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Alpha diversity of lichenized and aphyllophoroid fungi in two 1ha forest plots in the Samursky National Park (Republic of Dagestan, Russia)

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Abstract
Aim. The results of the inventory of species composition of epiphytic lichens and aphyllophoroid fungi on two 1 ha sample plots in lowland floodplain forests are presented. Such integrated studies of these groups of organisms are poorly known. Fungi, including lichenized fungi, are essential components of forest ecosystems. Data on their diversity and substrate distribution can provide important information on the condition and biological value of the forests studied.
Material and Methods. The main method of the fieldwork was the "1-ha method". For the alpha-diversity study, two 1-ha sample plots were established in well-preserved forest areas: the first one in a site of mixed broad-leaved forest with lianas, and the second one in communities dominated by *Carpinus betulus* and *Quercus robur*. The specimens were collected from all variety of woody substrate within plots in spring and autumn 2023.
Results. We have revealed 89 species of lichens and 60 species of aphyllophoroid fungi. The lichen families *Arthoniaceae*, *Lecanoraceae*, *Physciaceae*, *Ramalinaceae* and *Roccellaceae* contain 47.2 % of all species. High proportion of lichens with *Trentepohlia* photobiont (29.2 %), significant number of Arthoniomycetes (*Arthoniaceae*, *Lecanographaceae*, *Roccellaceae*) and crustose lichens (75.3 %) have been noted. Among the aphyllophoroid fungi identified in the sample plots, 11 species are new to Dagestan, including three species (*Antrodia leucaena*, *Coronicium gemmiferum*, *Steccherinum litschaueri*) recorded for the Caucasus for the first time. Fourteen species are new to the Samursky National Park.
Conclusion. The study of alpha diversity and substrate preferences of xylobionts revealed the richest and most specific phorophytes, as well as some ecological features of the surveyed plots. Most of the species were found on the bark and wood of *Carpinus betulus, Populus alba* and *Quercus robur*. The majority of species reported for the first time for the region have been recorded on these tree species. We expand the number of known species on *Populus alba*, on which only few species were previously known. High proportion of lichens with the *Trentepohlia* photobiont and the predominance of crustose species were revealed. In terms of basidiomata morphology, corticioid fungi dominated over polypores and clavarioids in general. The leading ecological and trophic group of aphyllophoroid fungi are saprotrophs. Revealed features indicate a significant contribution of the wood of the main forest-forming tree species to the preservation of the species richness of myco- and lichen biota.

Key Words
Ascomycota, Basidiomycota, biodiversity, broad-leaved forest, Eastern Caucasus, epiphytic lichens, inventory, protected area, wood-inhabiting fungi.

Альфа-разнообразие лихенизированных и афиллофороидных грибов на двух лесных участках площадью 1 га в Самурском национальном парке (Республика Дагестан, Россия)

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Резюме
Цель. Представлены результаты инвентаризации видового состава эпифитных лишайников и афиллофороидных грибов на двух 1 га пробных площадях в низменных пойменных лесах. Информация об их разнообразии и особенностях субстратной приуроченности может дать важные сведения о состоянии и биологической ценности изучаемых лесов.
Материал и методы. Основным методом полевых работ являлся «метод 1 га». Для исследования альфа-разнообразия были заложены две гектарные пробные площади: первая – на участке смешанного широколиственного леса с лианами, вторая – в сообществах с преобладанием *Carpinus betulus* и *Quercus robur*. Образцы были собраны со всего разнообразия древесного субстрата весной и осенью 2023 года.
Результаты. Выявлено 89 видов лишайников и 60 видов афиллофороидных грибов. Семейства *Arthoniaceae*, *Lecanoraceae*, *Physciaceae*, *Ramalinaceae* и *Roccellaceae* содержат 47,2 % всех видов лишайников. Отмечена высокая доля лишайников с фотобионтом *Trentepohlia* (29,2 %), значительное количество видов из класса Arthoniomycetes (*Arthoniaceae*, *Lecanographaceae*, *Roccellaceae*) и накипных лишайников (75,3 %). Среди афиллофороидных грибов 11 видов являются новыми для Дагестана, в том числе три вида (*Antrodia leucaena*, *Coronicium gemmiferum*, *Steccherinum litschaueri*) приводятся для Кавказа впервые. Четырнадцать видов грибов оказались новыми для Самурского национального парка.
Заключение. Изучение альфа-разнообразия и субстратной приуроченности ксилобионтов выявило наиболее богатые и специфичные форофиты, а также некоторые экологические особенности обследованных участков. Большинство видов было обнаружено на *Carpinus betulus*, *Populus alba* и *Quercus robur*. Виды, впервые найденные в регионе, были зарегистрированы также на этих породах деревьев. Увеличилось число известных видов на *Populus alba*, на котором ранее было известно лишь несколько видов. Выявлена высокая доля лишайников с фотобионтом *Trentepohlia* и преобладание накипных лишайников. Преобладающей морфологической группой базидиомицетов являются кортициоидные грибы. Ведущей эколого-трофической группой афиллофороидных грибов являются сапротрофы. Выявленные особенности указывают на значительный вклад древесины основных лесообразующих пород в сохранение видового богатства мико- и лишайниковой биоты.

Ключевые слова
Аскомицеты, базидиомицеты, широколиственные леса, Восточный Кавказ, эпифитные лишайники, инвентаризация, охраняемая территория, деревообитающие грибы.

INTRODUCTION

The forests concentrate a high diversity of organisms. At the same time, forests are mainly subject to anthropogenic degradation. Epiphytic lichens are considered the most reliable indicators of quality and continuous forest development [1–4]. In turn, aphyllophoroid fungi play a major role in wood decomposition and organic elements cycle in forests. Diversity data of these organisms can provide valuable insights of ecosystem health.

The important component of biodiversity is an alpha diversity which especially informative to identify areas with high ecological interest. The assessment of alpha diversity is required to achieve the most complete view of biodiversity [5]. It is refers to the diversity or species richness within a particular stand, community, habitat, or ecosystem [6]. In our case, alpha diversity refers to the number of different epiphytic lichens and aphyllophoroid fungi in the Samur forest. This is a unique habitat for many groups of organisms in the Eastern Caucasus among anthropogenically degraded and arid landscapes. There are many Hyrcanian elements, Tertiary relicts and rare species of vascular plants [7].

Comprehensive data on the biodiversity of aphyllophoroid and lichenized fungi for this unique habitat is absent. Our research expands the knowledge of these important organisms.

