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Umbilicaria aprina and *U. rhizinata* (Umbilicariaceae, lichenized Ascomycota) in Russia

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Summary. The distribution of *Umbilicaria aprina* and *U. rhizinata* in Russia was revised basing on morphological and molecular-phylogenetic data. *Umbilicaria aprina* is new to Alexandra Land Island (Franz Josef Land Archipelago), Sverdrup Island (Taimyr Dolgano-Nenets District), the republics of Altai, North Ossetia-Alania and Sakha-Yakutia. *Umbilicaria rhizinata* is new to the republics of Tyva and Buryatia, Putorana Plateau, Kamchatka Peninsula, and the Magadan Region and is therefore reported for the first time to the Asian Subarctic. New localities of the species in other regions are cited. The ITS\5.8S phylogenetic tree supports the distinctness of *U. aprina* and *U. rhizinata*. The distribution map is drawn and patterns of distribution of two species are discussed. *Umbilicaria aprina* occurs in the high Arctic between 74°N and 81°N, whereas the northernmost locality of *U. rhizinata* is in the vicinity of Norilsk on the Putorana Plateau (ca. 70°N). In mountains *U. aprina* grows at higher maximal elevations compared to *U. rhizinata*.

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Распространение *Umbilicaria aprina* и *U. rhizinata* (Umbilicariaceae, лихенизированные Ascomycota) в России

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Ключевые слова: Арктика, биогеография, таллоконидии, филогения, ITS ярДНК.

Аннотация. Выявлено распространение *Umbilicaria aprina* и *U. rhizinata* в России на основе морфологических и молекулярно-филогенетических данных. *Umbilicaria aprina* является новым видом на островах Земля Александры (архипелаг Земля Франца-Иосифа), Свердруп (Таймырский Долгано-Ненецкий округ), в республиках Алтай, Северная Осетия-Алания и Саха (Якутия). *Umbilicaria rhizinata* является новым для республик Тыва и Бурятия, плато Путорана, полуострова Камчатка и Магаданской области. Таким образом, вид *U. rhizinata* впервые зарегистрирован в Азиатской Субарктике. Указаны новые местонахождения в других регионах. Представлено филогенетическое дерево, подтверждающее различие *U. aprina* и *U. rhizinata*. Составлена карта распространения и обсуждены закономерности распространения двух видов. *Umbilicaria aprina* встречается в высоких широтах Арктики между 74° и 81° северной широты, тогда как самым северным местонахождением *U. rhizinata* являются окрестности Норильска на западе Плато Путорана (около 70° северной широты). Аналогично, в горах максимальные отметки *U. aprina* выше, чем у *U. rhizinata*.

Introduction

Species of Umbilicariaceae Chevall. are predominantly saxicolous lichens mostly found in higher latitudes or at higher elevations worldwide. *Umbilicaria aprina* Nyl. and *U. rhizinata* (Frey et Poelt) Krzewicka are related species from the '*Umbilicaria aprina* group' – a monophyletic batch of morphologically similar taxa within *Umbilicaria* Hoffm. subg. *Umbilicaria*. Species of the *Umbilicaria aprina* group have a slightly areolate or reticulate center of the grey-coloured upper thallus surface, scarce to dense, simple or branched rhizinomorphs, non-septate to 10-septate thalloconidia, and omphalodisc apothecia with asci containing hyaline, unicellular ascospores. Species of the *Umbilicaria aprina* group are characteristic to harsh environments in polar and high mountain regions (Davydov et al., 2017).

Umbilicaria aprina is a cosmopolitan species that occurs in the Arctic and Antarctic, as well as almost all highest mountains with glaciers (Ryvarden, 1968; Crespo, Sancho, 1982; Øvstedal, Lewis Smith, 2001; Hansen, 2003; Kristinsson et al., 2010; Hestmark, 2016). The first record of the species for Russia was made by A. V. Dombrovskaya (1970), as *Gyrophora canescens* Dombr. (= *U. aprina*) from Khibiny Mountains (Kola Peninsula). *Umbilicaria aprina* has been also reported for the Arctic: Franz Josef Land Archipelago (Konoreva et al., 2019), Severnaya Zemlya Archipelago and Novosibirskie Is. (Davydov, Zhurbenko, 2008), in the Caucasus (Davydov et al., 2019b), Baikal area in South Siberia (Urbanavichene, Urbanavichus, 2001), and Kamchatka Peninsula (Dombrovskaya, 1970; Davydov et al., 2011), as well as for Yakutia in the Lichen Flora of Russia (Davydov, 2017) but without exact location.

Umbilicaria rhizinata was first described as *U. decussata* (Vill.) Zahlbr. var. *rhizinata* Frey et Poelt from Himalaya Mts. in Nepal (Poelt, 1977), and subsequently raised to the species level by Krzewicka (2010) who additionally reported this taxon to Kilimanjaro Mt. (Tanzania) and the South American Andes in Bolivia (Krzewicka, 2010). The synonymy of *U. rhizinata* was clarified recently (Davydov, 2022) and the distribution of the species has been expanded to North America and Xinjiang in China. In Russia the species was recorded from the Altai Mts. and the Stanovoye Nagor'e Highlands (Davydov et al., 2019a, b; Davydov, 2022).

Umbilicaria rhizinata is closely related to *U. aprina* and differs mainly by a smaller size of 3–4 cellular (vs. 1–2 cellular) thalloconidia. The species boundaries are not clear for many taxa, and *U. rhizinata* is represented in the GenBank by a single ITS sequence. The aim of the study was to provide additional data on the distribution of two species in Russia mostly basing on recently collected specimens and to test the monophyly of *U. rhizinata* by molecular phylogenetic method using ITS sequences.

Materials and methods

Sampling and phenotypic studies

The core material for the study was collected by authors between 2009 and 2022 in different regions of Russia and deposited in herbaria ALTB, LE, LECB, MAG, UHU, and private collections of the authors.

