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The biogeographic analysis of lichens of Baunt District (Republic of Buryatia)

Биогеографический анализ лишайников Баунтовского района (Республика Бурятия)

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Summary. The article presentes data analysis of lichens of the Baunt District of the Republic of Buryatia. This region is characterized by a significant area, geomorphological heterogeneity of the surface, an extreme climate and interesting local ecosystems. Local lichens belong to the mountain-boreal biota, since the area is located in the boreal zone of the Holarctic. Lichen flora represents different phytogeographical patterns with residual and consistent interchange of vegetation formations. The most lichen species are concentrated in the areas of rock outcrops, especially carbonate outcrops. In extreme conditions, epiphytic lichens grow in shelters on various substrates in a medium-scale ecosystem: inside rocks, near thermal springs, in mountain forest valleys or on slopes exposed to the sun. The valleys that were not glaciated during the Quaternary period serve as shelters for the rare species of tropical and non-moral origin. As a result of the conducted research, several rare and vulnerable species of lichens have been identified, listed in the Red Books of various ranks.

Key words. Bering Land bridge, lichen flora, phytogeographic relation, Pleistocene

Реферат. Статья посвящена анализу лихенофлоры Баунтского района (Республика Бурятия). Этот район отличается значительной площадью, геоморфологической неоднородностью поверхности, экстремальным климатом и интересными местными экосистемами. Приводится биогеографический анализ флоры, состоящей из 248 видов лишайников. Большинство видов лишайников относятся к горно-бореальной биоте, поскольку район расположен в бореальной зоне Голарктики, с остатками степных формаций. Максимальное разнообразие лишайников сосредоточено в районах выхода горных пород, особенно карбонатных обнажений. В экстремальных условиях эпифитные лишайники ищут укрытие на различных субстратах в экосистеме среднего масштаба: внутри скал, вблизи термальных источников, в горных лесных долинах или на открытых солнцу склонах. Долины, которые не оледенели в четвертичный период, служат убежищами для редких видов тропического и неморального происхождения. Также приводятся редкие виды лишайников, внесенные в Крсные книги

Ключевые слова. Берингийский мост, лихенофлора, фитогеографические связи, плейстоцен.

This paper presents the analysis of previous data on the lichen flora of the Baunt District (Kharpukhaeva, Lishtva, 2020). A checklist was compiled with 248 species from 120 genera and 45 families. Baunt lichen flora is represented by different phytogeographical patterns with residual and consistent interchange of vegetation formations such as steppes, humid dark coniferous forests and tundra. The lichen flora showed a floristic relationship with the west of North America through Bering land bridge. In this paper, the author gives a biogeographical analysis and comparison of altitudinal preferences of lichens.

The mountainous terrain of the Baunt District is situated on the north of Vitimskoe Plateau. This district presents diverse surface areas, geomorphological heterogeneity, and fascinating ecosystems such as taiga, tundra, and exposed steppe slopes, among others. This plateau is rounded by the Vitim River between 54.4710° to 55.8694°N and 110.4381° to 116.9145°E. The Vitim River basin is comprised of Arctic drainage. Valley watershed altitudes vary from 1,600 metres in the north-west to 1,000 metres to the south-east, and the river flux orients toward the south-east. The Baunt Lake intermountain basin with its chain of lakes from 1,000–1,100 metres above sea level connects to the basin via the Tzypa River network. Due to the extreme climate, the district has a long frozen period (down to –51 °C) and small weighted mean yearly precipitation (360–410 mm) (Bufal, Vizenko, 1970). The territory is situated in the spreading permafrost zone, and the average annual air temperature is –0.6 °C, placing it in the northern taiga zone.

