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FOREST STANDS' AND PEAT DEPOSITS STRUCTURE IN EUTROPHIC BOGS OF THE ZAPADNODVINSKY DISTRICT IN TVER REGION

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Abstract. A comparative assessment of the silvicultural characteristics of tree stands, peat deposits and the dynamics of the virgin lowland eutrophic black alder bogs development has not been previously carried out, which determined the choice of the purpose of this study. In the forests of the Zapadnodvinsk district of the Tver region. Lowland rain-groundwater black alder bogs were selected for analysis, one of which has variable circulating water supply, while the other was stagnant. Studied within the framework of the study were the age, dynamic, and renewal characteristics, the condition of trees and forest stands, indicators of tree mortality, and the infestation of forest stands with wood-decaying fungi. A comparative assessment of the peats characteristics was carried out regarding the pH of the salt extract, the ash content, the bulk mass (density) and the carbon content in soil horizons. Eutrophic black alder swamps have a large presence of Norway spruce in different proportions and an insignificant presence of downy birch. When edaphic conditions change, this feature determines the possibility of changing the alder formation to the spruce one. Using the exponential approximation, high values of the relationship between the presence of spruce in age generations of age series were shown for the biogeocenosis with circulating water – $R_2 = 0.696$. Under eutrophic growth conditions, downy birch can reach an age of 150 years. The soils of black alder forests are considered lowland peats, are high in ash content and composed of thick woody peats up to 2–4 m with a high degree of decomposition throughout the deposit (40–55%). The carbon content in peats with a fairly high ash content is different: 34–46 and 46–51% respectively in black alder forests with stagnant and flowing water. A comparative assessment of two black alder eutrophic bogs shows that Norway spruce occupies a subordinate position in relation to black alder. Under conditions of flow-through moisture, the productivity of black alder is 1–2 quality classes higher than that of European spruce. In more stagnant moisture conditions, Norway spruce actively replaces black alder both in the tree layer and in the undergrowth. In terms of the structure of age series, successional dynamics and tree mortality, indigenous eutrophic black alder bogs of different ages maintain the balance of biomass as climax stable forest communities.

Keywords: *eutrophic bogs, black alder and Norway spruce formations, change in species composition, thick woody peats, circulating and stagnant water supply*

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Eutrophic bogs due to the peculiarities of mixed water-mineral nutrition, groundwater and supplemented by atmospheric precipitation, can have a tree layer including several species of tree species. Depending on the prevalence of one or another type of water and mineral nutrition, the presence of the main edifying species in stands, which determine the formational composition of biogeocenoses, may be different. In the study region, alder and spruce eutrophic bogs with black alder (*Álnus glutinósa* L.) or European spruce (*Pícea ábies* L.) dominating in the first tier, with admixture of birch, less often aspen. It is the mixed water-mineral nutrition that determines the diverse formational composition of the tree layer of this type of bogs. As a rule, among the dominant species — black alder and European spruce — there are downy birch (*Vetula pubescens* L.), aspen (*Populus tremula* L.), rarely smooth elm (Úlmus *laévis* Pall.). It can also be assumed that mixed nutrition, which implies the presence of several main species in the tree canopy, determines more intensive dynamic processes in structural changes in the species composition of forest stands, up to the change of formations of biogeocenoses, compared to upper and mesotrophic forest bogs.

Age, dynamic and sanitary characteristics of stands, indicators of tree rot, composition and structure of peat deposits of eutrophic bogs have been studied in a fragmentary manner. The relationships between individual indicators in stand structures and between tree and peat layers of eutrophic bogs have not been revealed (Yurkevich et al., 1968; Sicinski, Filipiak, 1992; Blagodarova, 2005; and others). In the present work, we studied the structures of two variants of eutrophic bogs, which differ in the features of periodic fluctuations of soil-soil water level (SWL). The biogeocenoses belong to communities undisturbed by economic and recreational activities with a natural evolutionary course of formation of structures and functions of their constituent stands.

The aim of the work is to study the structure of forest stands by species, age, renewal parameters, condition of trees and stands, volumes of wood fall, peculiarities of trees and stands affected by tree-destroying fungi; to identify structural and component features of peat strata horizons of the studied eutrophic bogs.