In this study, we explore the alpha diversity of epiphytic lichens and aphyllophoroid fungi in two 1-ha plots in lowland floodplain forests to understand the biodiversity patterns of each group and their ecological preferences.

Study area

The territory of Dagestan has fewer forests than any other region of the Northern Caucasus. Forests cover about 7 % of the republic's territory. Despite this there are various types of forests typical for the Caucasus [8].

In the lowlands, a few forests are concentrated along the coastal strip of rivers and in their deltas. The largest area of the floodplain forests is preserved in the delta of the Samur River on the border with Azerbaijan and on the Caspian Sea coast. Probably, these are the remnants of Hyrcanian forests preserved in a depleted form. This is a unique liana-tugai lowland forest in Russia with a significant number of Hyrcanian elements and a considerable number of rare species. To protect rare and endangered plants and animals, the “Delta Samura” protected area (10133 ha), which is a lowland part of the Samursky National Park, was established.

This area is transitional from temperate to subtropical climate with annual temperature of 12.6°C and the hottest months of July and August (average temperature is 24.5°C). Winter is warm and mild without snow with average temperature of January 1.4°C. Despite the low annual rainfall (400 mm), the high humidity (the relative air humidity is 78 %) is due to a high level of underground springs. In addition, the seaside location, many small rivers in the forest, and the high density of crowns form the conditions of the "greenhouse" effect [9].

The vegetative cover consists of 70 species trees and shrubs and more than 300 species of herbaceous plants, including 14 Tertiary relict species (*Acer laetum* C. A. Mey., *Alnus barbata* C. A. Mey., *Hedera pastuchowii* Woronow, *Prunus caspica* Kovalev et Ekimov, *Pyracantha coccinea* M. Roem., *Pyrus caucasica* Fed., *Vitis sylvestris* C. C. Gmel., etc.) [7; 10].

Open areas along the sea shore and along large delta channels are dominated by *Artemisia*-grasses semi-desert complexes and psammophilous/halophilous vegetation with the shrubs *Elaeagnus angustifolia* and *Tamarix ramosissima*. The large area of woodlands are formed by hornbeam (*Carpinus betulus* L.) forests without any herbal undergrowth and hornbeam-oak (*Quercus robur* L.) forests with participate of *Acer campestre* L., *Alnus barbata*, *A. incana* (L.) Moench, *Ulmus campestris* L. and various shrubs in the undergrowth (e.g. *Crataegus pentagyna* Walds. et Kit., *C. rhipidophylla* Grand., *Cydonia oblonga* Mill., *Euonymus* spp., *Prunus spinosa* L., *Rosa* spp., *Swida australis* (C. A. Mey.) Pojark. ex Grossh. Some areas are represented by groups of old poplar trees (*Populus alba* L., *P. nigra* L.) up to 30 m at a height and more than 1.5 m in diam.

Distinctive feature of the Samur forest is lianas, which are most developed in open areas (*Humulus lupulus* L., *Clematis orientalis* L., *Lonicera caprifolium* L., *Smilax excelsa* L.) or under forest canopy (*Clematis vitalba* L., *Hedera pastuchowii, Periploca graeca* L., *Vitis sylvestris*).

MATERIALS AND METHODS

The specimens of epiphytic lichens (include lichenicolous and non-lichenized saprophytic fungi) and aphyllophoroid fungi were collected from two 1-ha plots in the Samursky National Park (Fig. 1) in May and October 2023. The 1-ha method has been described in detail in previous works [11; 12]. For a survey of alpha diversity, two plots were selected in well-preserved old-growth forests: 1 – in mixed broad-leaved forest area with *Acer campestre*, *Alnus incana*, *Carpinus betulus*, *Cornus mas*, *Corylus avellana*, *Crataegus pentagyna*, *Mespilus germanica*, *Populus alba*, *Quercus robur*, which trunks are strongly shaded by lianas *Clematis vitalba*, *Hedera pastuchowii*, *Vitis silvestris*; 2 – in forest area dominated by *Carpinus betulus* and *Quercus robur*. Detailed characterization of investigated plots is described below.

The specimens were collected during two days per plot. All variety of woody substrates was studied – dry and fallen branches, deadwood, logs, snags, stumps, fallen and standing trunks, etc. Morphological and microscopic investigations of specimens were done by light microscopy technique using routine spot-tests for lichens (KOH, hypochlorite, paraphenylenediamine and UV light) and the standard set of chemicals (5% KOH, Melzer’s reagent, 0.1 % Cotton Blue) for aphyllophoroid fungi. The specimens are deposited in the herbaria of the Mountain Botanical Garden of the Dagestan Federal Research Centre of the RAS (DAG) and the Komarov Botanical Institute of the RAS (LE).

Investigated plots

1. Russia, Eastern Caucasus, Republic of Dagestan, Magaramkentsky district, Samursky National Park (“Delta Samura” area), 41.879067° N, 48,519098° E, alt. –20 m above the sea level, 06.05.2023–09.05.2023. 1-ha plot in the mixed broad-leaved forest (Fig. 2). Dominated tree species: *Carpinus betulus*, *Populus alba*, *Quercus robur* (sporadically). The second tree layer: *Acer campestre*, *Alnus incana*, *Fraxinus excelsior*. Undergrowth: *Cornus mas*, *Corylus avellana*, *Crataegus pentagyna*, *Mespilus germanica* and lianas *Clematis vitalba*, *Hedera pastuchowii*, *Pereploca graeca*, *Smilax excelsa*, *Vitis silvestris*. Herbal layer: *Euphorbia amygdaloides*, *Lonicera caprifolium*. Average height and diameter of dominated trees: *Carpinus betulus* – 14 m, 25 cm, *Populus alba* – 16 m, 45 cm. The relief of the plot is with deep ravines.

2. Russia, Eastern Caucasus, Republic of Dagestan, Magaramkentsky district, Samursky National Park (“Delta Samura” area), 41.82141° N, 48.527147° E, alt. 10 m above

the sea level, 26.10.2023–29.10.2023. 1-ha plot in hornbeam-oak forest (Fig. 3). Dominated tree species: *Carpinus betulus*, *Quercus robur*. The second tree layer: *Acer campestre*, *Crataegus pentagyna*, *Pyrus caucasica* (sporadically). Undergrowth: *Crataegus pentagyna, Cydonia oblonga, Mespilus germanica*, *Prunus divaricata*. Herbal layer: *Euphorbia amygdaloides* with participate of gramineae. Average height and diameter of dominated trees: *Carpinus betulus* – 14–16 m, 30 cm, *Quercus robur* – 14–16 m, 40–60 cm. The relief of the plot is flat.