Results and discussion. Species composition in leading families was similar to that in close-by regions (Kharpukhaeva, 2010; Makryj, Lishtva, 2005; Chesnokov, Lishtva, 2016). In the following taxonomic analysis, the family Parmeliaceae was the largest family in the Baunt lichen flora, with 48 taxa and 24 genera accepted at present. The second largest family was Cladoniaceae with 26 species followed by the Lecanoraceae and the Teloschistaceae families with 17 and 16 species, respectively. The largest genus was *Cladonia* (26 species) followed by *Peltigera* and *Lecanora* with 9 species each. The number of single-species' genera and two-species' genera was quite high (76 and 26, respectively), indicating insufficient information to characterise the overall lichen biota of the Baunt District. The actual lichen diversity of the region may reach 600–700 species and should undergo more intense lichenological exploration in the future.

A majority of the forest species (108 species) appears to be confined to large forests, while only 31 are epiphytic and known to be from older forests. The low abundance of epiphytic species is attributed to anthropogenic causes, as the regime is altered by both wildfire and anthropogenic disruptions, wherein forests around settlements and places of alluvial gold mining are transformed and frequently burned. In extreme conditions, epiphytic lichens sought shelter in medium-scale ecosystems, such as stone mosses, rock niches, in the vicinity of thermal springs, on dark coniferous forest dales, or on sun-exposed slopes. Some epiphytic species such as *Candelaria concolor* (Dicks.) Stein., *Flavopunctelia soredica* (Nyl.) Hale, *Flavoparmelia caperata* (L.) Ach., *Nephroma helveticum* Ach., and *N. isidiosum* (Nyl.) Gyeln. passed from tree and wood substrates to stone and mossy rocks. In the Baunt District, epiphytic lichens in normal conditions exhibited substrate preferences for a specific type of tree bark or wood. The epiphytic species *Evernia mesomorpha* Nyl. and *Ramalina dilacerata* (Hoffm.) Hoffm., however, were found on soil in tundra. Most of the lichens are eurytopic; only a few are stenotopic or other types of specialists, such as parasitic (*Caloplaca epithallina* Lynge) varieties or epilythic species attracted to basic or acid rocks.

The vegetation is primarily larch (*Larix gmelinii* (Rupr.) Rupr.) taiga. Typical larch forests of the mid-montane belt are marsh tea larch (*Ledum palustre* L.) and green mossy larch forests. Inter-montane depressions with and without valleys occupy meadow-swamp communities and dwarf birch thickets. Patches of steppes occur on the exposed slopes of the Ikatsky Range. These steppes retain a relic Pleistocene character. The open larch forests with moss and lichen form the upper timberline and are frequently accompanied by *Pinus pumila* (Pallas) Regel, *Dushekia fruticosa* (Rupr.) Pouzar, or *Betula divaricata* Ledeb. underbrush. An admixture of Siberian cedar (*Pinus sibirica* Du Tour) and birch (*Betula lanata* (Regel) V. N. Vassil.) occur in larch forests. The alpine tundra belt occurs between 1.800 and 2.200 metres above sea level. Traces of glaciations are pronounced in the mountains. Unsurprisingly, a high proportion of the boreal, arctic-alpine, and montane species were observed. The dominance of boreal (90 species) and montane (63 species) elements (34 % and 28 %, respectively) is likely due to the location of the Baunt District in the boreal zone with complex dissected plateaus yielding sharp relief. In the flora examined in this study, boreal lichens placement reflected natural conditions; most of the epiphytic lichens, epixylic lichens, and subepigeic lichens belong to the boreal element. The boreal element was non-specific; only *Evernia esorediosa* (Müll. Arg.) Du Rietz had an Asiatic origin.

The Boreal element of the Baunt District includes 90 species. Most of the boreal species were multiregional, exceeding the bounds of the coniferous forest zones, such as holarctic and pluriregional (23 and 50 species). Among the boreal species, 13 lichens were of Eurasian-North-American origin, especially noticeable for species of the genera *Cladonia* and *Peltigera* common in many coniferous forests of the northern hemisphere. Epiphytic and epixylic lichens of Eurasian-North-American origin include *Tuckermanopsis chlorophylla* (Willd.) Hale, *T. ciliaris* (Ach.) Gyeln., some *Bryoria* species, *Xylographa parellela* (Ach.) Fr., and *X. vitiligo* (Ach.) J. R. Laundon.