OBJECTS AND METHODOLOGY

Two eutrophic black alder bogs located in the forest areas of Velesky lesnichestvo, Zapadnodvinsky district, Tver region, were selected as study sites. The first sample area — black alder-herb-herb-tavolg forest (PP 1) (N56º 11.296´; E32º14.965´) — is located on a wide low flat shore of Lake Strakhovskoye and is connected with it by the same conditions of the CCSF fluctuation. The water supply of the stand of PP 1 since 2023 has been disturbed by beavers' activity, as a result of which the UPGW rises up to 1—2 cm above the bog surface, especially in case of excessive precipitation. The second sampling area — a black alder-grass-fern forest (PP 2) (N56º10´15´´; E32º08´16´´) — is located in a flat depression of a flowing stream, which determines the UFGW and the structure of the tree canopy, has a rather wide (up to 100 m) concave surface, surrounded by moraine hills (Storozhenko, Glukhova, 2022)

The forest inventory of stands was carried out at the PP, as well as tree enumeration with numbering, diameter measurement at 1.3 m height, and tree height using a Nicon Forestry Pro laser altimeter. Cores were taken from trees of all species using a Pressler age drill made by MORA (Sweden) to determine the age and presence of decayed fouts, as well as the stage and type of decay. The condition of trees (Rules..., 2020), their infestation, and species of tree-destroying fungi were determined (Storozhenko, 2011; Sicinski, Filipiak, 1992; Niemelä, 2005). The species composition and the amount of natural regeneration by height gradations at 0.5 m intervals were taken into account. When describing deadwood, the species of deadwood trunk, diameter at the tip, and decomposition stage were taken into account (Storozhenko, 1990, 2011). In the cameral period, tree volume indices and stand stocks were determined (Tretiakov et al., 1952; Sortimentnye..., 1986). Average morphometric and age indices of tree species composing stands were calculated. Age series were constructed for each tree species and the stand as a whole (Dyrenkov, 1984; Storozhenko, 2007), and the dynamic position of each species section of the stand and the biogeocoenosis as a whole was determined. Dependencies of indicators between each other were determined using Excel program.

At both PPs, soil samples from different horizons were taken to characterize the peat deposit using a 5 cm diameter TBG-1 peat drill with 50 cm nozzles. The degree of decomposition and botanical composition (type of peat) for the selected genetic horizons were determined in the All-Russian Research Institute of Vegetable Growing by O. N. Uspenskaya, carbon content — on a elemental analyzer vario MICRO cube (Germany), pH of salt extract and ash content — according to the method of E. V. Arinushkina (Arinushkina, 1970). Peat volumetric mass was determined using a peat drill. Moisture samples were taken from the desired horizon, dried to constant weight at 105 °C, and the volumetric mass was calculated (Semensky, 1966).

RESULTS AND DISCUSSION

The research results are presented according to a variant of the comparative evaluation of the data of different silvicultural and peat characteristics of the structures of the two bog systems accepted for study.

The surface of the bogs is a bog with bumps up to 1 m high, where predominantly woody species, including black alder, spruce and birch, grow. The flattened areas of the bog surface are mostly shrubs and grasses.

In the stands of PP 1, the shrub layer is dominated by bird cherry (*Padus rasemosa* (Lam.) Gilib.), ash willow (*Salix cineria* L.), mountain ash (*Sobrus aucuparia* L.), sweet cherry (*Frangula alnus* Mill.), black currant (*Ribus nigrum* L.). In the herbaceous layer of PP 1, the background species are the baseline species are the wilt (*Filipendula ulmaria* L. Maxim.), *dioecious* nettle (*Urtica dioica* L.), the fern (tansy) (*Athirium filix-femina* (L.) Roth et Mert.), whitefly (*Calla palustris* L.). Other species are forest dudnik (*Angelica Sylvestris* L.), sweet-bitter nightshade (*Solanum Dulcamara* L.), bitter core (*Cardamine amara* L.) and hairy-fruited (*Carex lasiocarpa* Ehrh.) and vesicular (*Carex vesicaria* L.) sedges. Sphagnum mosses are absent

In the shrub layer of PP 2, in addition to those listed in PP 1, there are willow five-spotted willow (*Salex pentandra* L.) and bramble (*Viburnum opulus* L.). In the herbaceous tier, common verbena (*Lysimachia vulgaris* L.), reed (*Phragmites australis* (Cav.), poisonous *vetch (Cicuta virosa* L.), *Thelipteris palustries* Schott.) and horsetail (*Equisetum fluviatile* L.) are added.