Figure 1. Location of the studied sample plots within Dagestan
Рисунок 1. Местоположение изученных пробных площадок на карте Дагестана

Figure 2. Forest area of the first 1ha plot
Рисунок 2. Участок леса на первой 1га пробной площади

Figure 3. Forest area of the second 1ha plot
Рисунок 3. Участок леса на второй 1га пробной площади

RESULTS AND DISCUSSION

In total, 89 species from 58 genera of lichens (Ascomycota) and 60 species from 50 genera of aphyllophoroid fungi (Basidiomycota) have been revealed in two surveyed plots (Table). Among the total list of lichens 20 species were not recorded within the first plot and 28 species were not observed at the second site. For both plots, 41 lichen species are common (the Sørensen similarity index is 0.63). For aphyllophoroid fungi, more significant differences between species composition in two plots have been identified (the Sørensen similarity index is 0.38). Only 14 aphyllophoroid fungi species are common to both sites. At the same time, 32 of 46 fungal species are unique for the first plot, and a half of species (14 of 28 species) registered within the second plot were found only there. Our species list includes species and genera new to the Republic of Dagestan and to the Caucasus. Detailed information on new records is presented below.

Table. List of revealed species of epiphytic lichens and aphyllophoroid fungi
Таблица. Список выявленных эпифитных лишайников и афиллофороидных грибов

Species Виды	**Plot 1** / Площадка 1	**Plot 2** / Площадка 2
	Substrate (Herb. No.) Субстрат (гербарный номер)	**Substrate (Herb. No.)** Субстрат (гербарный номер)
Lichens (incl. lichenicolous and non-lichenized fungi) Лишайники (включая лихенофильные и нелихенизированные грибы)		
Acrocordia cavata (Ach.) R.C. Harris	Pop (DAG 1506)	Que, Car.
Acrocordia gemmata (Ach.) A. Massal.	Ace, Aln, Car, Pop	Car, Mes, Que
Alyxoria varia (Pers.) Ertz & Tehler	Ace, Aln, Car, Cor, Pop, Que	Car, Pop, Que (DAG 1476)
Amandinea punctata (Hoffm.) Coppins & Scheid.		Que
Anaptychia ciliaris (L.) Körb.		Car, Que
Anaptychia setifera (Mereschk.) Räsänen		Car
Anisomeridium polypori (Ellis & Everh.) M.E. Barr	Car (DAG 1494)	Pop, Que
Arthonia atra (Pers.) A. Schneid.	Ace, Aln, Cor, Pop, Que (DAG 1483)	Car, Corn, Mes, Pop, Que
Arthonia radiata (Pers.) Ach.		Que
Arthothelium spectabile A. Massal.	Ace (DAG 1475), Car	Car (DAG 1493), Que
Athallia pyracea (Ach.) Arup, Frödén & Søchting		Que
Bacidia fraxinea Lönnr.		Pop
Bacidia polychroa (Th. Fr.) Körb.	Ace (DAG 1479), Aln, Car, Pop (DAG 1503)	Car (DAG 1495)
Bacidia rubella (Hoffm.) A. Massal.	Ace, Pop (DAG 1500)	Car, Que
Bacidina delicata (Larbal. ex Leight.) V. Wirth & Vězda	Car	
Bacidina phacodes (Körb.) Vězda	Ace (DAG 1482), Car, Pop (DAG 1499), Que	Car
Bactrospora dryina (Ach.) A. Massal.	Aln, Que	Que (DAG 1488)
Calicium glaucellum Ach.		Que log
Calicium salicinum Pers.	Que stump	Que log
Caloplaca cerina (Hedw.) Th. Fr.	Ace, Cor	Car, Mes, Que

Candelaria concolor (Dicks.) Stein	Car	
Candelariella aurella (Hoffm.) Zahlbr.	Pop	
Candelariella xanthostigma (Ach.) Lettau		Que
Catillaria nigroclavata (Nyl.) Schuler	Que	
Chaenotheca brunneola (Ach.) Müll. Arg.	Que stump (DAG 1473)	Que log (DAG 1492)
Chaenotheca furfuracea (L.) Tibell	Que	
Chaenotheca trichialis (Ach.) Hellb.	Que stump	
Chaenothecopsis pusilla (Ach.) Alb. Schmidt		Que log
Cladonia chlorophaea (Flörke ex Sommerf.) Spreng.		Que log
Cladonia coniocraea (Flörke) Spreng.	Que stump (DAG 1472)	Que, Que log
Cladonia fimbriata (L.) Fr.	Que stump	
Cladonia pyxidata (L.) Hoffm.	Que stump	
***Cladonia ramulosa* (With.) J.R. Laundon**	Que stump (DAG 1491)	
Dendrographa decolorans (Turner & Borrer) Ertz & Tehler	Pop (DAG 1504)	Pop (DAG 1511)
Diarthonis spadicea (Leight.) Frisch, Ertz, Coppins & P.F. Cannon	Aln (DAG 1485), Car (DAG 1496)	Que
***Diploicia canescens* (Dicks.) A. Massal.**	Que (DAG 1505)	
Dirina ceratoniae (Ach.) Fr.	Pop (DAG 1512)	
Enterographa crassa (DC.) Fée	Car, Que	Que
Enterographa hutchinsiae (Leight.) A. Massal.	Aln (DAG 1486), Car, Pop (DAG 1501), Que (DAG 1490)	
Flavoparmelia caperata (L.) Hale		Car, Que
Glaucomaria carpinea (L.) S.Y. Kondr., Lőkös & Farkas	Car, Que	
Glaucomaria leptyrodes (G.B.F. Nilsson) S.Y. Kondr., Lőkös & Farkas	Ace (DAG 1497), Car, Que	Mes
Graphis betulina (Pers.) Gray	Car	
Graphis scripta (L.) Ach. s. lat.	Ace, Aln, Car	Car, Mes, Que
Hyperphyscia adglutinata (Flörke) H. Mayrhofer & Poelt	Car	Car, Que
Inoderma byssaceum (Weigel) Gray	Que	
Lecania fuscella (Schaer.) A. Massal.	Pop (DAG 1507)	
Lecania naegelii (Hepp) Diederich & Van den Boom		Car, Que
Lecanographa lyncea (Sm.) Egea & Torrente	Que (DAG 1502)	
Lecanora argentata (Ach.) Malme	Car	
Lecanora glabrata (Ach.) Malme	Car	
Lecanora saligna (Schrad.) Zahlbr.		Que log
Lecidella elaeochroma (Ach.) M. Choisy	Ace, Aln, Car	Car
Lecidella euphorea (Flörke) Hertel		Car
Lecidella laureri (Hepp) Körb.	Ace	
Lepraria finkii (Hue) R.C. Harris	Car, Que	Que, Que log
Leptosillia wienkampii (J. Lahm ex Hazsl.) Voglmayr & Jaklitsch	Pop, Que	Que
Melanelixia subaurifera (Nyl.) O. Blanco & al.		Car, Que log
Micarea prasina Fr.	Que stump (DAG 1489)	Que log
Milospium graphideorum (Nyl.) D. Hawksw.	On *Graphis scripta* growing on Ace, Aln, Car	On *Graphis scripta* growing on Car, Pop
Mycocalicium subtile (Pers.) Szatala	Que stump	Que log
Opegrapha vermicellifera (J. Kunze) J.R. Laundon	Ace (DAG 1480), Car, Pop	Car, Pop, Que
Opegrapha vulgata (Ach.) Ach.	Que	
Pachnolepia pruinata (Pers.) Frisch & G.Thor	Car	
Parmelia sulcata Taylor	Car	Car, Que log
Parmelina tiliacea (Hoffm.) Hale		Car, Que log
Peridiothelia fuliguncta (Norman) D. Hawksw.	Aln (DAG 1487), Pop	
Phaeophyscia orbicularis (Neck.) Moberg	Que	Car, Corn, Mes, Que
Phlyctis agelaea (Ach.) Flot.	Ace, Car	Car, Mes
Phlyctis argena (Spreng.) Flot.	Car	Car
Physcia adscendens H. Olivier	Ace, Aln, Cor	Car, Mes
Physcia aipolia (Ehrh. ex Humb.) Fürnr.	Que	Car
Physcia tenella (Scop.) DC.		Car
Physconia distorta (With.) J. R. Laundon	Car	Que
Physconia enteroxantha (Nyl.) Poelt	Que	Que
Placynthiella dasaea (Stirt.) Tønsberg		Que log
Placynthiella icmalea (Ach.) Coppins & P. James	Que stump	
Porina aenea (Wallr.) Zahlbr.	Ace (DAG 1474), Aln, Car, Cor, Pop	Car, Mes, Que
Pyrenula chlorospila Arnold	Ace (DAG 1477), Aln, Car, Cor, Que	Car, Mes
Pyrenula nitida (Weigel) Ach.		Car, Que
Pyrenula nitidella (Schaer.) Müll. Arg.	Aln	Car
Ramalina farinacea (L.) Ach.	Car	Car, Que, Que log
Ramalina pollinaria (Westr.) Ach.	Car, Que	Car
Scutula effusa (Auersw. ex Rabenh.) Kistenich, Timdal, Bendiksby & S. Ekman	Pop (DAG 1498)	
Strigula glabra (A. Massal.) V. Wirth	Car	

