.4% of species, no more than 5.7% of the bird population, and no more than 15.6% of biomass.

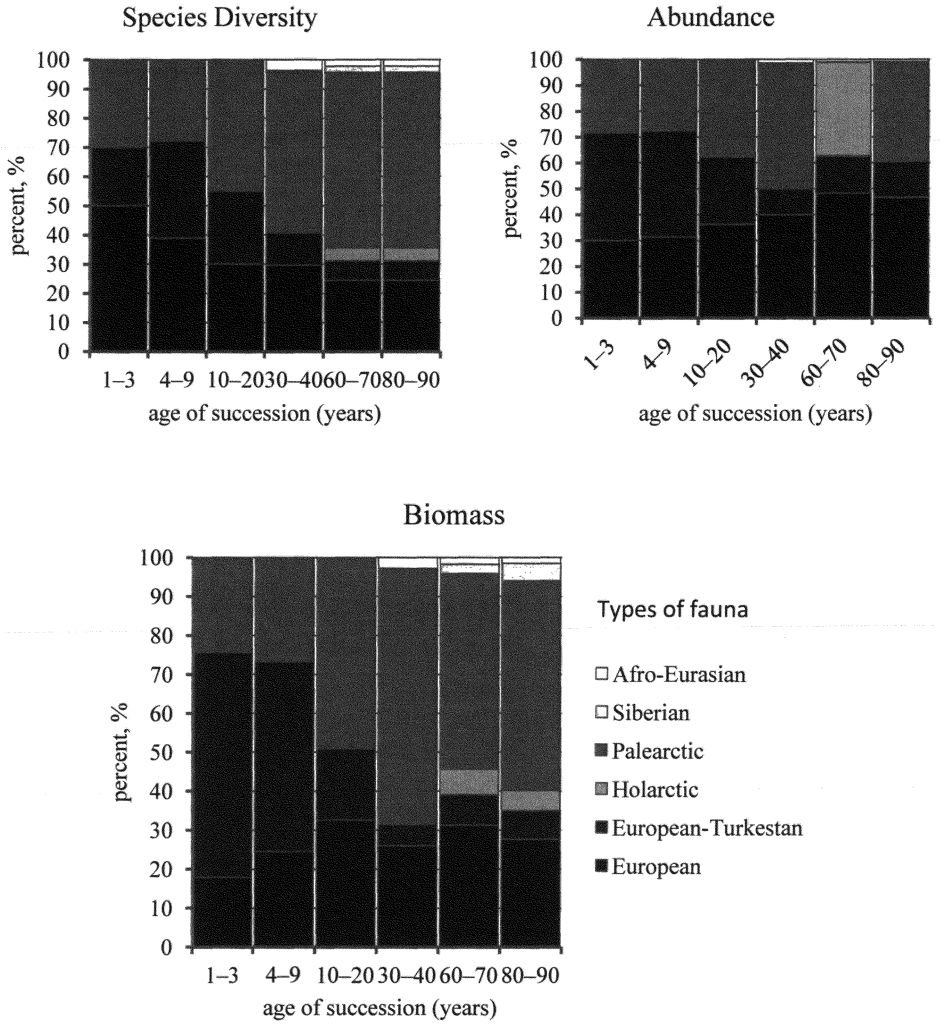

Figure 2. Faunal structure of the bird communities at different stages of succession of the bilberry pine forest.

An assessment of the similarity of species composition by the Jaccard index of bird community at different stages of secondary succession showed that the greatest similarity was observed between communities formed at the first two stages of succession (55.6), and at the age of 30–40 years or more (56.5–100.0%) (Table 4).

Table 4. The similarity of the bird communities at different stages of secondary succession in bilberry pine forests by the Jaccard index (%).

Age of succession, years	4–9	10–20	30–40	60–70	80–90
1–3	55.6	20.0	5.7	5.8	5.8
4–9		52.0	18.4	12.5	12.5
10–20			42.4	27.5	27.5
30–40				56.5	56.5
60–70					100.0

The Shannon diversity index increases with the growth of the stand and reaches the highest indicators at the last stages of succession (Table 1). Pielou's evenness index increases at the fi st four stages, and decreases slightly at the last two stages due to an increase in the share of the three dominant species, primarily Common Chaffinch, in the bird population (Tables 1 and 2).

Information about the summer avifauna of pine forests in south-western Belarus is available in monographs (Abramova 2007; Abramova and Haiduk 2009, 2013). It is shown (Abramova 2007) that in summer 38 species of birds live in bilberry-green moss pine forests in combination with shrub-longmoss pine forests (the Brest timber enterprise, Tomashovka forestry), the total abundance of which was 643.5 birds/km^2, the total biomass – 24.88 kg/km^2.