Additionally, specimens were studied from the herbaria HMAS, KPABG, KW, LE, and NS.

The specimens were examined using a stereomicroscope (Zeiss Stemi 2000-C) and a compound microscope (Zeiss Axio Lab.A1). Anatomical examination was undertaken using hand-cut sections mounted in water. Lichen substances were studied using high performance thin-layer chromatography (HPTLC) with solvent systems B′ (hexane: methyl tert-butyl ether: formic acid, 140 : 72 : 18) and C (toluene: acetic acid = 170 : 30) (Culberson, Kristinsson, 1970; Culberson, Johnson, 1982; Orange et al., 2001). We used a scanning electron microscope (SEM) to visualize thalloconidia. Microphotographs were obtained using a Carl Zeiss EVO MA 10 SEM. The samples were dried in air and fixed on aluminum stubs with double-sided sticky film, and then, gold was sprayed on them.

DNA extraction, amplification and sequencing

Single thallus parts (100–200 mg) were carefully checked for fungal infections and thoroughly cleaned of extraneous matter, excised under a magnifying lens, and transferred to sterile 1.5 ml reaction tubes. The samples were frozen in liquid nitrogen and powderized in the tubes using sterile pestles. DiamondDNA Plant Kit (ABT) was used for DNA extraction as recommended by the manufacturer.

To test the phylogenetic relationships within the species, the internal transcribed spacer region of nuclear ribosomal DNA (ITS) was amplified in a single reaction using ITS 1F-5' as a forward primer and ITS 4-3' or LR3-3' as a reverse primes (Vilgalys, Hester, 1990; White et al., 1990; Gardes, Bruns, 1993). Same primers were used for sequencing. Cycling conditions included initial denaturation at 94 °C for 35 cycles of 95 °C for 20 s, 52 °C for 40 s, 72 °C for 60 s, and a final extension step at 72 °C for 7 min. The program Geneious 6.0 (Biomatters Ltd., New Zealand) was used for assembling sequence reads and datasets. Consensus sequences were compiled from double-stranded sequenced parts of the sequences.

Sequences and phylogenetic reconstructions

To test the phylogenetic relationships of *Umbilicaria aprina* and *U. rhizinata* collected in Russia, the ITS region of the nrDNA (ITS1, 5.8S, and ITS2 nrDNA) was sequenced (Table). These markers were chosen because they were used in phylogenetic analyses recently (Davydov et al., 2017).

All newly obtained sequences were supplemented with sequences obtained during our previous study of Umbilicariaceae phylogeny (Davydov et al., 2017), representing species of the *U. aprina* group, as well as selection of sequences from different subgenera of *Umbilicaria* (Fig. 1); *Xylopsora friesii* (Ach.) Bendiksby et Timdal was used as the outgroup. Selection of the outgroup is based on our previous study (ibid.). GenBank Accession numbers are provided on Fig. 1. Newly generated sequences are listed in Table. ITS\5.8S 484 bp matrix were aligned using the MAFFT algorithm (Katoh et al., 2005). The most likely tree and 1000 rapid bootstrap replicates were calculated using RAxML 8.0.26 (Stamatakis, 2014) by raxmlGUI software version 1.3.1 (Silvestro, Michalak, 2012) applying the GTRGAMMA model of substitution to ITS1, 5.8S, and ITS2 subsets.

The tree topologies are taken from RAxML (Fig. 1). Bootstrap support values were noted onto the best scoring tree.

Table

Sample numbers and GenBank accession numbers for the newly obtained sequences of *Umbilicaria aprina* and *U. rhizinata*

Species name	Source: collection location and collection number or reference	GenBank accession number
Umbilicaria aprina	Russia, Franz Josef Land, Alexandra Land, Severnaya Bay, S. V. Chesnokov (ALTB–L7730)	OR916138
Umbilicaria aprina	Russia, Krasnoyarsk Territory, Sverdrup Is., L. A. Konoreva (ALTB–L7371)	OR916139
Umbilicaria aprina	Russia, Republic of Buryatia, Urgedeevsky Range, T. M. Kharpukhaeva (UUH, ALTB–L6594)	OR916140
Umbilicaria rhizinata	Russia, Republic of Altai, Altai Mts., Katunsky Range, E. A. Davydov 7446 (ALTB)	OR916141
Umbilicaria rhizinata	Russia, Republic of Altai, Altai Mts., Katunsky Range, E. A. Davydov 7421 (ALTB)	OR916142
Umbilicaria rhizinata	Russia, Kamchatka Peninsula, Petropavlovsk-Kamchatsky, Mishennaya Sopka Hill, D. E. Himelbrant and E. S. Kuznetsova K-1 (LE–L7465)	OR916143
Umbilicaria rhizinata	Russia, Altai Territory, Altai Mts., Tigireksky Range, E. A. Davydov 7562 (ALTB)	OR916144
Umbilicaria rhizinata	Russia, Krasnoyarsk Territory, Noril'sk, A. A. Ul'yanovskiy (ALTB)	OR916145
Umbilicaria rhizinata	Russia, Republic of Buryatia, Nam-Tzagan-Khutliyn-Nuruu Range, T. M. Kharpukhaeva (UUH–L01925)	OR916146
Umbilicaria rhizinata	Russia, Magadan Region, Malyk Lake, E. V. Zheludeva SU4883 (MAG)	OR916147
Umbilicaria rhizinata	Russia, Magadan Region, Urultun Lake, E. V. Zheludeva SU4884 (MAG)	OR916148

Results

Specimens of *U. aprina* and *U. rhizinata* were identified basing on their morphology and anatomy. Phylogenetic analysis supported the identifications. Thus, septation of thalloconidia is a constant diagnostic trait for *U. aprina* and *U. rhizinata*.

The phylogenetic study.