According to the results of experimental studies, it was determined that the soils of black alders of coarse-grass-tavolgovy and coarse-grass-fern peat lowland peat (*Fibric Histosols*), highly ashy, are composed of thick woody peats with a high degree of decomposition throughout the deposit (40—55 %) (Table 1). The thickness of peat deposits is 2.0 and 3.7 m, the deposits are underlain by sapropel and loams at PP 1 and PP 2, respectively.

The peats have slightly acidic reaction, the pH of salt extract is lower in peat of PP 1 (4.7) than in peat of PP 2 (5.6).

Table 1. Peat characteristics in black alder forests of coarse-grass-tavolgovy (PP 1) and coarse-grass-fern (PP 2)

Peat extraction depth, cm	Horizon thickness, cm	pH of salt extract		Ash content,%		Volume weight, g/cm^3		Carbon content,% to dry matter	
		PP1	PP2	PP1	PP2	PP1	PP2	PP1	PP2
0—10	10	4.3	5.4	15.1	18.6	0.16	0.17	44.2	45.8
10—20	10	4.3	5.4	11.6	15.4	0.10	0.18	45.9	47.9
20—30	10	4.4	5.3	11.4	13.5	0.12	0.17	46.0	48.2
30—40	10	4.4	5.4	19.3	12.2	0.18	0.16	42.1	48.9
40—50	10	4.4	5.5	14.9	11.3	0.19	0.17	44.3	49.0
50—60	10	4.5	5.5	24.7	10.9	0.14	0.17	39.3	49.7
60—70	10	4.5	5.5	35.4	10.7	0.12	0.17	33.9	49.3
70—80	10	4.6	5.4	34.5	10.2	0.21	0.15	34.4	49.9
80—90	10	4.6	5.6	34.5	9.8	0.16	0.15	34.4	50.5
90—100	10	4.5	5.5	33.8	9.7	0.21	0.16	34.7	50.1
100—150	50	4.7	5.6	27.5	9.6	0.15	0.23	37.9	50.8
150—190	40	4.7	5.5	41.5	13.7	0.18	0.21	30.9	47.6
190—200 sapropel	10	4.7	—	76.0	—	0.22	—	13.5	—
200—250	50	—	5.6	—	23.8	—	0.22	—	42.2
250—300	50	—	5.5	—	28.6	—	0.33	—	39.8
300—370	70	—	5.5	—	22.5	—	0.20	—	43.8

Peat ash content in both PPs differs significantly: higher ash content in black alder soil of stagnant moisture (11—35 %) and lower (11—19 %) in flowing soil. The high degree of peat decomposition determines also a significant volumetric mass (density) of these peats on average (0.16 — PP 1 and 0.19 — PP 2). The carbon content in the peats of black alder peats reaches a maximum of 46 and 51 % (with a rather high ash content) at PP 1 and PP 2, respectively.

Table 2 shows the characteristics of silvicultural indicators of the studied bogs.

As follows from Table 2, stands of both biogeocenoses have two main species — black alder and European spruce. In the stand of PP 1 there is some admixture of birch — 47 stems per 1 ha, while in PP 2 it is single. Aspen (*Populus tremula* L.) is also sporadically present in both communities.

In the low abundance stand of PP 1, birch has average height limits for the stand, reaching 25 m (stand tier 1[)], the largest average diameters — over 30 cm, equal to a maximum of 52 cm, and stem wood volume of 47.13 m^{3}ha, accounting for 12.6 % of the total stand stock. In eutrophic bogs, this species can reach an age of 130 and more years, which is extremely high age values for birch. At the same time, birch of the limiting age is located on high bumps, has powerful root paws starting from a height of 1—1.5 m, ribbed trunk and dark brown coloring of heartwood. The black alder section, dominant in terms of trunk wood reserves, includes the main number of trees from the stand composition (55.7 %) with large average tree diameters, high heights, which together with birch form the first tier of the stand, and the largest tree trunk diameters, which determines the largest participation of this species in the total stand reserve (Table 3). Spruce has a subordinate position, with insignificant average values of diameters and heights, but in terms of the number of trees it accounts for 37.7 % of the total number of trees. This stand structure may help in analyzing the dynamic position of the biogeocenosis.