Toniniopsis subincompta (Nyl.) Kistenich, Timdal, Bendiksby & S. Ekman s. lat.	Pop (DAG 1508)	
Tornabea scutellifera (With.) J.R. Laundon		Car
Xanthoria parietina (L.) Th. Fr.	Ace, Car, Cor, Pop	Car, Corn, Mes, Pop, Que
Zwackhia viridis (Ach.) Poetsch & Schied.	Car	
Total: 89 species Итого: 89 видов	**Total: 69 species** Всего: 69 видов Ace – 19, Aln – 15, Car – 34, Cor – 7, Pop – 19, Que – 21, Que stump – 10	**Total: 61 species** Всего: 61 вид Car – 36, Corn – 3, Mes – 11, Pop – 8, Que – 31, Que log – 15
Aphyllophoroid fungi / Афиллофороидные грибы		
Amaurodon viridis (Alb. et Schwein.) J. Schröt.		Que
Antrodia hyalina Spirin, Miettinen et Kotir.	Pop (LE F-348117)	
***Antrodia leucaena* Y.C. Dai et Niemelä**	Pop (LE F-348102)	
Artomyces pyxidatus (Pers.) Jülich	Pop	
***Athelia bombacina* (Link) Pers.**	Pop (LE F-348108)	
Athelia decipiens (Höhn. et Litsch.) J. Erikss.	Pop (LE F-348134)	Car (LE F-348145)
Auricularia mesenterica (Dicks.) Pers.	Car	
***Bjerkandera fumosa* (Pers.) P. Karst.**	Car	Que (LE F-348111)
Botryobasidium isabellinum (Fr.) D.P. Rogers	Pop (LE F-348116, LE F-348141)	Car (LE F-348146, LE F-348151)
Botryobasidium subcoronatum (Höhn. et Litsch.) Donk	Que (LE F-348124), Pop (LE F-348130)	
Byssomerulius corium (Pers.) Parmasto	Car	Car
***Coronicium gemmiferum* (Bourdot et Galzin) J. Erikss. et Ryvarden**		Que (LE F-348103)
Daedalea quercina (L.) Pers.		Que
Daedaleopsis confragosa (Bolton) J. Schröt.	Aln	
Efibula tuberculata (P. Karst.) Zmitr. et Spirin	Pop (LE F-348125)	Car
Etheirodon fimbriatum (Pers.) Banker		Que
Fibrodontia gossypina Parmasto	Pop (LE F-348101, LE F-348121)	
Fistulina hepatica (Schaeff.) With.		Que
Fomes fomentarius (L.) Fr.	Car	Car
Funalia trogii (Berk.) Bondartsev et Singer	Pop	
Fuscoporia ferruginosa (Schrad.) Murrill	Pop (LE F-348136)	
Fuscoporia torulosa (Pers.) T. Wagner et M. Fisch.	Car, Que (LE F-348143)	Que
Ganoderma lucidum (Curtis) P. Karst.	Car	
Gloeoporus pannocinctus (Romell) J. Erikss.	Car	Car
***Gloiothele lactescens* (Berk.) Hjortstam**	Pop (LE F-348112)	
***Heteroradulum deglubens* (Berk. et Broome) Spirin et Malysheva**	Pop (LE F-348104)	
Hymenochaete rubiginosa (Dicks.) Lév.	Que	Que
Irpex lacteus (Fr.) Fr.	Que (LE F-348144)	
Laetiporus sulphureus (Bull.) Murrill		Que
Lyomyces crustosus (Pers.) P. Karst.	Cor (LE F-348128)	
***Lyomyces sambuci* (Pers.) P. Karst.**	Cle (LE F-348110, LE F-348115)	
Neofavolus alveolaris (DC.) Sotome et T. Hatt.	Car	
Oxyporus corticola (Fr.) Ryvarden	Pop (LE F-348133)	
Peniophora cinerea (Pers.) Cooke		Car
Peniophora laeta (Fr.) Donk		Car
Peniophorella praetermissa (P. Karst.) K.H. Larss.	Cor (LE F-348129)	
Peniophorella pubera (Fr.) P. Karst.	Pop (LE F-348119, LE F-348131)	Car
Phaeophlebiopsis ravenelii (Cooke) Zmitr.		Que
Phanerochaete livescens (P. Karst.) Volobuev et Spirin	Cor (LE F-348139)	Que (LE F-348150), Car
Phellinus tremulae (Bondartsev) Bondartsev et P.N. Borisov	Pop	
Picipes badius (Pers.) Zmitr. et Kovalenko	Car	
Plicaturopsis crispa (Pers.) D.A. Reid	Cor (LE F-348142)	
***Porostereum spadiceum* (Pers.) Hjortstam et Ryvarden**		Que (LE F-348113)
Postia lactea (Fr.) P. Karst.	Pop (LE F-348135)	
Rigidoporus ulmarius (Sowerby) Imazeki	Pop	
Schizophyllum commune Fr.	Car	Car
***Sistotrema oblongisporum* M.P. Christ. et Hauerslev**	Car (LE F-348105)	
Sistotrema resinicystidium Hallenb.	Pop (LE F-348140)	
***Steccherinum litschaueri* (Bourdot et Galzin) J. Erikss.**	Cor (LE F-348107), Cle (LE F-348114)	
Stereum hirsutum (Willd.) Pers.	Car (LE F-348122), Cor (LE F-348137)	Que
Subulicystidium longisporum (Pat.) Parmasto	Pop (LE F-348118, LE F-348120, LE F-348132)	
Thanatephorus ochraceus (Massee) P. Roberts	Pop (LE F-348109)	
Tomentella sublilacina (Ellis et Holw.) Wakef.		Car (LE F-348147)
Trametes versicolor (L.) Lloyd		Que
Trechispora farinacea (Pers.) Liberta	Que (LE F-348127)	
Trechispora microspora (P. Karst.) Liberta	Que (LE F-348126)	
Trichaptum biforme (Fr.) Ryvarden		Car