According to M. S. Dolbik (1974), 11 species of songbirds with a total number of 2.21 p/1 ha were recorded in bilberry pine forests in the territory of the Belarusian Polesie (Lelchitsy and Luninets districts), including Willow Warbler *Phylloscopus trochilus* – 0.80, Common Chaffinch – 0.37, Spotted Flycatcher – 0.22, Eurasian Golden Oriole – 0.14, European Pied Flycatcher – 0.14, other species – 0.07 p/1 ha. These numbers are equal to or significantly higher than our data and the data indicated by Ravkin et al. (2001), according to which the average total density of the bird population for the subclass of small-leaved forests is 669 birds/km^2.

The succession of avifauna of bilberry pine forests is similar to broad-leaved pine forests in terms of species structure and bird population (Abramova 2007). In broad-leaved pine forests, 6 stages were identified from recently clear-cut area to climax forest (120–150 years). The number of species ranged from 12 in recently clear-cut area to 60 in climax forests. The total abundance gradually increased during the succession from 67.4 to 934.1 birds/km^2, with the exception of the age stage of 10–14 years, when it was the lowest (107.4 birds/km^2). The total biomass changed in parallel with abundance, increasing from 3.4 to 54.2 kg/km^2.

The studied indicators are somewhat lower, especially at the last stages of succession (90–100 years) in spruce forests, where 59 bird species were identified, the total abundance of which is 689.5 birds/km^2, and the biomass is 47.7 kg/km^2 (Abramova 2017, 2018). The main ecological parameters of the bird population (species diversity, abundance, biomass) are progressively increasing from recently clear-cut areas to high preclimax forest. The exception is the stage of dense thickets of bushes, shrubs and undergrowth (9–14 years), where the total abundance and biomass of birds is lower than at previous and next stages.

For comparison, we present data on the state of bird communities in coniferous forests in other regions. In the Western Moscow region, according to systematic observations in 1956–1968, from 24 to 37 species of birds nest in pine forests, the population density of birds varies from 150 to 300 p/km^2 (Inozemtsev 1987). In the mossy pine forests of the Berezinsky biosphere reserve (Belarus) in the first half of the summer in 1986–1987, 31 species were registered, the total abundance was 470 birds/km^2, the dominant species by abundance were Common Chaffinch, Tree Pipit and European Crested Tit *Parus cristatus* (Byshnev 1989).

In the pine forests of Poland, at various stages of renewal after a recent clear-cut, it was found that the number of breeding bird species increases from 2 to 30, the number of pairs per 10 ha increases from 2.3 to 62.9 (Głowaciński 1979) and the community of breeding birds with a large species diversity is more stable (Głowaciński 1981).

In the coniferous forests of the southern boreal forest (Kostroma region), the change of bird population during the overgrowth of various types of cuttings is similar. At recently clear-cut areas there are 5–8 species with an abundance of more than 0.1 pairs per 10 ha. These indicators increase 2–4 times during the subsequent stages of coniferous forest succession (Preobrazhenskaya and Borisov 1987).

Conclusions

Studies of the succession of bird communities in pine forests in southwestern Belarus and analysis of literature data have shown that the change of bird populations in forests is caused by a consistent succession of forest phytocenoses. Over the past 50 years, the succession of biocenoses has been significantly influenced by anthropogenic factors: forestry activities, reclamation of agricultural land adjacent to forests, and recreation.

In the process of secondary succession of bilberry pine forests, 6 stages of vegetation development were identified from a fresh clearcut to a 90-year-old forest. In parallel with the regular change of vegetation, the succession of bird communities also occurs. In the course of the study, 56 bird species belonging to 11 orders were registered. Passerine birds predominate at all stages of succession (66.8–100.0% of the total number of species). The main total indicators of the population in pine forests initially increase with the development of succession, but at the stage of young brush (10–20 years), the total number decreases. At the stage of plantings aged 30–40 years, species diversity and other indicators

increase and this trend continues as the age of the main forest-forming species increases. In the succession process of this ecosystem from the stage of fresh clear cut to the age of 80–90 years old, the number of species in the bird community increases 4.5 times, total abundance – 4.3 times and biomass – 5.5 times. As the age of the main tree species increases, the number of birds nesting in the trees rises and reaches the maximum at the last two stages – 33 species (73.3%), while the share of ground-nesting species falls. The highest variability of abundance (CV from 50.00 to 135.00 %) is typical for species whose abundance does not exceed 10.0 birds/km^2. In dendrophilous species with an average abundance, the values of the coefficient of variation range from 14.34 to 29.12 % at the last three stages of succession. The highest stability of abundance was found in Common Chaffinch (CV at the fifth stage was 14.59 %, at the sixth stage – 11.17 %) and Common Chiffchaff (12.58 and 12.80% respectively).

At the stages of grassland vegetation of meadow type (1–3 years) and young pine saplings (4–9 years), 3 types of fauna are represented in bird communities. The population is dominated by species of European-Turkestan type of fauna (41.1–41.7% of the total abundance, 48.8–57.8% of the total biomass). Starting from the 10-20-year-old succession stage, the bird community is dominated by a complex of Palearctic fauna types (45.0–60.1% of the number of species, 35.9–48.6% of the total abundance, 49.7–65.7% of the total biomass). The participation of European fauna types in the species diversity of bird communities and populations decreases with the development of succession (50.0–24.4%), and the share of birds in the population increases (30.0–48.3% respectively). In the last two stages of succession, there are 6 faunal types. The main contribution to the structure of bird communities is made by the Palearctic European fauna type, Holarctic type is represented by 2 species, Siberian and Afro-Eurasian type – by 1 species each.