Arctic-alpine lichens (65 species, 26 %) are widely distributed across arctic and high-mountain regions of the northern hemisphere. Arctic-alpine lichens give distinctive features of tundra vegetation, such as *Alectoria ochroleuca* (Hoffm.) A. Massal., *Alectoria sarmentosa* subsp. *vexillifera* (Nyl.) D. Hawksw., *Asahinea chrysantha* (Tuck.) W. Culb. et C. Culb., *Bryoria nitidula* (Th. Fr.) Brodo et D. Hawksw., *Cetraria islandica* (L.) Ach., *Cladonia stellaris* (Opiz) Pouzar et Vězda, *Flavocetraria cucullata* (Bellardi) Kärnefelt et Thell, *Flavocetraria nivalis* (L.) Kärnefelt et Thell, *Sphaerophorus fragilis* (L.) Pers., *Thamnolia vermicularis* (Sw.) Schaer. *Acarospora, Arctoparmelia, Caloplaca,* and *Lecanora* grow on large boulders, on stones in streams, and on residual outcrops and rocks in the subalpine and alpine zones. Epireliquitic and epibryophytic species such as *Candelariella kuusamoënsis* Räsänen, *Caloplaca jungermanniae* (Vahl) Th. Fr., *Ochrolechia frigida* (Sw.) Lynge, and *Pertusaria* *bryontha* (Ach.) Nyl., prefer moss and plant debris and are abundant in the tundra and subalpine zones. Most arctic-alpine species (59 species, 91 % from arctic-alpine group) belong to the Holarctic, multiregional, Eurasian-north-American group. Only two American-Asian and Asian species were found, the amphiberingian *Asahinea scholanderi* (Llano) W. Culb. et C. Culb., and the *Boreoplaca ultrafrigida* Timdal. The last one is the endemic of the North Asia. *Asahinea scholanderi* is cryophyte and has been found in abundance in habitats as high as 1,800 m. Its distribution is bound by the mountainous system of north-eastern Asia formed during the most recent pre-glacial period.

The montane group of epilytic lichens (66 species) was found on the mid-mountain belt and not restricted to any specific phytogeographical zone, resulting in wide distribution. This group includes three dominant groups, the multiregional (23 species, 35 % from montane group), the Holarctic (16 species), and the Eurasian-North-American (10 species), containing species of the genera *Aspicilia, Caloplaca, Lecanora*, and some species of the families *Cladoniaceae, Physciaceae, Parmeliaceae*, and others. One amphiberingian species, *Umbilicaria muehlenbergii* (Ach.) Tuck, and one Asian species, *Caloplaca bohlinii* H. Magn., were found. *Nephromopsis laureri* is an east-Asian species ranging from forests to the subalpine belt.

Fifteen species of nemoral lichens were found making up 6 % of the local lichen flora despite the cold climate. Fifteen of these species are well-distributed throughout the Holarctic; among them, *Arthonia didyma, Phaeophyscia kairamoi* (Vain.) Moberg, *Flavoparmelia caperata, Flavopunctelia soredica*, and others are Eurasian species. Only *Parmelia asiatica* is from East Asia. Some of them, such as *Pyxine sorediata*, *Flavoparmelia caperata, Flavopunctelia soredica* accommodate to the bleak climate in open, dry sites, to become rupicolous, against its epiphytic habitats in temperate boreal and tropical zone. *Pyxine sorediata* and *Pannaria conoplea* demanding to thermic conditions were found on exposed rocks and mossy stones in forest shelters.