***Vuilleminia coryli* Boidin, Lanq. et Gilles**	Cor (LE F-348106)	
Xylodon quercinus (Pers.) Gray		Que (LE F-348149)
Xylodon raduloides Riebesehl et Langer	Car (LE F-348123), Cor (LE F-348138)	Que (LE F-348148), Car
Total: 60 species Итого: 60 видов	**Total: 46 species** Всего: 46 видов Aln – 1, Car – 13, Cle – 2, Cor – 8, Pop – 21, Que – 2, Que stump – 4	**Total: 28 species** Всего: 28 видов Car – 14, Que – 16

Note / Примечание: Ace – *Acer campestre*, Aln – *Alnus incana*, Car – *Carpinus betulus*, Cle – *Clematis vitalba*, Corn – *Cornus mas*, Cor – *Corylus avellana*, Mes – *Mespilus germanica*, Pop – *Populus alba*, Que – *Quercus robur*

New records of lichens

Cladonia ramulosa (With.) J.R. Laundon (Fig. 4A) – new species to the Eastern Caucasus. This is a lichen of predominantly temperate and southern boreal zones. Most common in areas with humid-warm climate. In Russia, the species is known from the European Arctic to the south of Far East [13]. The specimen was found on the first 1-ha plot in mixed broad-leaved part of the forest on *Quercus* stump among bryophytes.

Diploicia canescens (Dicks.) A. Massal. (Fig. 4B) – new species and genus to the Republic of Dagestan. A mainly Mediterranean-Atlantic species known within Russia from southern regions – Southern Siberia and the Caucasus [13]. The specimen was found on the first 1-ha plot in mixed broad-leaved part of the forest where grows as epiphyte on *Quercus robur*.

New records of aphyllophoroid fungi

Antrodia leucaena Y.C. Dai et Niemelä – new species to the Caucasus. This polypore fungus was initially described from northern China, but later the species was found in Finland and in several regions of the European part of Russia [14]. European collections from *Populus tremula* wood agree with our specimen collected from fallen branches of *Populus alba* in the first 1-ha plot in mixed broad-leaved forest.

Athelia bombacina (Link) Pers. – new species to the Republic of Dagestan. One of widespread species of corticioid fungi. The fungus grows on both deciduous and coniferous woody debris as well as on dead ferns [15]. The specimen was collected from the fallen trunk of *Populus alba* in the first 1-ha plot in mixed broad-leaved forest.

Bjerkandera fumosa (Pers.) P. Karst. – new species to the Republic of Dagestan. The species is widely distributed within the Northern Hemisphere but is uncommon. It develops basidiomata on a wide range of deciduous tree species. In the Northern Caucasus, the species was registered for Krasnodar Krai [16] and the Kabardino-Balkarian Republic [17]. The specimens from the Samursky National Park were collected from the fallen trunk of *Carpinus betulus* in the first 1-ha plot in mixed broad-leaved forest and from the dry standing tree of *Quercus robur* in the second 1-ha plot in hornbeam-oak forest.

Coronicium gemmiferum (Bourdot et Galzin) J. Erikss. et Ryvarden – new species and new genus to the Caucasus. This rare and little-collected species was previously known in Russia only from the Republic of Karelia [18] and Nizhny Novgorod Oblast [19]. According to J. Eriksson and L. Ryvarden [20], the species has mainly southern distribution and can be considered as thermophilic. Our specimen (Fig. 5) was collected from fallen branches of *Quercus robur* in the second 1-ha plot in hornbeam-oak forest.

Gloiothele lactescens (Berk.) Hjortstam – new species to the Republic of Dagestan. The fungus mostly grows on decorticated trunks and stumps of deciduous wood, and it is quite common in Europe. K.H. Larsson and L. Ryvarden [21] suppose that this species seems to prefer moist forest conditions. In the Caucasus, *G. lactescens* is listed for Krasnodar Krai as well as for Armenia, Azerbaijan, and Iran [22]. The specimen was collected from the fallen trunk of *Populus alba* in the first 1-ha plot in mixed broad-leaved forest.

