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BIODIVERSITY STUDIES

New and rare species of jelly cyanolichens for Asia and the Russian Far East

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ABSTRACT

The locations of nine species of jelly cyanolichens of the families Coccocarpiaceae, Heppiaceae, Koerberiaceae, Lichinaceae, Massalongiaceae found in the Magadan Region are reported. *Spilonema paradoxum* Bornet is recorded for the first time in Asia; five species, *Ephebe perspinulosa* Nyl., *Heppia lutosa* (Ach.) Nyl., *Koerberia biformis* A. Massal., *Peccania coralloides* (A. Massal.) A. Massal., and *Thallinocarpon nigritellum* (Letau) P.M. Jørg., are new for the Russian Far East; *Polychidium muscicola* (Sw.) Gray is first found in the Magadan Region, and the two species, *Euopsis granatina* (Sommerf.) Nyl. and *Spilonema revertens* Nyl., are rare lichens in this region. The geographical distribution patterns and ecology of these species are discussed. Findings in the north of the Russian Far East of such lichens as *Heppia lutosa*, *Koerberia biformis*, *Peccania coralloides*, and *Thallinocarpon nigritellum* are the most interesting and unexpected in the phytogeographical respect. All of them are relic elements in the flora of the Magadan Region.

Keywords: jelly cyanolichens, new records, mesophilous and xerophilous relicts, Magadan Region, Russia

РЕЗЮМЕ

Макрый Т.В., Желудева Е.В. Новые и редкие для Азии и российского Дальнего Востока виды слизистых цианобионтных лишайников. Приводятся местонахождения 9 видов слизистых цианобионтных лишайников из семейств Coccocarpiaceae, Heppiaceae, Koerberiaceae, Lichinaceae, Massalongiaceae, выявленных в Магаданской области. *Spilonema paradoxum* Bornet впервые зарегистрирован в Азии; 5 видов, *Ephebe perspinulosa* Nyl., *Heppia lutosa* (Ach.) Nyl., *Koerberia biformis* A. Massal., *Peccania coralloides* (A. Massal.) A. Massal. и *Thallinocarpon nigritellum* (Letau) P.M. Jørg., являются новыми для российского Дальнего Востока; *Polychidium muscicola* (Sw.) Gray впервые найден в Магаданской области, а два вида, *Euopsis granatina* (Sommerf.) Nyl. и *Spilonema revertens* Nyl., являются редкими в данном регионе. Обсуждаются особенности географического распространения и экология приведенных видов. Наиболее интересными и неожиданными в фитогеографическом отношении являются находки на севере российского Дальнего Востока таких лишайников, как *Heppia lutosa*, *Koerberia biformis*, *Peccania coralloides* и, *Thallinocarpon nigritellum*. Все они являются реликтовыми элементами во флоре Магаданской области.

Ключевые слова: слизистые цианолишайники, новинки, мезофильный и ксерофильные реликты, Магаданская область, Россия

Jelly cyanolichens represent a group of lichens, in whose thalli cyanobacteria (blue-green algae) act as a photosynthesizing symbiont (photobiont). When moistened, the thalli of these lichens swell greatly and are capable of holding large amount of water (10–30 times larger than their weight). This is due to the fact that cyanobacteria take a much greater part in the formation of thalli of these lichens than fungi. Their thalli have all homoiomerous structure, these lack the cortex, which in ordinary lichens is formed by fungal hyphae. These lichens are all black when dry, and black, dark brown or dark olive green when wet. In the systematic respect, jelly cyanolichens belong to various families, orders and classes. They have various life forms, from crustose, squamulose, dwarf-fruticose, filamentous-fruticose to foliose. Their photobionts are representatives of various genera of cyanophytes.

These lichens live in a wide variety of ecotopes, while including deserts and highlands with their extreme conditions. These are resistant to drying out, high and low temperatures, high insolation and radiation. The resistance is facilitated by the gelatin sheaths of cyanobacteria, which fulfil the protective functions. Some of symbiotic cyanobacteria, along with oxygenic photosynthesis, are capable of fixation of nitrogen (from the atmosphere), what also elevates the ability of these lichens to exist under harsh conditions on poor mineral substrates.