Although zonal and extra-zonal Central Asian steppes are located further to the south, arid element comprised a significant percentage of the studied flora (12 species, 5 %). Distribution of most of the abundant arid species, such as *Anamylopsora pulcherrima* (Vain.) Timdal, *Psora testacea* (Hoffm.) Ach., *Squamarina lentigera* (Web.) Poelt, *Toninia sedifolia* (Scop.) Timdal., was continuous in latitude, spreading from the Mediterranean to Central Yakutia, and occasionally spreading across the Holarctic According to Golubkova (1983), calciferous outcrops and calcareous soils play a significant role in the advance of thermophilic xerophylic species. The closest extended steppes, however, are found in the Barguzin depression 200 kilometres to the west and the Uda valley 300 kilometres to the south. The Barguzin steppes are Central Asian and Pleistocene-residual, similar to the Baunt steppes on exposed slopes, and these species associate with these relic habitats. Underlying rocks in these communities are often carbonate in composition. In addition to the species mentioned above, more than 40 rupiculous lichen species were found; of these, calciferous species are *Placynthium stenophyllum* (Tuck.) Fink., *Caloplaca approximata* (Lynge) H. Magn., *C. castellana* (Räsänen) Poelt, *C. decipiens* (Ach.) Blomb. et Forssell, *C. flavovirescens* (Wulfen) Dalla Torre et Sarnth., *C. lactea* (A. Massal.) Zahlbr., *C. lithophila* H. Magn., *Thyrea confusa* Henssen, *Synalissa ramulosa* (Bernh.) Körb., *Rinodina calcigena* (Th. Fr.) Lynge, and *R. bischoffii* (Hepp) A. Massal. Not all 40 were arid species, but all are common to exposed steppes, such as *Xanthoparmelia stenophylla* (Ach.) Ahti et D. Hawksw, *Blennothallia crispa* (Weber ex F.H. Wigg.) Otálora, P. M. Jørg. et *Wedin*, *Collema tenax* (Sw.) Ach., *Lathagrium cristatum* (L.) Otálora, P. M. Jørg. et Wedin, *Endocarpon pusillum* Hedw., *Catapyrenium rufescens* (Ach.) Breuss., *Leptogium lichenoides* (L.) Zahlbr., *Toninia tristis* (Th. Fr.) Th. Fr., and others.

Flora of this region had formed in the post-glacial period and trend weakly autochthonous. Arctic-alpine flora of this region had reduced in the post-glacial period and is confined to high-mountainous area. Now the main type of vegetation is different varieties of larch forests, from larch grassy taiga to open larch lichen taiga. The larch forest biome is the most stable ecosystem in the Baunt District. The lichen composition of larch forests is the same. The youngest and most dynamic ecosystems of East Siberia including the Baunt District are the mountain pine (*Pinus pumila)* communities. *Pinus pumila* migrated via mountain chains in the late Pliocene-Eopleistocene. Patches of the Baunt steppes from the Pleistocene developed unevenly with distributional discontinuity.

The long period of connection between Eurasia and North America by the Bering land bridge facilitated migration of montane flora between these continents (Sinitzyn, 1962); this phenomenon is also demonstrated by the modern alpine and associated marginal steppe and montane floras of South Siberia and the mountains of middle North America (Weber, 2003). This trend is highlighted by the amphiberingian species (Yurtzev, 1982; Golubkova, 1983) with their Asian-American distribution and the Eurasian-North American species among lichens and vascular plants. These species are primarily located in arctic and mountainous regions in western North America and North-East Asia on other side of the Bering Sea like the vascular plants (Golubkova, 1983; Qian, 1993; Manchester, 1999). *Asahinea chrysantha* (Tuck.) W. L. Culb. et C. F. Culb., *Umbilicaria muhlenbergii* and *U. carolianiana* are biogeographically significant to the arctic-alpine zone from Alaska to North-East Asia through the Ural. *Asahinea scholanderi* was found throughout East Siberia, with the latest finding in the south-west of East Sayan (Urbanavichene, Urbanavichus, 2009). The western boundaries of amphiberingian species, such as vascular species *Pinus pumila,* extend into Siberia. The Eurasian-North American species *Caloplaca tominii* Savitz with mostly Central Asian distribution has one point in North America. Its occurrence in Canada (Yukon Territory, Kluane) is allowed by a periglacial phenomenon and continent connection (Nimis, 1981). In total, seven Asian-American species were found in the Baunt District; among them, 2 were from arid element group, 3 – montane, and 2 – arctic-alpine. In addition, 38 Eurasian-North American species occur there. These species are more diverse in their elements group, but most of them are arctic-alpine, boreal and montane.