The stand of the second PP includes only black alder and European spruce. It can be seen that by morphometric indices black alder prevails over spruce, which is included only in the second tier of the stand and is comparable in average height with spruce of the first PP. Obviously, spruce also occupies a subordinate position in the biogeocenosis of PP 2.

The analysis of the age structure of biogeocenoses makes it possible to assess several characteristics of communities, including the structure of age series, the dynamic successional position of the biogeocenosis, and the dynamics of its development in retrospect and in perspective for rather long time periods.

Dynamic characteristics are given for the main species involved in the formation of the stand stock, if they were to describe each species section as a separate stand — alder or spruce forest, birch forest, pine forest, etc.

The sum of tree number indices from the volumes of all species sections by age generations for the whole biogeocenosis determines its overall successional position.

The data in Table 3 show that the distribution of tree volumes in the age generations of PP 1 of the alder section has an excess of values tending toward the first three older generations, totaling 84.0 % of the total volume of the alder section.

Table 2. Silvicultural characteristics of spruce eutrophic bogs of Zapadnodvinskiy District, Tver Oblast.

Species composition of stands		Stock m^3ha^{-1}	Forest type	Medium height, m			Average diameter, cm			Medium age, years			Half a note	Bonnie-tet		Teenager	Under-sap	Type of air-plant structure
By the number trees	By stock			Alder	Spruce	Birch	Alder	Spruce	Birch	Alder	Spruce	Birch		Alder	Spruce			
6Ol4E+B	7Ol3E+B	373.3	Black alder-herb coarse-grass-tavolg forest	19.3	14.3	20.3	24.9	16.9	31.3	95	72	100	0.7	I	II	Ol, E, B	Cher, willow, smor, krush,	Ar
6Ol4E.	8Ol2E.	445.7	Chernoolshanik coarse–grass fern	22.1	14.4	—	31.0	17.0	—	97	93	—	0.7	I	II	Ol, E, Os, B.	Cher, riab, smor, krush,	Ar

Designations. Undergrowth: cher — cherry, smor — currant, krush — crucifer, rowan, Type of age structure: Ar — absolutely different-aged.

The maximum volume of trees of the third age generation was formed only 40 years ago, when the biogeocenosis was in the phase of climax. The current dynamics of the biogeocenosis age series defines it as climax-digressive with a confident tendency to the area of digression. The same tendency is characteristic of the distribution of the number of trees in age generations. The correlation values of tree volume values in age generations are indicative (Table 4). The correlation ratio calculated by linear approximation characterizes the relationship as "moderate" — $R^2 = 0.302$. At the same time, the correlation ratio calculated by exponential approximation characterizes the relationship as "significant", approaching "high" — $R^2 = 0.687$. It follows that the volumes of trees in the age generations of the alder section describe to a greater extent its different-age structure, however, gravitating to the area of digression.

The distribution of tree volumes in the age generations of the European spruce section at PP 1 characterizes it to a greater extent as digressive, with the average age of trees 72 years belonging to the fifth generation of the age series. The distribution of the number of trees in generations, on the contrary, characterizes the section as demutational, as the main number of trees is concentrated in generations below the average age of trees belonging to the spruce section. The relationship of stand volumes in generations with increasing age in the age series is estimated as weak by linear approximation and moderate by exponential approximation, i. e. spruce trees of different ages may be part of different age generations. The highest values of the relationship between the two parameters under discussion are observed in birch for both approximations, respectively, $R^2 = 0.816$ and $R^2 = 0.814$ — the relationship is "high, close", indicating a uniform distribution of tree volumes across the age generations of the age series. Indicators of volumes of joint values of trees of black alder, European spruce and birch PP 1 have expectedly insignificant values: at linear approximation $R^2 = 0.101$ — connection "weak", at exponential approximation $R^2 = 0.444$ — connection "moderate", which is quite explained by different values of number and volumes of trees in age generations, which define biogeocenosis as a community in dynamics from the phase of climax to the phase of digression. At the same time, the parameter correlation indices for both approximations are interpreted from "weak" to "moderate", which once again confirms the previously voiced thesis (Storozhenko, 2007) that only a uniform distribution of tree volumes in age generations corresponds to the assessment of the biogeocenosis as a climax community

The biogeocenosis of PP 2 in comparison with the previous eutrophic community has slightly different characteristics of water supply associated with flowing stream humidification, which determines higher morphometric, age and volume indices of the alder section of the stand and more subordinate position of spruce, which is included only in the second tier of the stand. Birch was encountered only once in the community and is not represented in the stand