Jelly cyanolichens represent mainly small lichens, which are often overlooked during collecting, and these also, for the most part, are difficult to identify. These lichens are very poorly studied on the territory of all Russia. Until present, only two species of jelly cyanolichens are known in the Magadan Region. These are *Euopsis granatina* (Sommerf.) Nyl. and *Spilonema revertens* Nyl. (Kotlov 1995, Zhurbenko 2003).

The Magadan Region is situated in the northeastern part of Russia (the north of the Russian Far East). In the south it is washed by the Sea of Okhotsk, in the north it borders on the Republic of Sakha (Yakutia) and the Chu-

kotka Autonomous Area. This is a mountainous area. The mountain systems, which form the Okhotsk-Kolyma watershed, separate the North-Eastern Priokhotye (the coast of the Sea of Okhotsk with adjacent plains and mountain slopes) from the continental part of the Magadan Region.

The territory is located in the climatic zone of tundra and forest-tundra (subarctic climatic zone) and only partly, in the very south-west (valleys of the rivers Tauy, Kava and Chelemdzha in its lower reaches), in the climate zone of coniferous forests. In general, three types of climate may be distinguished in the region: (i) the monsoon-type maritime climate on the coast of the Sea of Okhotsk, (ii) the sharply continental climate in the continental part of the Magadan Region) and (iii) the temperate continental climate in the narrow transition zone. The coastal monsoon climate is characterized by long, relatively warm winters with blizzards and snowfalls and cool summers with strong winds and fogs.

The vegetation is represented by larch, stone-birch and valley poplar-chozenia forests, and also subalpine thickets of dwarf Siberian pine and shrubby alder, mountain tundra and stone placers with open plant communities.

MATERIAL AND METHODS

The work was prepared on the basis of the results of handling of herbarium lichen specimens collected during 2012–2017 years by E.V. Zheludeva and O.A. Mochalova on the territory of the Magadan Region of Russia.

The lichens collected were identified in the Central Siberian Botanical Garden SB RAS. Lichen thalli were examined with a stereoscopic microscope; thalli sections were studied with a light microscope. The names of the species are given in accordance with Index Fungorum. Herbarium specimens are kept in the Herbarium of Institute of Biological Problems of the North FEB RAS (MAG) and in M.G. Popov Herbarium of the Central Siberian Botanical Garden SB RAS (NSK).

RESULTS

Nine species of jelly cyanolichens were discovered on the territory of the Magadan Region. Six species are found in the lower belt of mountains and in river valleys, the remaining three in the highlands.

COCCOCARPIACEAE Henssen

Spilonema paradoxum Bornet

The minute filamentous-fruticose lichen containing *Stigonema* as a photobiont. The thallus consists of branched loosely interwoven filaments (up to 40 μm thick) forming mats up to 20 mm in diameter, attached to the stones by blue-green rhizohyphae.

Distribution and ecology. Very rare species with a wide multi-regional disjunctive range is known in Europe (Fennoscandia and mountainous areas), North Africa, North and South America (Jørgensen 2007a). Throughout the area, it occurs on moist acid rocks, mainly in suboceanic and northern (in the southern hemisphere in the southern) mountain areas. In Russia, the species is reported only for Karelia (Fadeeva et al. 2007) based on herbarium materials from the 19–20th centuries.

Notes. The Magadan location of the species is the first in Asia and the second in Russia. It is separated from the known locations of the species in Fenoscandia, the Appalachians, and the Alps with vast disjunctions.

Specimens examined: Magadan Region, Omsukchansky District: Kilgan mountains, vicinity of Juliet mine, 61°11'40.05"N 153°56'34.05"E, subalpine belt, 952 m a.s.l., stony hillside, rocks along the stream, on rocky surface, 08.08.2012, E. Zheludeva, Ом-4470 (MAG, doublet in NSK).

Spilonema revertens Nyl.

The minute fruticose lichen containing *Stigonema* as a photobiont. It consists of stiff, more or less erect, branched filaments, which form dense cushions, in the lower parts of which abundant blue-green rhizohyphae are developed.