Heteroradulum deglubens (Berk. et Broome) Spirin et Malysheva – new species to the Republic of Dagestan. The species has a wide distribution stretching from the Mediterranean to the subarctic zone in Europe. In the Northern Caucasus, *H. deglubens* was recorded from the Kabardino-Balkarian Republic [23], the Karachay-Cherkess Republic, and Krasnodar Krai [24]. The favorable substrata are thin, dry, still attached branches of deciduous trees although some records are known from still standing or recently fallen logs [24]. Our specimen was collected from fallen branches of *Populus alba* in the first 1-ha plot in mixed broad-leaved forest.

Lyomyces sambuci (Pers.) P. Karst. – new species to the Republic of Dagestan. This corticioid fungus is known for mycologists as a broad cosmopolitan morphospecies presented by a species group or species complex [25]. The species occurs on many different substrata, mostly on deciduous wood more rarely on conifers [26]. The closest to the Republic of Dagestan localities of *L. sambuci* are known in the Chechen Republic [27] and in Azerbaijan [22]. The specimens from the Samursky National Park were collected from dry hanging and fallen shoots of *Clematis vitalba* in the first 1-ha plot in mixed broad-leaved forest.

Porostereum spadiceum (Pers.) Hjortstam et Ryvarden – new species to the Republic of Dagestan. This wood-inhabiting fungus is quite common species in Europe, in particular, widely distributed in Central and Southern Europe, and it is known in the Caucasus [22]. Among adjacent to the Republic of Dagestan regions, this species was revealed in the Chechen Republic [27]. The species prefers to grow on dead wood of deciduous trees, especially on broadleaves (*Acer*, *Fagus*, *Quercus*, *Ulmus*) [26]. Our specimen was collected from fallen branches of *Quercus robur* (Fig. 6, A) in the second 1-ha plot in hornbeam-oak forest.

Sistotrema oblongisporum M.P. Christ. et Hauerslev – new species to the Republic of Dagestan. The species is a widespread and frequent, which usually grows on smooth bark of only slightly decayed, fallen or hanging branches of deciduous trees [28]. Such plant genera, as *Acer*, *Alnus*, *Betula*, *Populus*, *Prunus*, *Quercus*, *Sorbus*, *Pinus*, and some others, have been registered as substrata for the species in Russia [29]. In the Caucasus, this species was previously found in Krasnodar Krai [30]. The specimen was collected from the fallen trunk of *Carpinus betulus* in the first 1-ha plot in mixed broad-leaved forest.

Steccherinum litschaueri (Bourdot et Galzin) J. Erikss. – new species to the Caucasus. A. Bernicchia and S.P. Gorjón [26] note that the species is uncommon in Europe. In Russia, *S. litschaueri* is known based on sporadic findings from the European part, the Urals, and Siberia. This hydnoid fungus develops basidiomata on both coniferous and deciduous wood. Our specimens were collected from fallen shoots of *Clematis vitalba* and dry standing stems of *Corylus avellana* in the first 1-ha plot in mixed broad-leaved forest.

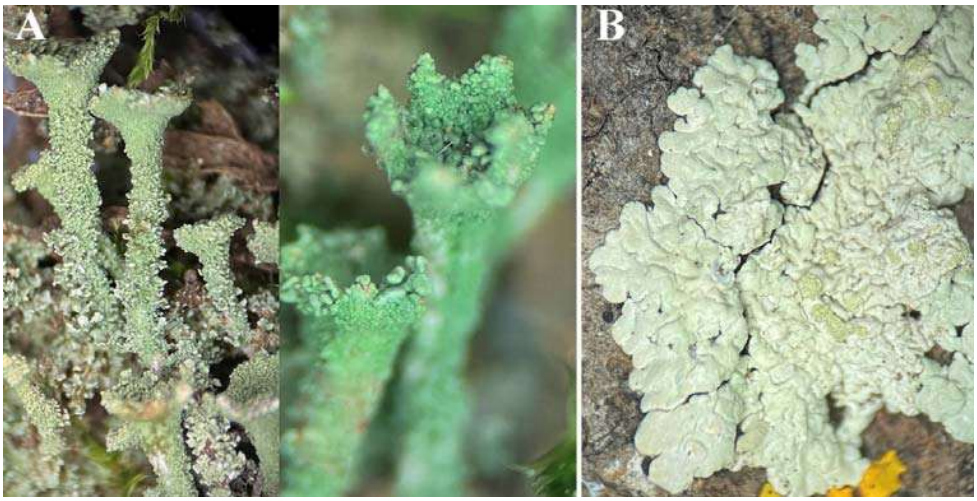

Figure 4. *Cladonia ramulosa* (A) and *Diploicia canescens* (B)
Рисунок 4. *Cladonia ramulosa* (A) *и Diploicia canescens* (B)

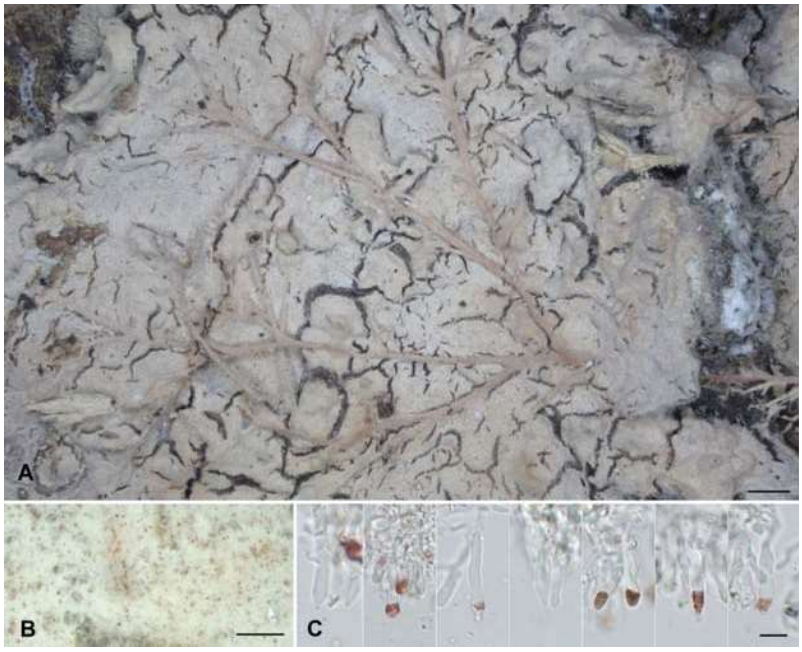

Figure 5. *Coronicium gemmiferum* (LE F-348103): basidioma with rhizomorphs (A), hymenophore part dotted by encrusted cystidia (B), and fusiform cystidia naked and with cap-like brown encrustation (C).
Scale bars: 1 mm (A), 100 µm (B), 10 µm (C)
Рисунок 5. *Coronicium gemmiferum* (LE F-348103): базидиома с ризоморфами (A), фрагмент гименофора с точечными вкраплениями от инкрустированных цистид (B), и веретеновидные цистиды, гладкие и с колпачковидной коричневой инкрустацией (C). *Масштабные линейки: 1 мм (A), 100 мкм (B), 10 мкм (C)*