Table 3. Age and dynamic structure of stands of eutrophic black alder bogs

Breed	Measured values, ex/m^3ha^{-1}	Number and volumes of trees in age generations								Total	Dynamics phase
		Before 40	41—60	61—80	81—100	101—120	121—140	141—180			
PP1											
Alder	Number of	33	40	27	87	140	53	13	—	393	Cl—Dg
	Tree volumes	1.1	1.7	3.4	32.7	116.4	65.7	22.5	—	243.5	Cl—Dg
Spruce	Number of trees	26	80	67	33	53	7	—	—	266	Dm
	Tree volumes	0.8	6.3	8.5	16.1	44.3	6.7	—	—	82.7	Cl—Dg
Birch	Number of trees	—	7	—	7	13	—	—	20	47	Dg
	Tree volumes	—	0.47	—	0.26	11.1	—	—	35.3	47.13	Dg
General	Number of trees	59	127	94	127	206	60	13	20	706	Cl
	Tree volumes	1.9	8.3	11.9	49.1	171.8	72.4	22.5	35.3	373.3	Cl—Dg
PP2											
Alder	Number of trees	33	40	0	20	67	87	20	—	267	Cl
	Tree volumes	0.2	0.5	0	24.1	21.9	43.2	10.1	—	380.3	Cl—Dg
Spruce	Number of trees	7	53	33	80	33	33	20	—	259	Cl
	Tree volumes	3.0	7.4	7.0	23.5	8.3	27.4	23.4	—	65.4	Dg
General	Number of trees	6.7	15.8	5.6	28.2	16.7	20.3	6.7	—	526	Cl
	Tree volumes	0.6	1.5	1.0	24.0	19.9	40.9	12.1	—	445.7	Cl—Dg

Denotations. Dynamics phase: Cl, climax; Dg, digression; Dm, demutation. Dual designations (Cl-Dg, etc.) explain the transitional positions of the community from one phase to another

Table 4. Relationship of tree volume indices with age generations — total and by tree species sections in the studied lowland eutrophic bogs

Breed	PP 1		PP 2.	
	Bonding equations	R^2	Bonding equations	R^2
Alder	y1= 10.9x — 8.814	0.302	y1=4.892—5.285	0.418
	$y2=0.699e^{0.710x}$	0.687	y2=4.892—5.285	0.418
Spruce	y1=4.417x — 2.26	0.265	y1=3.660x — 0.357	0.621
	$y2=1.203e^{0.504x}$	0.498	$y2= 3.061e^{0.319x}$	0.696
Birch	y1=11.53—17.05	0.816	—	—
	$y2=0.040e^{1.671x}$	0.814	—	—
General	y1=7.25 + 4.02	0.101	y1=4.721x — 4.6	0.456
	$y2=4.196e^{0.382x}$	0.444	$y2=0403e^{0.664x}$	0.689

Denotations. R^2 — correlation relation. y1 — linear approximation; y2 — exponential approximation. The omission of the alder PP 2 section in the graph is interpreted as a coincidence of linear and exponential approximations.

formula (Tables 2 and 3). The relationship of tree volumes in generations of the age series with increasing age of trees in generations for the black alder section is defined as "significant" only for the linear approximation.

For the stand of the spruce section, the discussed relationship is interpreted as significant for both approximations. For the whole biogeocoenosis, the relationship between the parameters is estimated as "moderate" for the straight-line approximation and "significant" for the exponential approximation. This means that, as in the PP 1 eutrophic bog variant, in the PP 2 biogeocenosis the volumes of trees in age generations describe to a greater extent its different-age structure, which, however, tends to the area of digression.

In general, a comparative assessment of the two eutrophic bogs shows that, firstly, in both cases, European spruce occupies a subordinate position to black alder in the stand structure. Secondly, flowing water supply of the forest area compared to more stagnant water supply conditions significantly affects the productivity of the main species — black alder is more productive than European spruce at I—II grades.

An important, if not decisive factor determining the formational position of a biogeocenosis in the future, is the species structure of natural regeneration in the biogeocenosis area (Table 5).