Distribution and ecology. The species with a wide Holarctic range is known in Europe, Asia, North America, Greenland (Jørgensen 2007a). The lichen lives on more or less dry (periodically wet) exposed siliceous rocks in the lower mountain belts, mainly in light coniferous forests and stony meadow steppes, and is usually associated with *Psorula rufonigra* (Tuck.) Gotth Schneid., while forming a stable synusiae. The lichen is widely distributed in Russia, while including the north of the European part, the Northern and Southern Urals, the North Caucasus, the Southern and Eastern Siberia, and the Russian Far East (south and north parts) (Urbanavichus 2010).

Notes. In the Magadan Region, the lichen was previously recorded from the Chersky Range (Susumansky District) (Zhurbenko 2003). The new location is the second in the region.

Specimens examined: Magadan Region, Olsky District: nature reserve "Magadansky", Kava-Chelomdzhinsky cluster, Kava River valley, 59°47'38.59"N 148°00'33.82"E, 41 m a.s.l., rocks on the river bank, on rocky surface, with *Psorula rufonigra* (Tuck.) Gotth. Schneid., 07.09.2012, E. Zheludeva, O-4471 (MAG).

HEPPIACEAE Zahlbr.

Heppia lutosa (Ach.) Nyl.

The small squamulose to granular-crustose lichen containing *Scytonema* as a photobiont. Squamules are rounded blackish up to 4 mm in diameter with deeply urceolate immersed red-brown apothecia up to 2 mm in diameter.

Distribution and ecology. The species has a wide multi-regional range including Europe, Asia, Africa, North America, Australia (Nimis 1993). It inhabits dry, temporarily moist, calciferous or siliceous soil in dry intermountain basins and in areas with a continental and semiarid climate (in steppes, prairies, open xerophilous plant communities). In Russia, the species is known in the North Caucasus (Urbanavichus 2010), the Southern Siberia (Altai, Tuva, Baikal region and Transbaikalia) (Makryi 2015), and on the Putorana Plateau (Lake Ayan) (Zhurbenko 1989).

Notes. The species is recorded for the first time in the Russian Far East. This is the only species collected in the continental part of the Magadan Region.

Specimens examined: Magadan Region, Yagodninsky District: upper reaches of the Tuscan River, cliff "Nelyudimy", 63°25'12.53"N 149°41'59.45"E, 641 m a.s.l., soil areas between rocks, on soil, 01.06.2013, O.A. Mochalova, Я-4477 (NSK).

KOERBERIACEAE T. Sprib. et Muggia

Koerberia biformis A. Massal.

The finely foliose dark olive green lichen containing *Scytonema* as a photobiont. The thallus forms small rosettes 5–20 mm in diameter; lobes elongate up to 2 mm long, 0.3–0.5 mm wide, branched, stellately radiating, with cylindrical isidia, sometimes with red apothecia.

Distribution and ecology. This is a rare species found scattered in areas with a warm, humid climate. For a long time it was considered as a narrow Mediterranean species, also known from North America (Nimis 1993). However, recent data give evidence of its wider distribution in the South Holarctic, including Europe (Portugal, France, Spain, Italy, Croatia, Austria), Asia (Turkey, Russia), North Africa (Algeria, Morocco) and North America (Mexico, USA – Pacific coast and the west) (Nimis 1993, Tretiach 1998, Ravera 2001, Schoeninger 2002). This is an epiphytic species growing on rough bark; in Europe and North America it lives predominantly on older trees such as *Castanea* and *Quercus*. It inhabits moist and open woodlands. In Russia, this species is known only from the Baikal Siberia; it is found in the Tunkinskie Goltsy (Tretiach 1998), the North Muya Range (Makryi 1999), the Sokhondo Nature Reserve (Urbanavichus & Urbanavichene 2002), the Khamar-Daban, and the Dzherginsky Nature Reserve (Kharpukhaeva & Urbanavichus 2006).