Oligotrophic lakes of East Siberia formed after the Pleistocene cooling, meaning some discovered species may be relics, suggesting this and other species may have been widespread. One of them, the aquatic lichen *Collema ramenskii* Elenk, originally found in the aquatic area of the Ladoga (Karelia), the Lake of Baikal, and the lakes of Baikalsky and Primorsky Ranges (Opredelitel …, 1975; Makryi, 1990; Lishtva, 2009), By drilling into Lake of Baunt sediments, regional paleoclimate over a considerable interval can be evaluated from 28.000 to 30.000 thousand years ago, during the Late Pleistocene and early Holocene (Krainov et al., 2017; Bezrukova et al., 2017). The last glacial maximum occurred twenty-five to thirty thousand years ago, during which pigweed, sagebrush, and motley-grassed steppes dominated. A neoglacial period followed 7,000 years ago, shifting prevalence to larch forests and mountain pine communities. At a later date, 0.8–5.0 thousand years ago, forests contracted, and steppe and tundra landscapes expanded.

Rare species were also found, such as *Asahinea scholanderi*, *Pyxine sorediata, Leptogium burnetiae,* and *Nephromopsis laureri* registered on the Russian Federation Red List (Red Book … 2008); *Gyalidea asteriscus* (Anzi) Aptroot et Lücking, *Pannaria conoplea*, and *Normandina pulchella* (Borrer) Nyl., are registered in Red List of Buryatia (Red Data Book … 2013). Four species red-listed in Russia are not threatened in Buryatia. For example, *Asahinea scholanderi* is cryophyte and has been found in abundance in habitats as high as 1,800 metres. Its distribution is bound by the mountainous system of north-eastern Asia and of north-western North America, formed during the most recent pre-glacial period. *Pyxine sorediata* and *Pannaria conoplea* survive from thermic period were found on exposed rocks and mossy stones in forest shelters. *Nephromopsis laureri* is an east-Asian species ranging from forests to the subalpine belt. *Boreoplaca ultrafrigida* Timdal is the one species endemic to North Asia.

Conclusions

1. The composition of the lichen flora of the Baunt District is mostly allochthonous with a low level of endemism. North American and Eurasian species migration across the Bering land bridge enriched lichen composition as demonstrated by multiple floristic affinities. Boreal element dominance in flora is closely aligned to bioclimatic zones. A hot point of lichen diversity was the forest ecosystem of the western macroslope of the Ikatsky Range, including the tundra and subalpine of Bolshoi Khopton, and on carbonate outcrops.

2. The lichen flora of the Baunt District has been constant over the last 6.6–7 thousand years from the end of the Pleistocene to the middle of the Holocene. These species represent different phytogeographical patterns with residual and consistent interchange of vegetation formations.

3. Arid, nemoral, and alpine lichens now inhabit several dramatically different ecological niches, including carbonate outcrops on exposed rocks for nemoral thermophilic and photophilic species, such as *Pyxine sorediata*. The youngest and most dynamic ecosystems of East Siberia including the Baunt District are the *Pinus pumila* mountain pine communities.

As the result, we assume that Baunt lichen flora is rich and various, but not yet completed. We do have enough data to conclude, however, that it is typical of allochthonous flora of South Siberia.

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