According to the ITS/5.8S phylogram (Fig. 1), the sequences of species of *Umbilicaria aprina* group cluster together with high statistical support (RAxML 100 % BS). Within *U. aprina* group, sequences of *U. aprina* and *U. rhizinata* clustered separately, which indicates distinctness of two species. Nine sequences of *Umbilicaria rhizinata* from different regions of Russia clustered together with high support (RAxML 87% BS), which indicates their identity. Six sequences of *Umbilicaria aprina* clustered in three subclades at the basal part of *U. aprina* group, but this segregation lacks bootstrap support.

The secondary chemistry.

All studied specimens were investigated by TLC. Both species showed the same spots pattern in TLC, and contain gyrophoric acid as a major and lecanoric as a minor compound.

The species and their distribution.

Umbilicaria aprina Nyl., 1869, Syn. Meth. Lich. 2: 12. (Fig. 2 A-D).

Holotype: [Ethiopia] "Abyssinia. Dedschen Mts, elev. 14200 ft. W. Schimper" (H–NYL! [H-NYL31742]).

= *Umbilicaria canescens* (Dombr.) N. S. Golubk.

≡ *Gyrophora canescens* Dombr.

Holotype: [Russia, Murmansk Region] "Peninsula Kolaënsis, montes Chibinensis, ad declivitatem australem montis Vudjavrczorr, elev. 380 m, in schistosis ad lapides nudis, No. 6. 05 VI 1965. A. V. Dombrovskaya" (LE! [L-266]).

The morphological description of the species is given in the literature (Ryvarden, 1968; Wei, Jiang, 1993; Hestmark, 2015; Davydov, 2017).

Selected specimens examined. Here we omit specimens which have been cited in our previous publications (Davydov, Zhurbenko, 2008; Davydov et al., 2011; Davydov et al., 2019b; Konoreva et al., 2019). RUSSIA. ***Murmansk Region***: "Khibiny Mts., Slope of Rasvumchorr Mt., elev. 744 m. 33.83661°N, 67.64343°E, on steep rock. 31 VII 2023. A. V. Melechin" (KPABG-L20976); "NW slope Woodyavrchorr Mt., elev. 400 m, 33.61900°N, 67.65508°E, on flat rocks. 28 VIII 1975. A. V. Dombrovskaya (KPABG-

L16332); "The slope of the valley of the Vuonnemjok River near the Yuksporrlak Pass, elev. 670 m. 33.834457°N, 67.658081°E, mountain tundra, on a cliff. 21 VII 1974. A. V. Dombrovskaya" (KPABG – L4434); "Monchegorsky District, Nyavka-tundra Range, in the middle course of the Liva River, 9 km upstream of the Livozero Lake, elev. 140 m, 31.354993°N, 67.834112°E, spruce forest, on a stone. 21 VII 1973. A. V. Dombrovskaya" (KPABG-L2707). ***Arkhangelsk Region***: "Franz Josef Land Archipelago, Alexandra Land Is., Severnaya Bay, the vicinity of the Omega research camp, elev. 15 m. 80°46'36.4"N, 47°48'00.9"E, rubble-moss-lichen community on the shore, on rocks. 13 VII 2019. S. V. Chesnokov" (ALTB–L7076); ibid., "elev. 14 m. 80°46'36.1"N, 47°48'35.0"E, large boulders on the shore, on rocks. 14 VII 2019. S. V. Chesnokov" (ALTB–L7730); ***Krasnoyarsk Territory***: "Taimyr Dolgano-Nenets District, Sverdrup Is., elev. 1 m. 74°33'22.2"N, 79°30'32.6"E, hummock-grass community, on rocks. 10 IX 2021.