The quantitative composition of natural regeneration in the area of the studied eutrophic bogs differs markedly between them. The quantitative composition of black alder undergrowth is almost 3 times more abundant in the flowing stream growth conditions of PP 2 than in the more stagnant conditions of PP 1. In contrast, the number of spruce undergrowth in PP 1 is almost 2.8 times higher than in PP 2. It can also be noted that, in general, the quantitative and species composition of undergrowth species in both sample plots is almost the same.

It is clear that the stand of PP 1 of stagnant moisture is in the dynamics of replacement of alder by spruce and in the near future will be completely defined as a spruce formation. In the conditions of flowing moistening of PP 2, the stand of spruce section with a long-term probability is in the state of stabilization.

Indicators of the condition of trees and the stand as a whole determine the degree of weakening of the biogeocenosis and possible trends of changes in its structures in the future.

From the data of Table 6 it can be seen that in general the condition of trees on the area of both eutrophic bogs can be recognized as quite acceptable with a slight trend to the weakened category with an average weakening score of 1.66. At the same time, the analysis of the relationship between the age of trees and the degree of their weakening on PP 1 is expressed by the correlation relation for the black alder section — R^2 = — 0.982, the relationship is negative, very close: the higher the age of trees, the worse their condition. For the section of European spruce the correlation relation — R^2 = — 0.006, there is no connection: with increasing age of trees the condition of spruce trees practically does not change.

Such dependencies confirm the above-mentioned tendency about the unstable position of black alder under conditions of stagnant moisture in PP 1 and, on the contrary,

Table 5. Quantitative composition of natural regeneration in lowland eutrophic bogs by species in gradations

Breed	Distribution of undergrowth by height gradations (m), pcs/ha								Total, pcs/ha
	Up to 0.5	0.6—1.0	1.1—1.5	1.6—2.0	2.1—2.5	2.6—3.0	3.1—3.5	3.6 и >	
Tree species — PP 1									
Alder	—	7	47	13	27	53	20	93	260
Spruce	193	100	67	100	47	47	27	13	594
Birch	—	—	20	—	7	—	—	—	27
Total undergrowth of tree species	193	107	134	113	81	100	47	106	881
Undergrowth — PP 1									
Cherry	—	47	127	207	100	87	13	—	581
Rowan	—	20	—	7	—	—	13	53	93
Juniper	—	—	—	13	—	—	—	—	13
Total undergrowth	—	67	127	227	100	87	26	53	687
Tree species — PP 2									
Alder	Univ.	Univ.	53	413	40	66	7	180	759
Spruce	86	40	20	40	7	7	7	7	214
Birch	—	—	—	—	7	7	—	—	14
Total undergrowth of tree species	86	40	73	453	54	80	14	187	987
Undergrowth — PP 2									
Willow	—	7	—	7	13	—	—	—	27
Linden	—	7	7	40	13	—	—	—	67
Witch hazel	—	—	13	13	—	—	—	—	26
Rowan	20	26	7	26	—	7	—	13	99
Grasshopper	26	53	40	247	40	7	—	—	413
Total undergrowth	46	93	67	333	66	14	—	13	632

Table 6. Indicators of the condition of trees and stands of eutrophic black alder bogs

Breed	Distribution of the number of trees by condition category, pieces—%						Total, pieces—%	Average score states
	1	2	3	4	5	6		
PP1								
Alder	213—55.8	133—32.8	40—9.8	7—1.6	—	—	393—100	1.6
Spruce	86—33.3	113—43.6	33—12.8	7—2.6	—	20—7.7	259—100	1.7
Birch	20—42.5	27—57.5	—	—	—	—	47—100	1.6
PP2								
Alder	190—56.6	109—32.1	31—9.4	0	0	10—1.9	340—100	1.6
Spruce	120—46.3	93—35.9	33—12.8	7—2.5	0	7—2.5	260—100	1.8

the confident stabilized position of spruce in the stand of PP 2.

Black alder under growing conditions in eutrophic bogs is affected by wood-destroying fungi (WDF) causing stem and root rots. At PP 1, the infestation of black alder trees by rot fautes reaches 60%, the trees of the alder section of PP 2 stand are affected by rots by 74%. In both cases alder infestation is interpreted as very high, certainly affecting the weakening of mechanical properties of trees, and only the peripheral conductive zone of trunks, not affected by rot, keeps them from falling out into the structure of deadwood. Since water supply to trees is carried out through the conductive system of trees (xylem) located at the periphery of the radial cut of the trunk, the central rot has little influence on water supply to crowns. Moreover, 84.2% of rots belong to the corrosive type, the rest — to the destructive type.