Notes. The species is first discovered in the Russian Far East. The locations of the lichen in the Magadan Region are the northernmost in the world. It is quite possible that there are no disjunctions in the distribution of this species on the territory of Russia, in this case, it may occur in all the mountainous areas of the Baikal Siberia, South Yakutia, on the Stanovoi and Dzhugdzhur ranges bordering the North-Eastern Priokhotye.

Specimens examined: Magadan Region: Olsky District: nature reserve "Magadansky", Kava-Chelomdzhinsky cluster, Chelomdzha River valley, Nevta creek, 59°49'46.81"N 148°10'46.25"E, 40 m a.s.l., thickets of dwarf pine [*Pinus pumila* (Pall.) Regel.] with larch [*Larix cajanderi* Mayr] and dwarf alder [*Duschekia fruticosa* (Rupr.) Pouzar] dwarf shrub-green moss, on larch trunk – on bark, 15.07.2012, E. Zheludeva, O-4486 (MAG, doublet in NSK); Ola River valley, place "Golden", 59°52'56.84"N 151°34'18.64"E, 140 m a.s.l., larch forest with sparse chosenias [*Chosenia arbutifolia* (Pall.) A. Skvorts.], on trunk of chosenia – on bark, 07.07.2013, E. Zheludeva, O-4484 (MAG); nature reserve "Magadansky", Yamsky cluster, left bank of the Yama River, 5 km below the upper cordon, Allelny Creek, 59°50'50.32"N 153°16'57.98"E, 106 m a.s.l., larch forest with poplar [*Populus suaveolens* Fisch.] and bird cherry, on bark of poplar, 08.07.2017, O.A. Mochalova (MAG); Severo-Evensky District: vicinity of Evensk, 13th km of the road along the Bolshaya Garmanda River, 62°01'14.34"N 159°17'29.96"E, 55 m a.s.l., chozenia-poplar forest (with dwarf pine and shrubs) moss-lichen, on trunk of chosenia – on bark and thallus of *Leptogium saturninum* (Dicks.) Nyl., 13.07.2015, E. Zheludeva, СЭ-4483 (MAG).

LICHINACEAE Nyl.

Ephebe perspinulosa Nyl.

The minute subfruticose lichen containing *Stigonema* as a photobiont. Thallus of filamentous brackish branches with short spine-like branchlets forming rosettes up to 30 mm in diameter.

Distribution and ecology. Arctic-alpine species with a Holarctic range is known in Europe, North America (Jørgensen 2007b, Schultz 2004) and Asia (Russia). It inhabits moist, frequently irrigated siliceous boulders and rocks, usually along the banks of mountain streams. In Russia, this rare lichen is reported to the Murmansk Region (Urbanavichus et al. 2008), Karelia (Fadeeva et al. 2007), the Baikalsky Range, the Eastern Sayan (Makryi 1990, Makryi & Voronyuk 2003), and the Siberian Arctic (Taimyr) (Andreev et al. 1996).

Notes. It is first recorded in the Russian Far East region.

Specimens examined: Magadan Region, Omsukchansky District: Kilgan Mountains, vicinity of the Juliet mine, 61°11'39.08"N 153°58'49.08"E, alpine belt, 1480 m a.s.l., stone placer (rocks with calcite veins) with dryad-shrub moss-lichen clumps, on stone – on lichens, 11.08.2012, E. Zheludeva, Ом-4478 (MAG).

Euopsis granatina (Sommerf.) Nyl.

The crustose lichen contaning *Gloeocapsa* as a photobiont. The thallus is reddish brown, white-spotted, forming small granulose cushions or lumps up to 10 mm in diameter, which are easily broken up.

Distribution and ecology. The rare arctic-alpine species, scattered occurring in the Holarctic (Europe, Asia, North America, Greenland), commonest in Northern Europe (Jørgensen 2007b). The lichen lives on moist siliceous boulders and rocks. In Russia, it is known in the Arctic (Novaya Zemlya, Taimyr, Chukotka) (Andreev et al. 1996), the north of the European part (Murmansk Region, Karelia) (Urbanavichus et al. 2008, Fadeeva et al. al. 2007), the Northern Urals (Hermansson et al. 2006), the north of the Krasnoyarsk Territory (Zhurbenko 1996), and the north of the Russian Far East (Kotlov 1995).