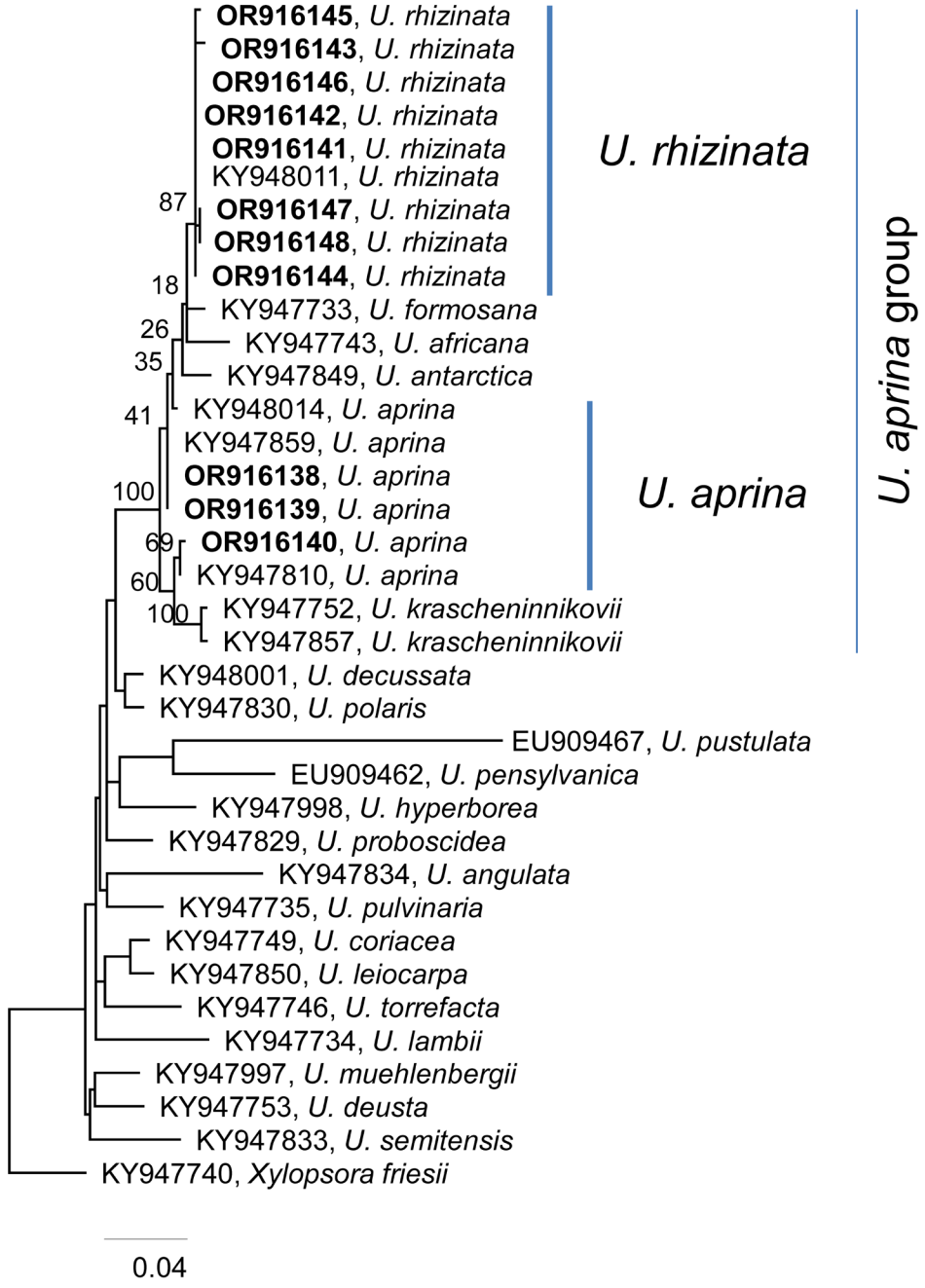

Fig. 1. The maximum likelihood (ML) phylogeny of the selected *Umbilicaria* ITS of nrDNA sequences. Numbers at the tree nodes indicate ML bootstrap percentages. Accession numbers are given to serve as operational taxonomic unit (OTU) names (www.ncbi.nlm.nih.gov). Originally produced sequence is marked in bold. Voucher specimens are listed in Table.

S. V. Chesnokov" (ALTB–L7370, L7373); ibid., "elev. 1 m. 74°33'22.5"N, 79°31'23.6"E, stones and driftwood on the shore, on rocks. 10 IX 2021. L. A. Konoreva" (ALTB–L7371, L7372); ***Republic of Yakutia***: "Bulunsky District, Novosibirsk Archipelago, Bunge Land, the central part. 3 IX 1954. E. S. Korotkevich" (KW–42979); "Tomponsky District, Verkhoyansk Mts., basin of the Lower Aldan River, left bank of the Hunkhada River below the mouth of the Nekucheen River (right bank of the Tompo River), elev. 1633.1 m, crustose epilithic lichen cold desert, on rocks. 18 IX 1951. V. Kuvaev 185/2" (LE–L6742); ***Kamchatka Territory***: "The vicinity of Petropavlovsk-Kamchatsky, the bank of the Halaktyrka River, elev. 100 m, 158.78351°N, 52.98618°E, on steep rock in *Betula* forest. 12 VII 1980. A. V. Dombrovskaya" (KPABG-L4410); "Valaginsky Range, peak of Pereval Mt., elev. 1780 m. 54°53'N, 159°55'E, on rocks. 25 VI 1984. A. Mikulin" (VLA 840625-18-1, ALTB–L6252); Mil'kovo District, SW slope of Tolbachik Volcano, lava stream, 55°46'35"N, 160°18'42"E, elev. 1610 m, dwarf shrub tundra. 16 VIII 2008. D. E. Himelbrant, I. S. Stepanchikova K-46-08" (LECB). ***Republic of Altai***: "Kosh-Agach District, N macroslope of Severo-Chuisky Range, elev. ca. 2500 m, on rocks. 19 VII 1981. N. V. Sedelnikova" (NS); ***Republic of Buryatia***: "Tunkinsky District, Urgedeyevsky Range, slope of the eastern exposition, high mountain lake, elev. 2350 m. 51°23'51.8"N, 102°12'33.3"E, lichen tundra, on rocks. 18 VII 2018. T. M. Kharpukhaeva" (ALTB–L6594).

Distribution in Russia: Murmansk Region (the Khibiny Range), Arkhangelsk Region (Franz Josef Land Archipelago), Krasnoyarsk Territory (Sverdrup Is., Severnaya Zemlya Archipelago), Republic of Yakutia (Novosibirsk Archipelago, Verkhoyansk Mts.), Kamchatka Territory (Gamchensky and Valaginsky Ranges), the Caucasus (republics of Kabardino-Balkaria and North Ossetia-Alania), Republic of Altai (Altai Mts.), Republic of Buryatia (Urgedeyevsky and Khamar-Daban ranges) (Fig. 3).

Umbilicaria rhizinata (Frey et Poelt) Krzewicka, 2010, Lichenologist 42(4): 491 (Fig. 2 E-H).

≡ *Umbilicaria decussata* (Vill.) Zahlbr. var. *rhizinata* Frey et Poelt in Poelt, 1977 Khumbu Himal 6(3): 419.

Lectotype: [Nepal]. "Mahalangur: Himal Khumbu, Moränen des Lobuche-Gletschers bei Lobuche, elev. 4950–5000 m. IX 1962. J. Poelt L247a" (M! [M0035585]; iso – M! [M0035586]).

= *Umbilicaria aprina* Nyl. var. *halei* Llano, 1956. J. Wash. Acad. Sci. 46: 183.

Holotype: [Canada]. "N.W.T.: Baffin Island, head of Clyde Fiord, on exposed gneiss boulders. 26 VIII 1950. M. E. Hale 450" (MIN! [MIN664956]).