In both biogeocenoses, the relationship of rot presence with tree crown condition is expressed as r = 0.12 with error m_r = 0.1 and reliability coefficient t = 1.2 and is interpreted as very weak, unreliable (Dvoretsky, 1971).

Fruiting bodies of wood-destroying fungi of *Basidiomycota* division were found on trunks of black alder trees at PP 1 and PP 2 in 5—10% of cases. The main pathogens causing black alder rot in the studied eutrophic bogs are alder truncatcher (*Phellinus alni* (Bond.) Parm.), true trout (*Fomes fomentarius* (L.) Fr.), false trout (*Phellinus igniarius (*L.: Fr) Quel.), as well as species from the genus *Armillaria*, mainly autumnal openok (*Armillaria borealis* Marxm. et Korhonen). All of them cause rot of the corrosive or dead-fiber type. Spruce in the stand has a single infestation with wood-destroying fungi.

Under unfavorable edaphic growing conditions or when trees are weakened as a result of DRG lesions, black alder trees are able to form secondary crowns, supplementing primary crowns by the volume of leaf surface (Table 7).

Under conditions of flowing moisture in black alder forest PP 2, the formation of secondary crowns mainly along the trunk part of trees is observed in 46% of trees and reaches on average 41.3% of the total volume of crowns. The peculiarity of secondary crowns formation is observed in almost all deciduous species. In black alder this phenomenon was observed for the first time (Storozhenko, Glukhova, 2022).

From the modern biogeocenotic point of view, woody debris is considered as the most important element of forest biogeocenosis, forming part of the total biomass balance of the community (Storozhenko, 2011, 2007; Golovchenko et al., 2023). In the studied lowland eutrophic bogs developing

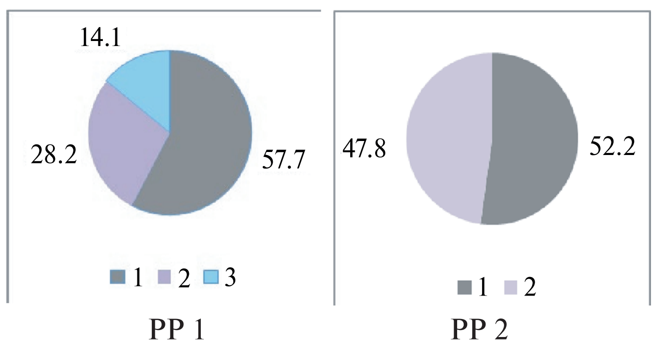
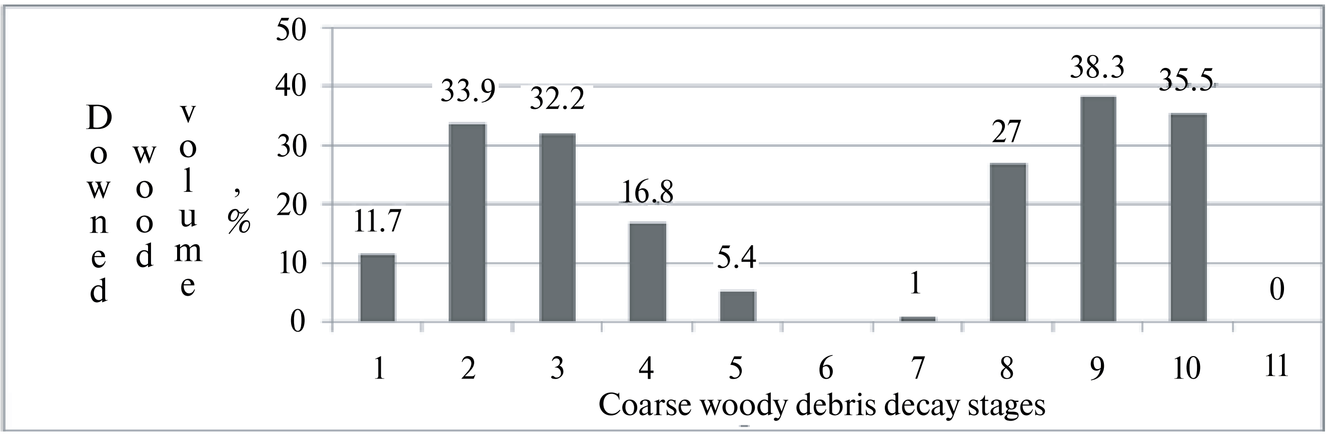


Fig. 1. Participation of tree species in the total volume of deadwood in biogeocenoses of stagnant (PP 1) and flowing (PP 2) moistened areas,%.
Denotations. Colors of the diagram: gray — black alder (1); purple — spruce (2); blue — downy birch (3).