Figure 6. Basidiomata of *Porostereum spadiceum* (LE F-348113) (A) and *Rigidoporus ulmarius* (B). *Scale bars: 1 cm (A), 10 cm (B)*
Рисунок 6. Базидиомы *Porostereum spadiceum* (LE F-348113) (A) and *Rigidoporus ulmarius* (B).
Масштабные линейки: 1 см (A), 10 см (B)

Vuilleminia coryli Boidin, Lanq. et Gilles – new species to the Republic of Dagestan. The species is infrequent in some localities, but not rare, and despite its species epithet, it is able to grow on dead but still attached branches of *Corylus avellana*, as well as *Fraxinus*, *Ostrya*, *Quercus*, *Ulmus* [22; 26]. In the Caucasus, this corticioid fungus is registered for the Karachay-Cherkess Republic [22], Krasnodar Krai [30], and outside Russia in Armenia, Iran, and Turkey [22]. The specimen was collected from fallen branches of *Corylus avellana* in the first 1-ha plot in mixed broad-leaved forest.

Almost all of species new to the Republic of Dagestan were collected within the first 1-ha plot in mixed broad-leaved forest, with an exception for *Porostereum spadiceum* found on *Quercus robur* in the second 1-ha plot in hornbeam-oak forest.

Lichens

Most of epiphytic lichens were found within two plots on bark of *Carpinus betulus* (34 and 36 species) and *Quercus robur* (21 and 31 species). Moreover, these phorophytes are substrata for "specific" lichens, not observed on other trees and shrubs on the plots. There are 13 such species (e.g. *Anaptychia setifera*, *Bacidina delicata*, *Graphis betulina*, *Pachnolepia pruinata*, *Tornabea scutellifera*) on *Carpinus betulus*, and 11 species (e.g. *Chaenotheca furfuracea*, *Diploicia canescens*, *Inoderma byssaceum*, *Lecanographa lyncea*, *Opegrapha vulgata*) on *Quercus robur*. In the first plot, 19 species each were recorded on *Acer campestre* and *Populus alba*. A total of 10 epixylic species (*Calicium salicinum*, *Chaenotheca brunneola*, *C. trichialis*, *Cladonia coniocraea*, *C. fimbriata*, *C. pyxidata*, *C. ramulosa*, *Micarea prasina*, *Mycocalicium subtile*, *Placynthiella icmalea*) were identified here on the dead wood of rotten *Quercus robur* stumps. *Alnus incana* and *Corylus avellana* are less diverse in lichens (15 and 7 species, respectively). In the second plot, low lichen diversity was also noted for single trees of *Cornus mas* (3 species), *Mespilus germanica* (11 species), *Populus alba* (8 species). Epixylic lichens here are more diverse. A total of 15 species were found on the dead wood of *Quercus robur* logs (e.g. *Calicium glaucellum*, *C. salicinum*, *Chaenotheca brunneola*, *Chaenothecopsis pusilla*, *Lecanora saligna*, *Micarea prasina*, *Mycocalicium subtile*, *Placynthiella dasaea*).

High diversity of lichens was revealed in the families of *Ramalinaceae* (11 species in total: 9 species in the first plot, 7 in the second plot), *Physciaceae* (10: 10, 6), *Lecanoraceae* (8: 6, 4), *Roccellaceae* (7: 7, 4), *Arthoniaceae* (6: 5, 4), which contain 47.2 % (42 species) of all species. Genera with three or more species include *Cladonia* (5), *Lecanora* (4) and *Bacidia*, *Chaenotheca*, *Lecidella*, *Physcia*, *Pyrenula*, which comprise three species each.

The most common species of lichens in studied plots are *Acrocordia gemmata, Alyxoria varia, Arthonia atra, Arthothelium spectabile, Bacidina phacodes, Graphis scripta, Lecidella elaeochroma, Milospium graphideorum, Opegrapha vermicellifera, Phaeophyscia orbicularis, Phlyctis agelaea, Physcia adscendens, Porina aenea, Pyrenula chlorospila, Xanthoria parietina.* However, there are more valuable and rare species, e.g., *Bactrospora dryina*, *Dendrographa decolorans*, *Diarthonis spadicea*, *Inoderma byssaceum*, *Lecanographa lyncea*, *Pachnolepia pruinata*.

The ecological features of surveyed plots are reflected in the ratio of the number of lichen species with different growth forms and photobiont type. In general, we notice a low proportion of foliose and fruticose lichens within two plots (24.7 %). Lichen crusts are predominant, with 75.3 % of species. The total ratio of crustose species to foliose and fruticose is 3:1 (4.75:1 in the first plot, 2.6:1 in the second plot). Fruticose and foliose lichens in the studied plots are presented by representatives of genera *Anaptychia*, *Cladonia*, *Flavoparmelia*, *Hyperphyscia*, *Melanelixia*, *Parmelia*, *Parmelina*, *Phaeophyscia*, *Physcia*, *Physconia*, *Ramalina*, *Tornabea*, and *Xanthoria*. These species occur locally in open habitats or mainly on tree tops. The dense crown and low light exposure under the forest canopy is probably a factor responsible for the low proportion of foliose and fruticose lichens in the plots. Species with photobiont of green globose cells are prevail. Species with a green globular cell photobiont are predominant. Lichens with *Trentepohlia* are 29.2 %.

The high proportion of lichens with *Trentepohlia* photobiont, as well as the significant number of Arthoniomycetes (*Arthoniaceae*, *Lecanographaceae and Roccellaceae*) and crustose lichens are character features for warm lowland floodplain broad-leaved forests.