The morphological description of the species is given in the literature (Poelt, 1977; Krzewicka, 2010; Hestmark, 2015; Davydov, 2017, 2022).

Selected specimens examined. Here we omit specimens which have been cited in our previous publications (Davydov, Zhurbenko, 2008; Davydov et al., 2011; Davydov et al., 2019a, b; Davydov, 2022). RUSSIA, ***Krasnoyarsk Territory***: "the western part of the Putorana Plateau, Norilsk, the vicinity of the Talnakh District, elev. 371 m, 69.478630°N, 88.543432°E, steep slope-scree without vascular plants, on rocks. 04 IX 2021. A. A. Ulyanovskiy" (LE); ***Magadan Region***: "Omsukchansky District, foothills of Kilganskie Range, vicinity of mining camp Dzuletta, ca. 500 km NE from Magadan, elev. 1480 m. 61°11'39.8"N, 153°58'49.8"E, local summit at the slope, on rocks. 11 VIII 2012. L. S. Yakovchenko 1265" (hb. Yakovchenko); "Susumansky District, left bank of Urultun Lake, elev. 975 m. 63°48'17.42"N, 148°14'37.34"E, rocky scattering on the slope, on rocks. 20 VIII 2021. E. V. Zheludeva" (MAG, ALTB–L6933); ibid., "Malyk Lake, mouth of the Okhandya River, mountain slope on the left bank, elev. 961 m. 63°34'39.96"N, 147°54'43.94"E, rocky area near the waterfall, on rocks. 25 VII 2020. E. V. Zheludeva" (MAG, ALTB–L6934); ***Kamchatka Territory***: "Elizovsky District, Petropavlovsk-Kamchatsky, E slope of Mishennaya Sopka Hill, elev. 370 m. 53°2'36"N, 158°38'28"E, on rocks (old lava). 29 VII 2002. D. E. Himelbrant, E. S. Kuznetsova K-1" (LE L-7465); ***Republic of Altai***: "Kosh-Agachsky District, Sailjugem Range, left bank of the Bayan-Chagan River, at 5.5 km upstream of the junction of the Karasu River, elev. 2600–2800 m. 49°30'42"N, 88°46'48"E, on rocks. 13 VI 2014. E. A. Davydov 14502 and L. S. Yakovchenko" (ALTB); "Ust'-Koksinsky District, Katunsky Range, upper reaches of the Ak-Kem River, right bank, elev. 2895 m. 49°57'23.3"N, 86°29'14.5"E, stone fields and rocks (Plot-21), on boulders. 12 VIII 2009. E. A. Davydov 7388" (ALTB); ibid., "watershed between the Ak-Kem and Kucherla Rivers, elev. 2605 m. 50°00'57.2"N, 86°27'09.8"E, stone fields and rocks (Plot-25), on stones. 15 VIII 2009. E. A. Davydov 14403" (ALTB); ibid., "elev. 2621 m. 50°00'28.9"N, 86°27'52.4"E, stone fields and rocks (Plot-30), on boulders. 19 VIII 2009. E. A. Davydov 7447" (ALTB); ibid., "elev. 2650 m. 50°01'16.9"N, 86°26'55.4"E, stone fields and rocks (Plot-24), on boulders. 15 VIII 2009. E. A. Davydov 7446" (ALTB); ibid., "elev. 2381 m. 50°01'58.9"N, 86°26'05.8"E,

stone fields and rocks, on boulders. 14 VIII 2009. E. A. Davydov 7421" (ALTB); Katunsky Range, right bank of the Multa River near Verkhnee Multinskoe Lake, elev. 1773 m. 49°56'N, 85°51'E, *Abies sibirica-Pinus sibirica* forest with stones in a water, on rocks. 5 VII 2000. E. A. Davydov 5660" (ALTB); ***Republic of Tuva***: "Mongun-Taiginsky District, Mongun-Taiga Massif, headwaters of the Mugur River, at 27.5