At various stages of succession, 3 species included in the Red Book of the Republic of Belarus (2015) were identified, while 25 species were of international conservation significance.

References

1. Abramova I.V. (2007) Structure and dynamics of the bird population of the ecosystems of the south-west of Belarus. BrSU, Brest.
2. Abramova I.V. (2017) Succession of bird populations during the restoration of spruce forests in the South-Western part of Belarus Succession of bird population in the course of secondary spruce forest restoration in South-Western Belarus. Journal of the Belarusian State University. Geography and Geology 2: 31–39.
3. Abramova I.V. (2018) Taxonomic structure of spruce forest avifauna at different stages of succession in south-western Belarus. [in:] Pryrodnaye asyaroddze Palessya: asablivastsi i perspektyvy razvitstsya. Alternativa, Brest, pp. 187–189.
4. Bednorz J., Bogucki Z. (1982) Secondary succesion of breeding bird communities in dry pine–forests in Poland. [in:] XVIII Congressus Internationalis Ornithologicus. Abstracts of symposia and poster presentations. Moscow, pp. 171–172.

5. Bibby K., Jones M., Marsden S. (2000) Methods of field expeditionary research. Research and bird counting. Moscow.
6. Byshnev I.I. (1989) Spring dynamics of bird population in some types of forest and marsh ecosystems of the Berezinsky Reserve. [in:] Zapovedniki Belarusi. 13, pp. 81–89.
7. Danilov N.N. (1958) Changes of the avifauna of overgrown felling in the Middle Urals. Journal of Zoology. 37/12: 1898–1903.
8. Dolbik M.S. (1974) Landscape structure of Belarusian avifauna. Nauka i tekhnika, Minsk.
9. European birds of conservation concern: populations, trends and national responsibilities, (2017) Cambridge, UK : BirdLife International. 172 p.
10. Gayduk V.E., Abramova I. V. (2009) Ecology of birds of South-Western Belarus. Non-Passeriformes. BrSU, Brest.
11. Gayduk V.E., Abramova I. V. (2013) Ecology of birds of South-Western Belarus. Passeriformes. BrSU, Brest.
12. Głowaciński Z. (1975) Succession of bird communities in the Nielopolomice Forest (Southern Poland). Ecol. Pol. 23. №2: 231–263.
13. Głowaciński Z. (1979) Some ecological parameters of avian communities in the succession series of a cultivated pine forest. Bull. Acad. Pol. sci., ser. sci. boil. 27. №3: 169–177.
14. Głowaciński Z. (1981) Stability in bird communities during the secondary succession of a forest ecosystem. Ecol. Pol. 29. №1: 73–95.
15. Helle P., Mőnkkőnen M. (1986) Annual fluctuations of land bird communities in different successional stages of boreal forest. Ann. Zool. Fennici. 23: 269–280.
16. Järvinen O. (1979) Geographical gradients of stability in European land bird communities. Oecologia. 38: 51–69 https://link.springer.com/article/10.1007/BF00347824
17. Järvinen O., Väisänen R. (1976) Finnish line transect censuses. Ornis fenn. Vol. 53. №4: 115–118.
18. Johnson D.V., Odum E.P. (1975) Breeding bird populations in relation to plant succession on the piedmont of Geogria. Ecology. 37: 50–62.
19. Lovchiy N.F. (2012) Cadastre of pine forest types in Belarusian Polesie. Bel. navuka, Minsk.
20. Nikiforov M.E. (2008) Formation and structure of the avifauna of Belarus. Bel. navuka, Minsk.
21. Novikov G.A., Koshkina T.V., Kerzina M.N. (1956) The role of animals in forest life. Moscow University Press, Moscow.
22. Preobrazhenskaya E.S., Borisov B.I. (1987) Change of bird population during the overgrowing of different types of clear cuts of Privetluzhya. [in:] Vliyanie antropogennoi transformatsii landshafta na naselenie nazemnykh pozvonochnykh zhivotnykh : tezisy vsesoyuznogo soveshchaniya. Part 2. Moscow, pp. 157–158.
23. Ravkin E.S., Byshnev I.I., Kachanov S.K. et al. (2001) The spatial diversity of the summer population of birds in the East European and West Siberian plains. [in:] The achievements and problems of ornithology in Northern Eurasia at the turn of the century. Kazan, pp. 212–236.
24. Ravkin Yu.S. (1967) To the method of recording birds in forest landscapes. [in:] Nature of foci of tick-borne encephalitis in the Altai. Novosibirsk, pp. 66–75.
25. Red Book of the Republic of Belarus. Animals, 2015. Minsk.
26. Voous K.H. (1962) Die Vogelwelt Europas. Hamburg. Berlin.
27. https://www.birds.cornell.edu/clementschecklist/; 10.01.2021