Notes. In the Magadan Region, this species was reported for the Upper Kolyma Highlands (Yagodninsky District: Nelkoba River and Mount Haran) (Kotlov 1995).

Specimens examined: Magadan Region, Olsky District: vicinity of Magadan, Arman highway, 15th km, "Kapsha", 59°41'58.91"N 150°42'55.02"E, 536 m a.s.l., stone placer under the snowfield, on stone, 09.06.2017, E. Zheludeva, M-4479 (MAG, doublet in NSK).

Peccania coralloides (A. Massal.) A. Massal.

The small dwarf-fruticose lichen contaning a chroococcoid photobiont. Thallus of cylindrical lobes (0.5–1 mm in diameter) in the center and foliate lobes along the periphery forming dense black (often pruinose) cushions 5–10 mm high and 5–25 mm in diameter, always with numerous lecanorine apothecia 0.3–0.6(1) mm wide.

Distribution and ecology. The species has the ancient Mediterranean range including South Europe, North Africa, Western and Central Asia (Golubkova 1981, Nimis 1993). It is a calciphilous lichen occurring on steep sunny surfaces of calciferous rocks (rarely also on basic rocks). In Russia, this lichen is known from several locations in the Southern Siberia (Altai, Tuva, and the Baikal region) (Sedelnikova 1985, 1997, Makryi 1986, 2008), the Southern Urals (Vondrakova 2014), and the North Caucasus (Urbanavichus 2010).

Notes. The species is recoded for the first time in the Russian Far East. The Magadan location of the species is the northernmost and easternmost separated from the main part of the range with a wide disjunction.

Specimens examined: Magadan Region, Olsky District, Olsky firth, Atargan peninsula (between the "Rotten Corner" and the beginning of the spit), 59°33'41.68"N 151°28'13.35"E, 88 m a.s.l., stony hillside, outcrops of rocks with stone screes, on rock (calciferous rocks), 31.03.2016, E. Zheludeva, O-4480 (MAG, doublet in NSK).

Thallinocarpon nigritellum (Letau) P.M. Jørg.
≡ *Lichinella nigritella* (Letau) P. Moreno et Egea

The foliose-fruticose lichen containing *Chroococcidiopsis* as a photobiont. Thallus of ascending and erect, ligulate, branched lobes, 1–5 mm wide (with thickened margins and spherical isidia) forming cushions up to 10–15 mm high and 20 mm in diameter.

Distribution and ecology. The species has a South-Holarctic range. It is known from Central and Mediterranean

Europe, Asia, North Africa, North America (Jørgensen 2007b, Schultz 2007). This lichen grows on calciferous or base-rich siliceous rocks (on steeply inclined surfaces in the shade), occurs in more or less dry habitats in the areas with a temperate or semi-arid climate. In Russia, the lichen is known from the Southern Siberia (Makryi 1999, 2008) and the Southern Urals (Vondrakova 2014).

Notes. It is a new species for the Russian Far East. Its location in the Magadan Region is separated from the main part of the range with a wide disjunction.

Specimens examined: Magadan Region, Olsky District: Olsky firth, Atargan peninsula (between the "Rotten Corner" and the beginning of the spit), 59°33'41.68"N 151°28'13.35"E, 88 m a.s.l., stony hillside, outcrops of rocks with stone screes, on rock (carbonate rocks), 31.03.2016, E. Zheludeva, O-4481 (MAG, doublet in NSK).

MASSALONGIACEAE Wedin, P.M. Jørg. et E. Wiklund

***Polychidium muscicola* (Sw.) Gray**

The small fruticose lichen containing *Nostoc* as a photobiont. Tallus of cylindrical, sometimes slightly flattened and foveolate, dichotomously or finger-like branched, dark brown, more or less shiny filaments (50–130 μm diam.), forming cushions up to 10 mm high and 30 mm in diameter.