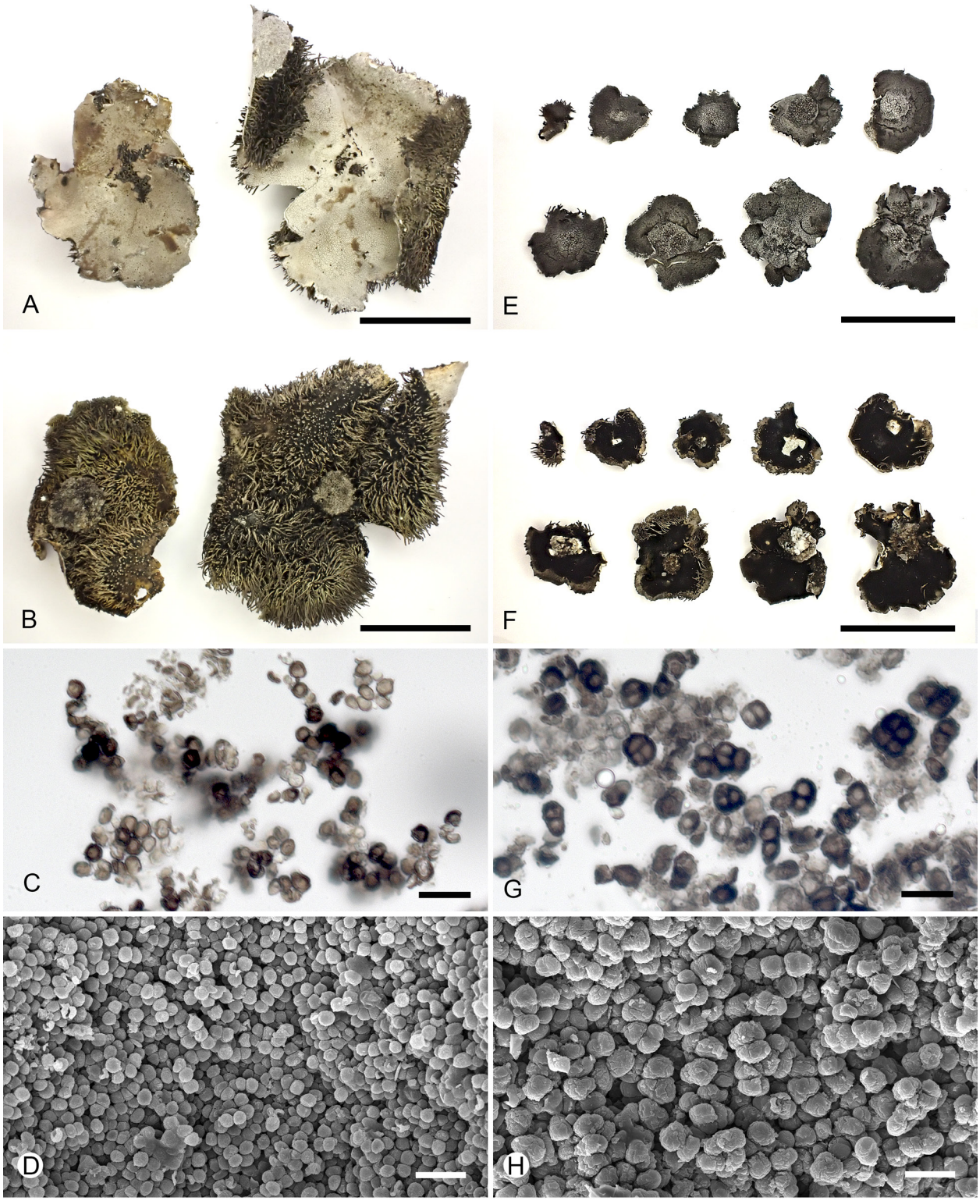

Fig. 2. The habit and thalloconidia of *Umbilicaria aprina* and *U. rhizinata*. A–D. *Umbilicaria aprina* (ALTB–L7730): A – upper side; B – lower side; C – thalloconidia in water; D – SEM of thalloconidia on the lower surface. E–H. *Umbilicaria rhizinata* (ALTB–L6879): E – upper side; F – lower side; G – thalloconidia in water; H – SEM of thalloconidia on the lower surface. Scales: A, B, E, and F = 1 cm; C, D, G, and H = 20 μm.

km W from Mugur-Aksy, elev. 2800 m. 50°18'35"N, 90°04'06"E, alpine meadows and mountain tundra with stones, on a boulder. 13 VII 2014. E. A. Davydov 14477, 14503 and L. S. Yakovchenko" (ALTB); ibid., "at 27 km W from Mugur-Aksy, elev. 2720 m. 50°19'11"N, 90°04'31"E, alpine meadows and mountain tundra with stones, on a boulder. 13 VII 2014. E. A. Davydov 14471, 14476 and L. S. Yakovchenko" (ALTB); ibid., "left side of the Toolaity River's Valley, at 3.5 km upstream from the Eski-Toolaity Lake, elev. 2450–2600 m. 50°11'N, 90°09'E, mountain tundra, stone field, on a boulder. 04 VII 2014. E. A. Davydov 14475 and L. S. Yakovchenko" (ALTB); ibid., "right side of the Khairykan River's Valley, at 3.7 km upstream from its mouth (Mugur River), elev. 2520 m. 50°18'20"N, 90°12'06"E, stone fields within alpine meadows and mountain tundra, on a boulder. 12 VII 2014. E. A. Davydov 14472 and L. S. Yakovchenko" (ALTB); ***Altai Territory***: "Zmeinogorsky District, Tigireksky Range, headwaters of Bolshoy Tigirek River, at 11 km N of Tigirek Settlement and 2.7 km SE of Razrabotnaya Mt., elev. 1800 m. 51°02'53"N, 83°00'41"E, timberline, on stone field. 4 VIII 2010. E. A. Davydov 7562" (ALTB); ibid., "at 11.5 km S of Tigirek Settlement and 3 km NW of Razrabotnaya Mt., elev. 1540–1600 m. 51°02'53"N, 83°00'27"E, rocks and stonefields, on rocks at the top of the Range. 21 VII 2012. E. A. Davydov 7258" (ALTB); ***Republic of Buryatia***: "Tunkinsky District, Nam-Tzagan-Khutliyn-Nuruu Mt., northern slope, elev. 1933 m. 51°22'15.7"N, 102°09'40.4"E, stream shore, silicate rock outcrops, on rocks. 16 VII 2018. T. M. Kharpukhaeva" (UUH-L01925).

Distribution in Russia: Krasnoyarsk Territory (Putorana Plateau), Magadan Region (Kilganskie and Cherskogo ranges), Kamchatka Territory (Mishennaya Sopka Hill), Altai Mts (Altai Territory, republics of Altai and Tyva), Republic of Buryatia (Nam-Tzagan-Khutliyn-Nuruu Range), Trans-Baikal Territory (Kodar Ridge). (Fig. 3).

Fig. 3. The known distribution of *Umbilicaria aprina* (red) and *U. rhizinata* (black) in Russia based on the investigated specimens.

Discussion

We proved the distinction of two species of *Umbilicaria aprina* group: *U. aprina* and *U. rhizinata*. *Umbilicaria aprina* is a well-known species from harsh Polar and glacial high mountain habitats. Locally, especially in regions with a maritime climate, e.g. Kamchatka or Kola Peninsula, *U. aprina* can grow on rocks near the timberline or even in upper part of the forest belt. It is a common trait for other arctic alpine species and depends on a local climate. The species is widespread in continental Antarctica

and is a model for studies in physiology of lichens in harsh condition, e. g. photosynthetic activity in different water content (Kappen, Breuer, 1991), CO_2 exchange and water relations in lichens at subzero temperatures (Schroeter et al., 1994; Schroeter, Scheidegger, 1995), photosynthesis and respiration at low temperatures and strong sun irradiance conditions (Green et al., 1998; Kappen et al., 1998; Sancho et al., 2003; Singh et al., 2012), seasonal activity (Schroeter et al., 2011), and dehydration resistance (Harańczyk et al., 2008). The distribution of *U. aprina* has been extensively studied (see the introduction). Nevertheless, here we report the species for the first time to Alexandra Land Island (Franz Josef Land Archipelago), Sverdrup Island (Taimyr Dolgano-Nenets District), and Yakutia.