Table 7. Volume indices of secondary crowns of black alder in eutrophic bog PP 1

Indicators	Volumes of secondary crowns of black alder trees by gradations of primary crowns replacement, in% of the whole crowns										Total, pieces, %
	Up to 10	11—20	21—30	31—40	41—50	51—60	61—70	71—80	81—90	91—100	
Copies	80	80	60	7	13	—	13	40	13	87	393
%	12.9	22.2	16.6	1.8	3.8	—	3.8	11.1	3.7	24.1	100



Designations. Stages of deadwood decomposition: 1—5 PP1, 7—11 PP 2.
Fig. 2. Distribution of valley totals of all rocks by decomposition stage in biogeocenosis PP 1 and PP 2.

under conditions of natural succession, woody fallout in the form of deadwood has significant volumes and different indicators of species participation in the total volume of deadwood (Fig. 1).

Time periods of deadwood decomposition stages: 1 — up to 3 years; 2—4—20; 3—21—30; 4—31—40; 5—41—50 years. In black alder forest PP 1, deadwood of all tree species is present in the volume of 125.1 m^3 per 1 ha of biogeocoenosis area, which is 33.5% of the stand stock; in PP 2 biogeocoenosis deadwood is present in the volume of 73.7 m^3 per 1 ha or 16.5% of the stand stock. Distribution of deadwood total values of all species by decomposition stages is presented in Fig. 2.

Similar values of dead wood volume distribution by decomposition stages in both PPs of the analyzed eutrophic bogs indicate similar trends in the dynamics of woody debris, despite differences in moisture content.

CONCLUSION

All studied eutrophic bogs have a mixed species composition of three main tree species — black alder, European spruce and downy birch in different ratios of trees of species sections of stands depending on the numerical and volumetric indices in the age generations of the age structure of biogeocenoses.

The peculiarity of the species composition of the stands of the studied eutrophic bogs can be considered the presence of spruce and black alder in the first tier regardless of the dominant species in the tier and the overwhelming dominance of spruce undergrowth in the composition of natural regeneration. This feature determines the possibility of replacing alder formation with spruce formation as an insurance option for preservation of forest environment in case of changes in edaphic conditions in the dynamics of forest communities growth.

In the studied communities there is an admixture of birch trees of different ages, there are few cases of high ages (more than 100—150 years). The peculiarity of this species in edaphic conditions of eutrophic bogs of the region, especially in conditions of more stagnant moisture, is the ability of birch trees to live up to the age of 200 years

The ability of black alder to form secondary crowns on tree trunks and branches as a response to deterioration of edaphic conditions leading to a decrease in the volume of primary crowns was confirmed.

The analysis of numerical and volumetric indices of eutrophic bog structures in the region confidently shows the possibility of change from alder to spruce formations. High indicators of the relationship between the presence of spruce in the age generations of age series for the biogeocenosis PP 2 with flowing moisture as a formed structural feature of the subordinate position of spruce in the stand are determined, which confirms the trend of possible changes of alder formations to spruce.

In general, the comparative assessment of the two eutrophic bogs shows that, firstly, in both cases, European spruce occupies a subordinate position to black alder in the stand structure. Secondly, flowing water supply of the forest area (PP 2) compared to more stagnant moisture conditions (PP 1) significantly affects the productivity of the main species — in flowing growth conditions the productivity of black alder is higher in I—II grades than that of European spruce. On the contrary, in more stagnant moisture conditions, European spruce replaces black alder both in the tree stand and in the undergrowth.

The studied black alder forests grow on thick peat soils composed of lowland tree peats with a high degree of decomposition. The existing differences between the soils of the studied eutrophic bogs are explained, first of all, by the geomorphology of the location and hydrological regime. Soils of stagnant black alder have higher acidity, ash content, slightly lower density and lower carbon content in contrast to the black alder, which occupies a flowing position in the relief.

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