Distribution and ecology. The species has a multi-regional range. It is widely distributed in the Holarctic (Europe, Asia, North Africa, North America, Greenland), and has also have been recorded in several locations in the mountainous regions of the Southern Hemisphere (Piterans 1975). It occurs in moist stony ecotopes from the lower mountain conifer forests belt to high mountains, and grows on mossy siliceous rocks on a thin layer of fine earth, on plant remains or among mosses. In Russia, this species is known from the European part (North and Arctic), the Urals (Northern and Southern), Siberia (Southern, Eastern, Arctic), as well as from the northern and Arctic parts of the Russian Far East (Urbanavichus 2010).

Notes. The species is recorded for the first time in the Magadan Region.

Specimens examined: Magadan Region: Omsukchansky District: Kilgan Mountains, vicinity of the Juliet mine, 61°11'39.08"N 153°58'49.08"E, alpine belt, 1480 m a.s.l., stone placer (rocks with calcite veins) with dryad-shrub moss-lichen clumps, on stone – on interlayers of fine earth with *Toninia squalida* (Ach.) A. Massal., *Arthrorhaphis alpina* (Schaer.) R. Sant. and mosses, 11.08.2012, E. Zheludeva, Ом-4482 (MAG); Khasynsky District: Olskoe Plateau, slope of Mount Begemot, 63°37'28.30"N 151°15'35.69"E, 1082 m a.s.l., stony shrub-lichen tundra, on soil, 12.07.2017, E. Zheludeva, X-3699 (MAG).

DISCUSSION

On the whole, nine species of jelly cyanolichens belonging to eight genera and five families were discovered in the Magadan Region. All of them are new or rare for this territory.

Six species are characterized by wide ranges (three species by multi-regional and three species by Holarctic ranges), and three species have narrow ranges, i.e. the ancient Mediterranean (one species) and South Holarctic (two species) ranges. Large disjunctions are observed in the distribution of most species, what indicates the great age of these species and the relict nature of some of them in the area under study.

The most interesting and unexpected findings are *Koerberia biformis*, *Peccania coralloides*, *Thallinocarpon nigritellum* and *Heppia lutosa*. The first species is mesophilous relict, three others are xerophilous relics.

Heppia lutosa was found in the spurs of the Chersky Range. This is the continental part of the Magadan Region, for which (as well as for Yakutia) habitats are typical, where small areas of relict cryophilic steppes are preserved.

Koerberia biformis was discovered in the mixed valley forests of the lower reaches of the Chelomdzha, Ola, Yama, Bolshaya Garmanda Rivers flowing into the Sea of Okhotsk ("Okhotsk" part of the Magadan Region). These locations are characterized by milder climatic conditions due to the influence of the sea, and in the valley of the Chelomdzha River (Chelomdzha depression) due to the special microclimate.

Peccania coralloides, and also *Thallinocarpon nigritellum*, were found on the Atargan Peninsula. The existence of these species on Atargan is explained by the presence of calcium-bearing rock outcrops there, as well as by the milder coastal climate.

In the hemiarctic lichen flora of the Magadan Region, the presence of such not typical for this region cyanolichens, different in ecology, chorology and origin, inhabiting specific ecotopes, indicates to a complex genesis of the lichen flora of the North-East Siberia.

CONCLUSION

The locations of nine species of jelly cyanolichens of the families Coccocarpiaceae, Heppiaceae, Koerberiaceae, Lichinaceae, Massalongiaceae found in the Magadan Region are reported. *Spilonema paradoxum* is recorded for the first time in Asia; five species, *Ephebe perspinulosa*, *Heppia lutosa*, *Koerberia biformis*, *Peccania coralloides*, and *Thallinocarpon nigritellum*, are new for the Russian Far East; *Polychidium muscicola* is first found in the Magadan Region, and the two species, *Euopsis granatina* and *Spilonema revertens*, are rare lichens in this region.

Findings in the north of the Russian Far East of such lichens as *Heppia lutosa*, *Koerberia biformis*, *Peccania coralloides*, and *Thallinocarpon nigritellum* are the most interesting and unexpected in the phytogeographical respect. All of them are relic elements in the flora of the Magadan Region.

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