In contrast to the previous species, the ecology and the distribution of *U. rhizinata* have so far been insufficiently studied, and the available data are scattered to discuss the range and ecological preferences of the species. The knowledge on the distribution of *U. rhizinata* has been increasing significantly; here we report the species as new to such macro regions as the republics of Tyva and Buryatia, Putorana Plateau, Kamchatka Peninsula, and the Magadan Region. Thus, for the first time, we have the opportunity to assess differences in ecology and distribution of two species. In Russia both species occur in Arctic-Subarctic or high mountain ('alpine') saxicolous communities above the timberline, but we never collected both species in the same locality. This fact may point at different distributional patterns of the species. *Umbilicaria aprina* occurs in high Arctic between 74°N and 81°N, whereas the northernmost locality of *U. rhizinata* is in the vicinity of Norilsk in Putorana Plateau (ca. 70°N). Both species, *U. aprina* and *U. rhizinata*, occurred in different localities in the same mountain region, in the republics of Altai, Buryatia, the Magadan Region, and Kamchatka Peninsula. Similarly, in the mountainous regions, *U. aprina* grows in harsher environment conditions – higher elevations or north-exposed slopes.

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REFERENCES / ЛИТЕРАТУРА

Crespo A., Sancho L. G. 1982. *Umbilicaria aprina* Nyl. en el Hemisferio Sur (Andes peruanos). *Lazaroa* 4: 357–360.

Culberson C. F., Johnson A. 1982. Substitution of methyl tert.-butyl ether for diethyl ether in the standardized thin-layer chromatographic method for lichen products. *J. Chromatogr.* 238(2): 483–487. DOI: 10.1016/S0021-9673(00)81336-9

Culberson C. F., Kristinsson H. D. 1970. A standardized method for the identification of lichen products. *J. Chromatogr.* 46(1): 85–93. DOI: 10.1016/S0021-9673(00)83967-9

Davydov E. A. 2017. Family Umbilicariaceae. In: M. P. Andreyev, D. E. Himelbrant (eds.). *The lichen flora of Russia: genus Protoparmelia, families Coenogoniaceae, Gyalectaceae and Umbilicariaceae*. Moscow; St. Petersburg: KMK Scientific Press Ltd. Pp. 66–136. [In Russian] (***Давыдов Е. А.*** Семейство Umbilicariaceae. Флора лишайников России: Род *Protoparmelia*, семейства Coenogoniaceae, Gyalectaceae и Umbilicariaceae. Под ред. М. П. Андреева, Д. Е. Гимельбранта. М.; СПб.: Тов-во науч. изд. КМК, 2017. С. 66–136).

Davydov E. A. 2022. On the status of *Umbilicaria aprina* var. *halei* and *U. canescens* (Umbilicariaceae, lichenized Ascomycota). *Phytotaxa* 533(1): 91–97. DOI: 10.11646/phytotaxa.533.1.6

Davydov E. A., Chesnokov S. V., Konoreva L. A., Andreev M. P. 2019a. Umbilicariaceae (lichenized Ascomycota) from the Stanovoye Nagor'e Highlands (South Siberia, Russia). *Herzogia* 32(2): 472–484. DOI: 10.13158/heia.32.2.2019.472

Davydov E. A., Himelbrant D. E., Stepanchikova I. S. 2011. Contribution to the study of Umbilicariaceae (lichenized Ascomycota) in Russia. II. Kamchatka Peninsula. *Herzogia* 24: 229–241. DOI: 10.13158/heia.24.2.2011.251

Davydov E. A., Peršoh D., Rambold G. 2017. Umbilicariaceae (lichenized Ascomycota) – trait evolution and a new generic concept. *Taxon* 66(6): 1282–1303. DOI: 10.12705/666.2

Davydov E. A., Urbanavichus G. P., Urbanavichene I. N., Selivanov A. E. 2019b. *Umbilicaria freyi* – a new lichen species for Russia and other noteworthy records of *Umbilicaria* from the Elbrus region (Central Caucasus, Kabardino-Balcaria). *Turczaninowia* 22, 2: 94–109. DOI: 10.14258/turczaninowia.22.2.5

Davydov E. A., Zhurbenko M. P. 2008. Contribution to Umbilicariaceae (lichenized Ascomycota) studies in Russia. I. Mainly Arctic species. *Herzogia* 21: 157–166.

Dombrovskaia A. V. 1970. *Lishayniki Khibin* [*Lichens of the Khibiny*]. Leningrad: Nauka. 184 pp. [In Russian]. (***Домбровская А. В.*** Лишайники Хибин. Л.: Наука, 1970. 184 с.).

Gardes M., Bruns T. D. 1993. ITS primers with enhanced specificity for basidiomycetes – application to the identification of mycorrhizae and rusts. *Molec. Ecol.* 2: 113–118. DOI: 10.1111/j.1365-294X.1993.tb00005.x

Green T. G. A., Schroeter B., Kappen L., Seppelt R. D., Maseyk K. 1998. An assessment of the relationship between chlorophyll a fluorescence and CO_2 gas exchange from field measurements on a moss and lichen. *Planta* 206: 611–618. DOI: 10.1007/s004250050439

Hansen E. S. 2003. New or interesting Greenland lichens and lichenicolous fungi V. *Mycotaxon* 86: 149–155.