Aphyllophoroid fungi

Altogether 60 aphyllophoroid fungi species belonging to 50 genera, 26 families and 11 orders of Agaricomycetes (Basidiomycota) have been identified within two studied plots. Most fungal species are related to the orders *Polyporales* (23 species) and *Hymenochaetales* (12 species), followed by the orders *Cantharellales* and *Russulales* with five species each. The predominance of these orders in the taxonomic structure is a typical pattern for forest ecosystems. Among aphyllophoroid fungi species registered during this research, 11 species are new to the Republic of Dagestan, including three species (*Antrodia leucaena*, *Coronicium gemmiferum*, *Steccherinum litschaueri*) recorded for the Caucasus for the first time. Moreover, 14 species (*Artomyces pyxidatus*, *Athelia decipiens*, *Funalia trogii*, *Irpex lacteus*, *Peniophora cinerea*, *Phellinus tremulae*, *Picipes badius*, *Plicaturopsis crispa*, *Schizophyllum commune*, *Thanatephorus ochraceus*, *Tomentella sublilacina*, *Trechispora farinacea*, *T. microspora*, *Xylodon quercinus*) are new to the Samursky National Park. Previously, these species were found for the Republic of Dagestan as a result of mycological investigations carried out on protected forest areas of the Tlyaratinsky Zakaznik (Tlyaratinsky District) and the Verkhniy Gunib Nature Park (Gunibsky District) [31–35]. In addition, the finding of *Rigidoporus ulmarius* (Fig. 6, B) on drying broad-trunked tree of *Populus alba* at the first plot is noteworthy. This species has a central and southern distribution in Europe, preferring mild winter temperature, and grows on deciduous trees, preferably on *Ulmus* and *Populus*, causing a white heart rot resulting at large cavities inside the trunk [36]. Earlier, *R. ulmarius* was collected on poplar in the forest on bank of the Samur River in 1979, and it was introduced in pure culture. Currently, the strain LE-BIN 0652 *R. ulmarius* is maintained in the Komarov Botanical Institute Basidiomycetes Culture Collection (St. Petersburg). The nearest to the Republic of Dagestan findings of this species are known from Krasnodar Region [37] and the Republic of Crimea [38], and from Transcaucasia (Armenia, Azerbaijan, Georgia, Iran) [22].

The most common species of aphyllophoroid fungi within studied plots are *Botryobasidium isabellinum*, *Fuscoporia torulosa*, *Hymenochaete rubiginosa*, *Stereum hirsutum*, *Subulicystidium longisporum*, *Xylodon raduloides*, noted based on the maximum of observations and collected specimens. All of these species, except for *Subulicystidium longisporum*, were revealed at both plots.

In terms of basidiomata morphology, corticioid fungi, represented by 36 species, dominated over polypores (23 species) and clavarioids (one species, *Artomyces pyxidatus*) in general. The ratio of the number of poroid and corticioid

fungi species did not differ significantly for both 1-ha plots (0.56–0.67), but more species with poroid hymenophore were recorded at the first plot dominated by *Populus alba* and *Carpinus betulus* (18 polypore species vs. 10 polypore species at the second plot). It seems to be explained in part by the conditions of higher stable moisture content in the first forest plot. On the other hand, the second plot dominated by *Carpinus betulus* and *Quercus robur* was characterized by low diversity and small volume of dead wood (Fig. 3), which could be an expected substrate for the development of xylotrophic fungi.

The leading ecological and trophic group of aphyllophoroid fungi revealed are saprotrophs developing on dead wood of the main forest-forming tree species. The highest number of xylotrophic fungi species was recorded on *Populus alba* (21 species) and *Carpinus betulus* (13 species) wood in the first plot, and on *Quercus robur* (16 species) and *Carpinus betulus* (14 species) wood in the second plot. The majority of species reported for the first time for the region have been recorded on these tree species. Of them, four fungal species (*Antrodia leucaena*, *Athelia bombacina*, *Gloiothele lactescens*, and *Heteroradulum deglubens*) were found on fallen trunks and branches of *Populus alba*. Three new to the Republic of Dagestan species (*Bjerkandera fumosa*, *Coronicium gemmiferum*, and *Porostereum spadiceum*) were registered on dead wood of *Quercus robur*. Two fungal species each were found on wood of *Carpinus betulus* (*Bjerkandera fumosa*, *Sistotrema oblongisporum*), *Clematis vitalba* (*Lyomyces sambuci*, *Steccherinum litschaueri*), and *Corylus avellana* (*Steccherinum litschaueri*, *Vuilleminia coryli*). The identified distribution of fungal species, including rare and new to the region, by inhabited tree species indicates the critical need to conserve wood of the main forest-forming species.

Among xylotrophic species, white rot fungi predominate, accounting for more than 78% of the identified species diversity of aphyllophoroid basidiomycetes, or 47 species. Brown rot fungi, which are incapable of decomposing lignin in wood, comprise about 17% of the fungal list, or 10 species. The latter ones are polypores from the genera *Antrodia*, *Daedalea*, *Fistulina*, *Laetiporus*, *Postia*, and corticioid members of the genera *Botryobasidium* and *Sistotrema*.

Mycorrhizae-forming fungi are presented by *Amaurodon viridis*, *Thanatephorus ochraceus*, and *Tomentella sublilacina* developing their basidiomata on dead wood of fallen trunks and branches. They were collected from both studied plots. Notably, a single species from the order *Cantharellales* (*Thanatephorus ochraceus*) was found within the first plot, while representatives of the order *Thelephorales* (*Amaurodon viridis* and *Tomentella sublilacina*) were recorded only within the second plot.

During the fieldwork new localities of rare and protected at the federal level species *Ganoderma lucidum*, as well as regionally protected species *Fistulina hepatica*, were registered, that is accompanied the previously obtained monitoring data on their populations in the Samursky National Park [39].

CONCLUSION

The study of alpha diversity and substrate preferences of xylobionts with the substrate revealed the richest and most specific phorophytes, as well as some ecological features of the surveyed plots. Most of the species were found on the bark of *Carpinus betulus, Populus alba* and *Quercus robur*. The majority of species reported for the first time for the region have been recorded on these tree species. We expand the number of known lichens on *Populus alba* to 22 species, on which only few species were previously known. High proportion of lichens with the *Trentepohlia* photobiont and the predominance of crustose species were revealed. The largest number of species of xylotrophic fungi was observed on the wood of *Populus alba* (21 species) in the first plot and on the wood of *Quercus robur* (16 species) and *Carpinus betulus* (14 species) in the second plot. In terms of basidiomata morphology, corticioid fungi, dominated over polypores and clavarioids in general. The leading ecological and trophic group of aphyllophoroid fungi are saprotrophs.

The revealed distribution of species, including rare and new to the region, by inhabited tree species indicates a significant contribution of the wood of the main forest-forming species to the preservation of the species richness of myco- and lichen biota.

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Все авторы в равной степени участвовали в написании рукописи и несут ответственность при обнаружении плагиата, самоплагиата или других неэтических проблем.

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All authors are equally participated in the writing of the manuscript and are responsible for plagiarism, self-plagiarism and other ethical transgressions.

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