Harańczyk H., Bacior M., Olech M. A. 2008. Deep dehydration of Umbilicaria aprina thalli observed by proton NRM and sorption isotherm. *Antarctic Science* 20: 527–535. DOI: 10.1017/S0954102008001363

Hestmark G. 2015. *Umbilicaria aprina* new to the Pyrenees. *Graphis Scripta* 27(1–2): 42–45.

Hestmark G. 2016. The lichen genus *Umbilicaria* in Ecuador. *Nordic J. Bot.* 34: 257–268. DOI: 10.1111/njb.00952

Kappen L., Breuer M. 1991. Ecological and physiological investigations in continental Antarctic cryptogams. II. Moisture relations and photosynthesis of lichens near Casey Station, Wilkes Land. *Antarct. Sci.* 3(3): 273–278. DOI: 10.1007/BF00239692

Kappen L., Schroeter B., Green T. G. A., Seppelt R. D. 1998. Chlorophyll a fluorescence and CO_2 exchange on *Umbilicaria aprina* under extreme light stress in the cold. *Oecologia* 113(3): 325–331. DOI: 10.1007/s004420050383

Katoh K., Kuma K., Toh H., Miyata T. 2005. MAFFT version 5: improvement in accuracy of multiple sequence alignment. *Nucl. Acids Res.* 33: 511–518. DOI: 10.1093/nar/gki198

Konoreva L. A., Kholod S. S., Chesnokov S. V., Zhurbenko M. P. 2019. Lichens of Franz Josef Land Archipelago. *Polish Polar Res.* 40(2): 139–170. DOI: 10.24425/ppr.2019.128372

Kristinsson H., Zhurbenko M., Hansen E. S. 2010. *Panarctic checklist of lichens and lichenicolous fungi. CAFF Technical Report No. 20.* Akureyri: CAFF International Secretariat. 120 pp.

Krzewicka B. 2010. *Umbilicaria rhizinata* comb. nov. (lichenized Ascomycota). *Lichenologist* 42: 491–493. DOI: 10.1017/S0024282910000010

Orange A., James P. W., White F. J. 2001. *Microchemical methods for the identification of lichens*. London: British Lichen Society. 101 pp.

Øvstedal D. O., Smith R. I. L. 2001. *Lichens of Antarctica and South Georgia: a guide to their identification and ecology*. *Studies in Polar Research*. Cambridge: Cambridge University Press. 411 pp.

Poelt J. 1977. Die Gattung *Umbilicaria* (Umbilicariaceae). Flechten des Himalaya 14. *Khumbu Himal* 6: 397–435.

Ryvarden L. 1968. *Umbilicaria aprina* Nyl., a rare lichen. *The Bryologist* 71: 366–368. DOI: 10.1639/0007-2745(1968)71[366:UANARL]2.0.CO;2

Sancho L. G., Pintado A., Green T. G. A., Pannewitz S., Schroeter B. 2003. Photosynthetic and morphological variation within and among populations of the Antarctic lichen *Umbilicaria aprina*: implications of the thallus size. *Biblioth. Lichenol.* 86: 299–311.

Schroeter B., Green, T. G. A., Kappen L., Seepelt R. D. 1994. Carbon dioxide exchange at subzero temperatures. Field measurements on *Umbilicaria aprina* in Antarctica. *Cryptog. Bot.* 4(2): 233–241.

Schroeter B., Green T. G. A., Pannewitz S., Schlensog M., Sancho L. G. 2011. Summer variability, winter dormancy: Lichen activity over 3 years at Botany Bay, 77°S latitude, continental Antarctica. *Polar Biol.* 34(1): 13-22. DOI: 10.1007/s00300-010-0851-7

Schroeter B., Scheidegger C. 1995. Water relations in lichens at subzero temperatures: structural changes and carbon dioxide exchange in the lichen *Umbilicaria aprina* from continental Antarctica. *New Phytologist* 131(2): 273–285. DOI: 10.1111/j.1469-8137.1995.tb05729.x

Silvestro D., Michalak I. 2012. RaxmlGUI: A graphical front-end for RAxML. *Organisms Diversity Evol.* 12: 335–337. DOI: 10.1007/s13127-011-0056-0

Singh J., Gautam S., Pant A. B. 2012. Effect of UV-B radiation on UV absorbing compounds and pigments of moss and lichen of Schirmacher Oasis region, east Antarctica. *Cell. Mol. Biol.* 58(1): 80–84.

Stamatakis A. 2014. RAxML version 8: a tool for phylogenetic analysis and post-analysis of large phylogenies. *Bioinformatics* 30: 1312–1313. DOI: 10.1093/bioinformatics/btu033

Urbanavichene I. N., Urbanavichus G. P. 2001. Additamentum ad lichenofloram reservati Baicalensis. II. *Novosti Sist. Nizsh. Rast.* 35: 205–208. [In Russian] (***Урбанавичене И. Н., Урбанавичюс Г. П.*** Дополнение к флоре лишайников Байкальского заповедника. II // Новости сист. низш. раст., 2001. Т. 35. С. 205–208).

Vilgalys R., Hester M. 1990. Rapid genetic identification and mapping of enzymatically amplified ribosomal DNA from several Cryptococcus species. *J. Bacteriol.* 172: 4238–4246. DOI: 10.1128/jb.172.8.4238-4246.1990

Wei J. C., Jiang Y. M. 1993. *The Asian Umbilicariaceae (Ascomycota). Mycosystema Monographicum. No. 1*. Beijing: Int. Acad. Publ. 217 pp.

White T. J., Bruns T. D., Lee S. B., Taylor J. W. 1990. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: M. A. Innis, D. H. Gelfand, J. J. Sninsky, T. J. White (eds.). *PCR protocols. A guide to methods and applications.* San Diego, California: Academic Press. Pp. 315–322.